Subdivided Module Catalogue
for the Subject
Physics International
as a Master's with 1 major
with the degree "Master of Science"
(120 ECTS credits)

Examination regulations version: 2020
Responsible: Faculty of Physics and Astronomy

Learning Outcomes

After having successfully completed their studies the graduates safulfil the following requirements:

- The graduates are highly skilled in abstract thinking, they are able to think analytically, they have a high problem-solving competence and are able to structure complex interrelations.
- The graduates have a wide overview of the different areas of physics and of connections to other sciences.
- They have profound knowledge of the mathematical and theoretical basics of physics as well as profound knowledge of the theoretical and experimental methods to gain new insights.
- They are able to transfer their abilities and expertise to research projects and know the current state of research in at least one speciality.
- With the help of primary literature, especially in English, they are able to become acquainted with the current state of research in a speciality .
- They have the ability to independently apply physical and mathematical methods to concrete experimental or theoretical physical tasks, to develop solutions and to interpret and assess the results.
- Even with incomplete information they are in a position to work independently on physical problems, applying scientific methods and following the rules of good scientific practice, and to present, assess and attend to the results and consequences of their work.
- They are able to discuss physical topics on the current state of research with other physicists and also to explain connections to physics to non-scientists.
- As physicists they are able to work in or even lead interdisciplinary and international teams with (natural) scientists and/or engineers in research, industry and economy.

Scientific qualification

- The graduates have profound knowledge of the mathematical, experimental and theoretical basics of physics
- The graduates can resort to profound knowledge of the theoretical and experimental methods to gain new insights
- The graduates have a wide overview of the different areas of physics
- The graduates know scientific areas adjacent to physics and realise interdisciplinary connections .
- The graduates have are highly skilled in abstract thinking, they are able to think analytically, they have a high problem-solving competence and are in a position to structure complex interrelations
- The graduates transfer their abilities and expertise to research projects and know the current state of research in at least one speciality .
- The graduates are able to discuss physical topics on the current state of research with other physicists.
- The graduates are in a position to independently apply physical and mathematical methods to concrete experimental or theoretical physical tasks, to develop solutions and to interpret and assess the results.
- With the help of primary literature, especially in English, the graduates are able to become acquainted with the current state of research in a speciality.

Qualification to start a job

- Even with incomplete information the graduates are in a position to work independently on physical problems, following the rules of good scientific practice, and to present, assess and attend to the results and consequences of their work.
- As physicists the graduates are able to work in or even lead interdisciplinary and international teams with (natural) scientists and/or engineers in research, industry and economy.

- The graduates have the ability to independently apply physical and mathematical methods to concrete experimental or theoretical physical tasks, to develop solutions and to interpret and assess the results.
- The graduates are able to transfer their abilities and expertise to research projects and know the current state of research in at least one speciality.

Self-development

- Even with incomplete information the graduates are in a position to work independently on physical problems, and to present, assess and attend to the results and consequences of their work.
- The gradues know the rules of good scientific practice and take them into account

Qualification for social commitment

- The graduates are able to critically reflect scientific developments and to capture their impact on economy, society and environment. (technological impact assessment)
- The graduates have enlargened their knowledge concerning economic, social, natural scientific or cultural questions (to name but a few) and are able to attend to their views reasonably.
- The graduates are able to discuss physical topics on the current state of research with other physicists and also to explain physical correlations to non-scientists.
- The graduates have developped the willingness and ability to show their skills in participative processes and actively contribute to decisions.

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)):

06-Feb-2020 (2020-16)

09-Jun-2021 (2021-63)

06-Sep-2022 (2022-55)

12-Jun-2024 (2024-75)

14-Nov-2024 (2024-97)

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
Electives Field (60 ECTS credits)				
Subfield Physics (55 ECTS credits)				
Advanced Laboratory Courses (9 ECTS credits)				
11-P-FM1-Int-201-m01	Advanced Laboratory Course Master Part 1	3	B/NB	121
11-P-FM2-Int-201-m01	Advanced Laboratory Course Master Part 2	3	B/NB	122
11-P-FM3-Int-201-m01	Advanced Laboratory Course Master Part 3	3	B/NB	123
11-P-FM4-Int-201-m01	Advanced Laboratory Course Master Part 4	3	B/NB	124
Advanced Seminar (5 ECTS credits)				
11-OSP-A-Int-201-m01	Advanced Seminar Physics A	5	NUM	119
11-OSP-B-Int-201-m01	Advanced Seminar Physics B	5	NUM	120
Experimental Physics (10 ECTS credits)				
11-BSV-Int-201-m01	Image and Signal Processing in Physics	6	NUM	58
11-OHL-Int-201-m01	Organic Semiconductors	6	NUM	117
11-PMM-Int-201-m01	Physics of Advanced Materials	6	NUM	127
11-SPI-Int-201-m01	Spintronics	6	NUM	148
11-FK2-Int-201-m01	Solid State Physics 2	8	NUM	88
11-FKS-Int-201-m01	Solid State Spectrocopy	6	NUM	90
11-MAG-Int-201-m01	Magnetism	6	NUM	107
11-HNS-Int-201-m01	Optical Properties of Semiconductor Nanostructures	6	NUM	97
11-HPH-Int-201-m01	Semiconductor Physics	6	NUM	99
11-QTR-Int-201-m01	Quantum Transport	6	NUM	138
11-QIC-Int-201-m01	Advanced Theory of Quantum Computing and Quantum Information	6	NUM	134
11-NOP-Int-201-m01	Nano-Optics	6	NUM	115
11-PTS-Int-201-m01	Phenomenology and Theory of Superconductivity	6	NUM	128
08-PCM4-161-m01	Ultrafast spectroscopy and quantum-control	5	NUM	13
11-CSFM-Int-201-m01	Advanced Topics in Solid State Physics	6	NUM	68
11-ASM-Int-201-m01	Methods of Observational Astronomy	6	NUM	49
11-TPE-Int-201-m01	Experimental Particle Physics	6	NUM	164
11-ASP-Int-201-m01	Introduction to Space Physics	6	NUM	50
11-MAS-Int-201-m01	Multi-wavelength Astronomy	6	NUM	110
11-CSAM-Int-201-m01	Advanced Topics in Astrophysics	6	NUM	67
11-MRI-Int-201-m01	Advanced Magnetic Resonance Imaging	6	NUM	112
11-SSC-Int-201-m01	Surface Science	6	NUM	150
11-BIC-Int-201-m01	Basic Imaging Concepts	6	NUM	55
11-IRP-Int-201-m01	Basic Imaging Reconstruction and Processing	6	NUM	101
11-CAP-Int-201-m01	Contemporary Astrophysics	6	NUM	62
11-AAI-Int-201-m01	Advanced Astro Imaging	6	NUM	43
11-CTA-Int-201-m01	Advanced Computer Tomography	6	NUM	69
11-EIM-Int-201-m01	Electron and Ion Microscopy	6	NUM	71
11-SPT-Int-201-m01	Scanning Probe Technologies	6	NUM	149
11-FPA-Int-201-m01	Visiting Research	10	NUM	91

11-EXE5-Int-201-m01	Current Topics in Experimental Physics	5	NUM	73
11-EXE6-Int-201-m01	Current Topics in Experimental Physics	6	NUM	75
11-EXE7-Int-201-m01	Current Topics in Experimental Physics	7	NUM	76
11-EXE8-Int-201-m01	Current Topics in Experimental Physics	8	NUM	77
11-EXE6A-Int-201-m01	Current Topics in Experimental Physics	6	NUM	74
11-EXP6-Int-201-m01	Current Topics in Physics	6	NUM	80
Theoretical Physics (10 ECTS credits)				
11-QM2-Int-201-m01	Quantum Mechanics II	8	NUM	136
11-TQO-Int-221-m01	Theoretical Quantum Optics	8	NUM	169
11-RTT-Int-201-m01	Theory of Relativity	6	NUM	144
11-RMFT-Int-201-m01	Renormalization Group Methods in Field Theory	8	NUM	142
11-PKS-Int-201-m01	Physics of Complex Systems	6	NUM	125
11-QIC-Int-201-m01	Advanced Theory of Quantum Computing and Quantum Information	6	NUM	134
11-TFK-Int-201-m01	Theoretical Solid State Physics	8	NUM	162
11-TFK2-Int-201-m01	Theoretical Solid State Physics 2	8	NUM	160
11-TEFK-Int-201-m01	Topological Effects in Solid State Physics	8	NUM	156
11-FFK-Int-201-m01	Field Theory in Solid State Physics	8	NUM	86
11-AKTF-Int-201-m01	Selected Topics of Theoretical Solid State Physics	6	NUM	46
11-CMS-Int-201-m01	Computational Materials Science (DFT)	8	NUM	63
11-KFT-Int-201-m01	Conformal Field Theory	6	NUM	105
11-KFT2-Int-201-m01	Conformal Field Theory 2	6	NUM	103
11-GRTM-Int-201-m01	Group Theory	6	NUM	95
11-TPSM-Int-201-m01	Particle Physics (Standard Model)	6	NUM	165
11-CRP-Int-201-m01	Renormalization Group and Critical Phenomena	6	NUM	65
11-BWW-Int-201-m01	Bosonisation and Interactions in One Dimension	6	NUM	60
11-GGD-Int-201-m01	Introduction to Gauge/Gravity Duality	8	NUM	93
11-AKM-Int-201-m01	Cosmology	6	NUM	45
11-AST-Int-201-m01	Theoretical Astrophysics	6	NUM	52
11-EPP-Int-201-m01	Introduction to Plasma Physics	6	NUM	72
11-APL-Int-201-m01	High-Energy Astrophysics	6	NUM	47
11-NMA-Int-201-m01	Computational Astrophysics	6	NUM	114
11-QFT1-Int-201-m01	Quantum Field Theory I	8	NUM	130
11-QFT2-Int-201-m01	Quantum Field Theory II	8	NUM	132
11-TEP-Int-201-m01	Theoretical Elementary Particle Physics	8	NUM	158
11-ATTP-Int-201-m01	Selected Topics of Theoretical Elementary Particle Physics	6	NUM	54
11-BSM-Int-201-m01	Models Beyond the Standard Model of Elementary Particle Physics	6	NUM	56
11-STRG1-Int-201-m01	String Theory 1	8	NUM	152
11-STRG2-Int-201-m01	String Theory 2	6	NUM	154
11-RAI-Int-211-m01	Radio Astronomical Interferometry	6	NUM	140
11-SLQ-Int-241-m01	Black Holes	6	NUM	146
11-TPSM-Int-211-m01	Particle Physics (Standard Model)	8	NUM	167
11-FPA-Int-201-m01	Visiting Research	10	NUM	91
11-EXT5-Int-201-m01	Current Topics of Theoretical Physics	5	NUM	81
11-EXT6-Int-201-m01	Current Topics of Theoretical Physics	6	NUM	83

11-EXT7-Int-201-m01	Current Topics of Theoretical Physics	7	NUM	84
11-EXT8-Int-201-m01	Current Topics of Theoretical Physics	8	NUM	85
11-EXT6A-Int-201-m01	Current Topics of Theoretical Physics	6	NUM	82
11-EXP6A-Int-201-m01	Current Topics in Physics	6	NUM	79
11-APM-Int-241-m01	Astrophysics	6	NUM	48
11-ATP-Int-241-m01	Atmospheric Physics	6	NUM	53
11-OQS-Int-241-m01	Open Quantum Systems	6	NUM	118
Subfield Non-Physical Minors				
10-M-ORSaf-152-m01	Operations Research for students of other subjects	10	NUM	41
10-M-VAN-152-m01	Advanced Analysis	7	NUM	42
10-M=AAANin-152-m01	Applied Analysis	10	NUM	26
10-M=ADGMin-152-m01	Differential Geometry	10	NUM	27
10-M=AFTHin-152-m01	Complex Analysis	10	NUM	28
10-M=ALTHin-152-m01	Lie Theory	10	NUM	29
10-M=ATOPin-152-m01	Topology	10	NUM	30
10-M=AZTHin-152-m01	Number Theory	10	NUM	31
10-M=VGDSin-152-m01	Groups and their Representations	10	NUM	33
10-M=VGEMin-152-m01	Geometrical Mechanics	10	NUM	34
10-M=VNPEin-152-m01	Numeric of Partial Differential Equations	10	NUM	37
10-M=VDIMin-152-m01	Discrete Mathematics	5	NUM	32
10-M=VMPHin-152-m01	Selected Topics in Mathematical Physics	10	NUM	36
10-M=VPDPin-152-m01	Partial Differential Equations of Mathematical Physics	10	NUM	38
10-M=VPRGin-152-m01	Pseudo Riemannian and Riemannian Geometry	10	NUM	39
10-I=DB-161-m01	Databases	5	NUM	15
10-I=PA-161-m01	Analysis and Design of Programs	5	NUM	18
10-I-RAK-152-m01	Computer Architecture	5	NUM	24
10-I-APR-172-m01	Advanced Programming	5	NUM	20
10-I-BS-191-m01	Operating Systems	5	NUM	22
10-I=KI1-161-m01	Artificial Intelligence 1	5	NUM	16
08-FU-SAM-161-m01	Sensor and Actor Materials - Functional Ceramics and Magnetic Particles	5	NUM	12
08-FU-EEW-152-m01	Electrochemical Energy Storage and Conversion	5	NUM	9
08-FU-MW-161-m01	Structure and Properties of Modern Materials: Experiments vs. Simulations	5	NUM	11
11-EXNP6-Int-201-m01	Nonphysical Minor Subject	6	NUM	78
Master Project Modules (60 ECTS credits)				
11-FS-P-Int-201-m01	Professional Specialization Physics International	15	B/NB	92
11-MP-P-Int-201-m01	Scientific Methods and Project Management Physics International	15	B/NB	111
11-MA-P-Int-201-m01	Master Thesis Physics International	30	NUM	109

Module title				Abbreviation
Electrochemical Energy Storage and Conversion				08-FU-EEW-152-m01

Module coordinator	Module offered by
holder of the Chair of Chemical Technology of Material Synthesis	Chair of Chemical Technology of Material Synthesis

ECTS	Method of grading	Only after succ. compl. of module(s)
5	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	undergraduate	--

Contents

Chemistry and application of: battery systems (aqueous and non-aqueous systems such as lead, nickel cadmium and nickel metal hydride, sodium sulphur, sodium nickel chloride, lithium ion accumulators), electrochemical double layer capacitors, redox-flow batteries, fuel cell systems (AFC, PEMFC, DMFC, PAFC, SOFC), solar cells (Si, CIS, CIGS, GaAs, organic and dye solar cell), thermoelectric devices.

Intended learning outcomes

Students have developed a knowledge of electrochemical energy storage and conversion and are able to apply that knowledge to research problems.

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

V (2) + P (1) + E (1)

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)

a) assessment and b) Vortestate/Nachtestate (pre and post-experiment examination talks approx. 15 minutes each, log approx. 5 to 10 pages each) and assessment of practical assignments (2 to 4 random examinations), weighted 7:3
Language of assessment: German and/or English
Assessment offered: Once a year, summer semester

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Bachelor's degree (1 major) Nanostructure Technology (2015)
Master's degree (1 major) Physics (2016)
Master's degree (1 major) Nanostructure Technology (2016)
Master's degree (1 major) Functional Materials (2016)
Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Bachelor's degree (1 major) Nanostructure Technology (2020)
Bachelor's degree (1 major) Quantum Technology (2021)

Master's degree (1 major) Quantum Technology (2021)

Module title	Abbreviation
Structure and Properties of Modern Materials: Experiments vs. Simulations	08-FU-MW-161-m01

Module coordinator	Module offered by
degree programme coordinator Funktionswerkstoffe (Functional Matrierials)	Chair of Chemical Technology of Material Synthesis

ECTS	Method of grading	Only after succ. compl. of module(s)
5	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Material properties of metals and ceramics: correlation of structure/property relations through experiments and simulations.

Intended learning outcomes

Students gain an insight into the properties of modern materials: aerospace aluminium alloys and high-performance ceramics. They are introduced to measuring methods and calculation methods using numerical simulation. A special focus is on the relation between the micro/nanoscopic structure of materials and the resulting properties.

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

V (2) + S (1)

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)

a) talk (approx. 30 minutes) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, approx. 30 minutes total)
Language of assessment: German and/or English
Assessment offered: Once a year, winter semester

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics (2016)
Master's degree (1 major) Nanostructure Technology (2016)
Master's degree (1 major) Functional Materials (2016)
Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Technology (2021)

Module title				Abbreviation
Sensor and Actor Materials - Functional Ceramics and Magnetic Particles				08-FU-SAM-161-m01
Module coordinator			**Module offered by**	
degree programme coordinator Funktionswerkstoffe (Functional Matrierials)			Chair of Chemical Technology of Material Synthesis	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
5	numerical grade		--	
Duration		**Module level**	**Other prerequisites**	
1 semester		graduate	--	

Contents

Fabrication, effects and applications of sensory and actuatory materials such as piezoelectrics, shape memory materials and magnetostrictive materials. Electrorheological and magnetorheological fluids, magnetofluids.

Intended learning outcomes

Students have developed fundamental knowledge in the area of sensory and actuatory materials.

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

V (2) + P (2)

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)

a) written examination (approx. 90 minutes) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, approx. 30 minutes per candidate)
Language of assessment: German and/or English
Assessment offered: Once a year, summer semester
P: creditable for bonus

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics (2016)
Master's degree (1 major) Nanostructure Technology (2016)
Master's degree (1 major) Functional Materials (2016)
Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Technology (2021)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Ultrafast spectroscopy and quantum-control				08-PCM4-161-m01
Module coordinator			**Module offered by**	
lecturer of the seminar "Nanoskalige Materialien"			Institute of Physical and Theoretical Chemistry	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
5	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Prior completion of modules 08-PCM1a and 08-PCM1b recommended.		

Contents

This module discusses advanced topics in ultrafast spectroscopy and quantum control. It focuses on ultrashort laser pulses, time-resolved laser spectroscopy and coherent control.

Intended learning outcomes

Students are able to describe the generation of ultrashort laser pulses and to characterise them. They can explain the theory of time-resolved laser spectroscopy and name experimental methods. They can describe the principles and applications of quantum control.

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

S (2) + Ü (1)
Module taught 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)

a) written examination (approx. 90 minutes) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) talk (approx. 30 minutes)
Language of assessment: German and/or English

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Chemistry (2016)
Master's degree (1 major) Mathematics (2016)
Master's degree (1 major) Physics (2016)
Master's degree (1 major) Nanostructure Technology (2016)
Master's degree (1 major) Computational Mathematics (2016)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Master's degree (1 major) Chemistry (2018)
Master's degree (1 major) Computational Mathematics (2019)
Master's degree (1 major) Mathematics (2019)
Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)

Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020) Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020) Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Technology (2021) Master's degree (1 major) Computational Mathematics (2022) Master's degree (1 major) Functional Materials (2022) Master's degree (1 major) Mathematics (2022) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024) Master's degree (1 major) Computational Mathematics (2024) Master's degree (1 major) Mathematics (2024)

Module title				Abbreviation
Databases				10-I=DB-161-m01
Module coordinator			**Module offered by**	
Dean of Studies Informatik (Computer Science)			Institute of Computer Science	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
5	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Relational algebra and complex SQL statements; database planning and normal forms, XML data modelling; transaction management.

Intended learning outcomes

The students possess knowledge about data modelling and queries in SQL, transactions as well as about easy data modelling in XML.

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

V (2) + Ü (2)

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. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Separate written examination for Master's students.
Language of assessment: German and/or English
creditable for bonus

Allocation of places

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Additional information

Focuses available for students of the Master's programme Informatik (Computer Science, 120 ECTS credits): SE, IS, HCI, GE.

Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Computer Science (2016)
Master's degree (1 major) Physics (2016)
Master's degree (1 major) Digital Humanities (2016)
Master's degree (1 major) Computer Science (2017)
Master's degree (1 major) Computer Science (2018)
Master's degree (1 major) Physics (2020)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Artificial Intelligence 1				10-I=KI1-161-m01
Module coordinator			Module offered by	
holder of the Chair of Computer Science VI			Institute of Computer Science	
ECTS	Method of grading	Only after succ. compl. of module(s)		
5	numerical grade	--		
Duration	Module level	Other prerequisites		
1 semester	graduate	--		

Contents

Intelligent agents, uninformed and heuristic search, constraint problem solving, search with partial information, propositional and predicate logic and inference, knowledge representation.

Intended learning outcomes

The students possess theoretical and practical knowledge about artificial intelligence in the area of agents, search and logic and are able to assess possible applications.

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

V (2) + Ü (2)

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. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Language of assessment: German and/or English
creditable for bonus

Allocation of places

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Additional information

Focuses available for students of the Master's programme Informatik (Computer Science, 120 ECTS credits): AT,SE,IS,HCI

Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Computer Science (2016)
Master's degree (1 major) Mathematics (2016)
Master's degree (1 major) Physics (2016)
Master's degree (1 major) Nanostructure Technology (2016)
Master's degree (1 major) Computational Mathematics (2016)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Master's degree (1 major) Computer Science (2017)
Master's degree (1 major) Computer Science (2018)
Master's degree (1 major) Computational Mathematics (2019)
Master's degree (1 major) Mathematics (2019)

Master's degree (1 major) Information Systems (2019) Master's degree (1 major) Nanostructure Technology (2020) Master's degree (1 major) Physics (2020) Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020) Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020) Master's degree (1 major) Aerospace Computer Science (2020) Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Technology (2021)

Module title				Abbreviation
Analysis and Design of Programs				10-I=PA-161-m01

Module coordinator	**Module offered by**
holder of the Chair of Computer Science II	Institute of Computer Science

ECTS	**Method of grading**	**Only after succ. compl. of module(s)**
5	numerical grade	--

Duration	**Module level**	**Other prerequisites**
1 semester	graduate	--

Contents

Program analysis, model creation in software engineering, program quality, test of programs, process models.

Intended learning outcomes

The students are able to analyse programs, to use testing frameworks and metrics as well as to judge program quality.

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

V (2) + Ü (2)

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. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Language of assessment: German and/or English
creditable for bonus

Allocation of places

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Additional information

Focuses available for students of the Master's programme Informatik (Computer Science, 120 ECTS credits): SE,IS,ES,GE

Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Computer Science (2016)
Master's degree (1 major) Mathematics (2016)
Master's degree (1 major) Physics (2016)
Master's degree (1 major) Nanostructure Technology (2016)
Master's degree (1 major) Computational Mathematics (2016)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Master's degree (1 major) Computer Science (2017)
Master's degree (1 major) Computer Science (2018)
Master's degree (1 major) Computational Mathematics (2019)
Master's degree (1 major) Mathematics (2019)
Master's degree (1 major) Information Systems (2019)

Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Technology (2021)
Master's degree (1 major) Computational Mathematics (2022)
Master's degree (1 major) Mathematics (2022)

Module title				**Abbreviation**
Advanced Programming				10-I-APR-172-m01
Module coordinator			**Module offered by**	
holder of the Chair of Computer Science II			Institute of Computer Science	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
5	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	undergraduate	--		

Contents

With the knowledge of basic programming, taught in introductory lectures, it is possible to realize simpler programs. If more complex problems are to be tackled, suboptimal results like long, incomprehensible functions and code duplicates occur. In this lecture, further knowledge is to be conveyed on how to give programs and code a sensible structure. Also, further topics in the areas of software security and parallel programming are discussed.

Intended learning outcomes

Students learn advanced programming paradigms especially suited for space applications. Different patterns are then implemented in multiple languages and their efficiency measured using standard metrics. In addition, parallel processing concepts are introduced culminating in the use of GPU architectures for extremely quick processing.

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

V (2) + Ü (2)

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. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Language of assessment: German and/or English
creditable for bonus

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

§ 22 II Nr. 3 b)

Module appears in

Bachelor's degree (1 major) Computer Science (2017)
Bachelor's degree (1 major) Computer Science (2019)
Module studies (Bachelor) Computer Science (2019)
Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020)
Bachelor's degree (1 major) Business Information Systems (2020)

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Bachelor's degree (1 major) Computer Science und Sustainability (2021)
Master's degree (1 major) Quantum Technology (2021)
Bachelor's degree (1 major) Business Information Systems (2021)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2022)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2023)
Bachelor's degree (1 major) Business Information Systems (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)
Bachelor's degree (1 major) Business Information Systems (2024)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2024)
Bachelor's degree (1 major) Digital Business & Data Science (2024)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2025)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2025)
Bachelor's degree (1 major) Games Engineering (2025)

Module title				**Abbreviation**
Operating Systems				10-I-BS-191-m01
Module coordinator			**Module offered by**	
holder of the Chair of Computer Science II			Institute of Computer Science	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
5	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	undergraduate	--		

Contents

Introduction to computer systems, development of operating systems, architecture principles, interrupt processing in operating systems, processes and threads, CPU scheduling, synchronisation and communication, memory management, device and file management, operating system virtualisation.

Intended learning outcomes

The students possess knowledge and practical skills in building and using essential parts of operating systems.

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

V (2) + Ü (2)
Module taught in: 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. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Language of assessment: German and/or English
creditable for bonus

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Bachelor's degree (1 major) Computer Science (2019)
Master's degree (1 major) Nanostructure Technology (2020)
Master's degree (1 major) Physics (2020)
Bachelor's degree (1 major) Business Information Systems (2020)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Bachelor's degree (1 major) Aerospace Computer Science (2020)
Bachelor's degree (1 major) Computer Science und Sustainability (2021)
Master's degree (1 major) Quantum Technology (2021)
Bachelor's degree (1 major) Business Information Systems (2021)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2022)

Bachelor's degree (1 major) Artificial Intelligence and Data Science (2023) Bachelor's degree (1 major) Mathematics (2023) Bachelor's degree (1 major) Business Information Systems (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024) Bachelor's degree (1 major) Artificial Intelligence and Data Science (2024)

Module title				Abbreviation
Computer Architecture				10-I-RAK-152-m01
Module coordinator			Module offered by	
Dean of Studies Informatik (Computer Science)			Institute of Computer Science	
ECTS	Method of grading	Only after succ. compl. of module(s)		
5	numerical grade	--		
Duration	Module level	Other prerequisites		
1 semester	undergraduate	--		

Contents

Instruction set architectures, command processing through pipelining, statical and dynamic instruction scheduling, caches, vector processors, multi-core processors.

Intended learning outcomes

The students master the most important techniques to design fast computers as well as their interaction with compilers and operating systems.

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

V (2) + Ü (2)

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. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Language of assessment: German and/or English
creditable for bonus

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

§ 22 II Nr. 3 b)
§ 69 I Nr. 1 c): Rechnerarchitektur

Module appears in

Bachelor's degree (1 major) Computer Science (2015)
Bachelor's degree (1 major) Mathematics (2015)
Bachelor's degree (1 major) Computational Mathematics (2015)
Bachelor's degree (1 major) Aerospace Computer Science (2015)
First state examination for the teaching degree Gymnasium Computer Science (2015)
Master's degree (1 major) Physics (2016)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2016)
Bachelor's degree (1 major) Aerospace Computer Science (2017)
Bachelor's degree (1 major) Computer Science (2017)
Bachelor's degree (1 major) Computer Science (2019)
Master's degree (1 major) Physics (2020)

Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020)
Supplementary course MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2020)
Master's degree (1 major) Physics International (2020)
Bachelor's degree (1 major) Aerospace Computer Science (2020)
Bachelor's degree (1 major) Computer Science und Sustainability (2021)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2022)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2023)
Bachelor's degree (1 major) Mathematics (2023)
Master's degree (1 major) Physics International (2024)
Bachelor's degree (1 major) Artificial Intelligence and Data Science (2024)
Master's teaching degree Gymnasium MINT Teacher Education PLUS, Elite Network Bavaria (ENB) (2025)
Bachelor's degree (1 major) Games Engineering (2025)

Module title				**Abbreviation**
Applied Analysis				10-M=AAANin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

In-depth study of functional analysis and operator theory, Sobolev spaces and partial differential equations, theory of Hilbert spaces and Fourier analysis, spectral theory and quantum mechanics, numerical methods (in particular FEM methods), principles of functional analysis, function spaces, embedding theorems, compactness, theory of elliptic, parabolic and hyperbolic partial differential equations with methods from functional analysis.

Recommended previous knowledge:
Familiarity with the contents of the module "Functional Analysis" is strongly recommended.

Intended learning outcomes

The student is acquainted with the fundamental notions, methods and results of higher analysis. He/She is able to establish a connection between his/her acquired skills and other branches of mathematics and questions in physics and other natural and engineering sciences.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Differential Geometry				10-M=ADGMin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Central and advanced results in differential geometry, in particular about differentiable and Riemannian manifolds.

Recommended previous knowledge:
Basic knowledge from the modules "Introduction to Differential Geometry", "Introduction to Topology" and "Geometric Analysis" is recommended.

Intended learning outcomes

The student is acquainted with concepts and methods for differentiable manifolds or Riemannian manifolds, is able to apply these methods and knows about the interaction of local and global methods in differential geometry.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Complex Analysis				10-M=AFTHin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

In-depth study of mapping properties of analytic functions and their generalisations with modern analytic and geometric methods. Structural properties of families of holomorphic and meromorphic functions. Special functions (e. g. elliptic functions).

Recommended previous knowledge:
Basic knowledge of the contents of the module "Introduction to Complex Analysis" is recommended.

Intended learning outcomes

The student is acquainted with the fundamental notions, methods and results of higher complex analysis, in particular the (geometric) mapping properties of holomorphic functions. He/She is able to establish a connection between his/her acquired skills and other branches of mathematics and applications in other subjects.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Lie Theory				10-M=ALTHin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Linear Lie groups and their Lie algebras, exponential function, structure and classification of Lie algebras, classic examples, applications, e. g. in physics and control theory.

Recommended previous knowledge:
Basic knowledge of the contents of the modules "Functional Analysis" and "Introduction to Topology" is recommended. Furthermore, basic knowledge of the contents of the module "Introduction to Differential Geometry" is useful.

Intended learning outcomes

The student is acquainted with the fundamental results, theorems and methods in Lie theory. He/She is able to apply these to common problems, and knows about the interactions of group theory, analysis, topology and linear algebra.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Topology				10-M=ATOPin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
10	numerical grade		--	
Duration		**Module level**	**Other prerequisites**	
1 semester		graduate	--	

Contents

Set-theoretic topology, topological invariants (e. g. fundamental group, connection), construction of topological spaces, covering spaces.

Intended learning outcomes

The student is acquainted with the fundamental results, theorems and methods in topology and is able to apply these to common problems.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title	Abbreviation
Number Theory	10-M=AZTHin-152-m01

Module coordinator	Module offered by
Dean of Studies Mathematik (Mathematics)	Institute of Mathematics

ECTS	Method of grading	Only after succ. compl. of module(s)
10	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Number-theoretic functions and their associated Dirichlet series resp. Euler products, their analytic theory with applications to prime number distribution and diophantine equations; discussion of the Riemann hypothesis, overview of the development of modern number theory.

Recommended previous knowledge:
Basic knowledge of algebra and number theory is assumed, such as can be acquired in the modules "Introduction to Algebra", „Introduction to Number Theory“ and "Applied Algebra".

Intended learning outcomes

The student is acquainted with the fundamental methods of analytics number theory, can deal with algebraic structures in number theory and knows methods for the solution of diophantine equations. He/She has insight into modern developments in number theory.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Discrete Mathematics				10-M=VDIMin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
5	numerical grade		--	
Duration	**Module level**		**Other prerequisites**	
1 semester	graduate		--	

Contents

Advanced methods and results in a selected field of discrete mathematics (e. g. coding theory, cryptography, graph theory or combinatorics)

Recommended previous knowledge:
Basic knowledge of the contents of the module "Introduction to Discrete Mathematics" is required.

Intended learning outcomes

The student is acquainted with advanced results in a selected topic in discrete mathematics.

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

V (3) + Ü (1)
Module taught in: 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)

a) written examination (approx. 60 to 90 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 15 minutes) or
c) oral examination in groups (groups of 2, approx. 10 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Groups and their Representations				10-M=VGDSin-152-m01

Module coordinator	Module offered by
Dean of Studies Mathematik (Mathematics)	Institute of Mathematics

ECTS	Method of grading	Only after succ. compl. of module(s)
10	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Finite permutation groups and character theory of finite groups, interrelations and special techniques such as the S-rings of Schur.

Recommended previous knowledge:
Basic knowledge of algebra is assumed, such as can be acquired in the modules "Introduction to Algebra" and "Applied Algebra".

Intended learning outcomes

The student masters advanced algebraic concepts and methods. He/She gains the ability to work on contemporary research questions in group theory and representation theory and can apply his/her skills to complex problems.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Geometrical Mechanics				10-M=VGEMin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
10	numerical grade		--	
Duration		**Module level**	**Other prerequisites**	
1 semester		graduate	--	

Contents

The module builds on the topics covered in module 10-M=ADGM and discusses these in more detail: symplectic geometry, cotangent bundles and other examples of symplectic manifolds, symmetries and Noether theorem, phase space reduction, normal forms, introduction to Poisson geometry.

Recommended previous knowledge:
Advanced knowledge of differential geometry is required, such as can be acquired in the module "Differential Geometry". Knowledge of the contents of the module "Introduction to Topology" is also recommended. Knowledge of theoretical mechanics can also be useful.

Intended learning outcomes

The student is acquainted with selected advanced applications of differential geometry to geometric mechanics. He/She is able to establish a connection between his/her acquired skills and other branches of mathematics and questions in physics.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)

Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Selected Topics in Mathematical Physics				10-M=VMPHin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Selected topics in mathematical physics, for example continuum mechanics, fluid dynamics, mathematical material sciences, geometric field theory, advanced topics in quantum theory.

Recommended previous knowledge:
Depending on the content, basic and advanced knowledge from different areas of analysis is required. In case of doubt, it is recommended to consult the lecturer.

Intended learning outcomes

The student is acquainted with an advanced topic in mathematical physics. He/She is able to establish a connection between his/her acquired skills and other branches of mathematics and questions in physics.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Numeric of Partial Differential Equations				10-M=VNPEin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Types of partial differential equations, qualitative properties, finite differences, finite elements, error estimates (numerical methods for elliptic, parabolic and hyperbolic partial differential equations; finite elements method, discontinuous Gelerkin finite elements method, finite differences and finite volume methods).

Recommended previous knowledge:
We recommend basic knowledge of functional analysis and partial differential equations, such as can be acquired in the modules "Introduction to Functional Analysis" and "Applied Analysis".

Intended learning outcomes

The student is acquainted with advanced methods for discretising partial differential equations.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Partial Differential Equations of Mathematical Physics				10-M=VPDPin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Elliptic, parabolic, and hyperbolic equations; Laplace equation, heat equation and wave equation as standard examples; initial and boundary value problems; well-posed and ill-posed problems; solution methods; extensions and generalisations; Hilbert space methods; Sobolev spaces and Fourier transforms.

Recommended previous knowledge:
Basic knowledge from the modules "Ordinary Differential Equations" and "Introduction to Partial Differential Equations" is recommended, as well as basic knowledge of functional analysis.

Intended learning outcomes

The student is acquainted with fundamental concepts and solution methods in the theory of partial differential equations, as well as standard examples from mathematical physics. He/She is able to establish a connection between his/her acquired skills and other branches of mathematics and questions in physics.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)
Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				Abbreviation
Pseudo Riemannian and Riemannian Geometry				10-M=VPRGin-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

The module builds on the topics covered in module 10-M=ADGM and discusses these in more detail: Riemannian and pseudo-Riemannian manifolds, Levi-Civita connection and curvature, geodesics and the exponential map, Jacobi fields, comparison theorems in Riemannian geometry, submanifolds, integration, d'Alembert and Laplace operators, causal structure of Lorenz manifolds, Einstein equations and applications in general relativity theory.

Recommended previous knowledge:
Advanced knowledge of differential geometry is required, such as can be acquired in the module "Differential Geometry". Knowledge of the contents of the modules "Introduction to Topology", "Geometric Mechanics" and "Lie Theory" is also recommended.

Intended learning outcomes

The student is acquainted with advanced topics in differential geometry on Riemannian and pseudo-Riemannian manifolds. He/She is able to establish a connection between his/her acquired skills and other branches of mathematics and questions in physics.

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

V (4) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes, usually chosen) or
b) oral examination of one candidate each (approx. 20 minutes) or
c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester
creditable for bonus

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Mathematics International (2015)
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Mathematics International (2021)

Master's degree (1 major) Mathematics International (2022)
Master's degree (1 major) Physics International (2024)
Master's degree (1 major) Mathematics International (2025)

Module title				**Abbreviation**
Operations Research for students of other subjects				10-M-ORSaf-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	undergraduate	--		

Contents

Linear programming, duality theory, transport problems, integral linear programming, graph theoretic problems.

Intended learning outcomes

The student is acquainted with the fundamental methods in operations research, as required as a central tool for solving many practical problems especially in economics. He/She is able to apply these methods to practical problems, both theoretically and numerically.

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

V (4) + Ü (2)

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)

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

Allocation of places

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Additional information

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Workload

300 h

Teaching cycle

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

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Module appears in

Bachelor's degree (1 major) Computer Science (2015)
Master's degree (1 major) Physics (2016)
Bachelor's degree (1 major) Computer Science (2017)
Bachelor's degree (1 major) Computer Science (2019)
Master's degree (1 major) Physics (2020)
Master's degree (1 major) Physics International (2020)
Bachelor's degree (1 major) Computer Science und Sustainability (2021)

Module title				**Abbreviation**
Advanced Analysis				10-M-VAN-152-m01
Module coordinator			**Module offered by**	
Dean of Studies Mathematik (Mathematics)			Institute of Mathematics	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
7	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	undergraduate	--		
Contents				
Continuation of analysis in several variables, integration theorems.				
Intended learning outcomes				
The student is acquainted with advanced topics in analysis. Taking the example of the Lesbegue integral, he or she is able to understand the construction of a complex mathematical concept.				
Courses (type, number of weekly contact hours, language — if other than German)				
V (4) + Ü (2)				
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)				
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				
Allocation of places				
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Additional information				
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Workload				
210 h				
Teaching cycle				
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Referred to in LPO I (examination regulations for teaching-degree programmes)				
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Module appears in				
Bachelor's degree (1 major) Mathematics (2015) Bachelor's degree (1 major) Mathematical Physics (2015) Bachelor's degree (1 major) Computational Mathematics (2015) Bachelor's degree (1 major) Mathematical Physics (2016) Master's degree (1 major) Physics (2016) Master's degree (1 major) Nanostructure Technology (2016) Master's degree (1 major) Nanostructure Technology (2020) Master's degree (1 major) Physics (2020) Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Technology (2021) Bachelor's degree (1 major) Mathematics (2023)				

Module title				Abbreviation
Advanced Astro Imaging				11-AAI-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1) Image Acquisition: a) Motivation: History of Astronomical Imaging - From the Eye to the Detector; b) Atmospheric Transmission: Ground Based vs. Space Based Imaging; c) Observing Techniques and Instruments; d) Optical Detector Types and CCD Properties; e) Imaging in Other Bands of the Electromagnetic Spectrum

2) Image Processing: a) Data Formats and Imaging Software; b) Basic Methods: Pixel Operations and Statistics; c) Basic Methods II: Image Operations; d) Image Reduction- / Calibration; e) Imaging in Color f) Image Processing Algorithms

3) Advanced Processing: a) FITS File Format; b) Image Reconstruction; c) Fourier Analysis; d) Speckle Interferometry; e) Maximum Entropy Methods; f) Interferometry; g) Image Classification, Machine Learning Methods

4) Outlook: a) Future Challenges: Scientific Questions / Instruments / Data Processing; b) Future Facilities Radio to Gamma-rays; c) Imaging in Other Scientific Fields

Intended learning outcomes

The aim of the module is to convey a fundamental understanding of imaging methods using examples from modern astronomy, incorporating measurements from ground- and space-based instruments. The students acquire the following qualifications: ability to process and interpret raw-image data, to perfom data reduction, image analysis, application and improvement of processing algorithms. The concepts and methods are not limited to the field of astronomy but applicable to many other areas.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload
180 h
Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Cosmology				11-AKM-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Expanding Space-Time, Friedmannian Cosmology, Basics of General Relativity, The Early Universe, Inflation, Dark Matter, Primordial Nucleosynthesis, Cosmic Microwave Background, Structure Formation, Galaxies and Galaxy Clusters, Intergalactic Medium, Cosmological Parameters

Intended learning outcomes

Basic knowledge of cosmology. Knowledge of the theoretical methods of cosmology and the ability to relate those to observations. Insight into current research topics and is able to work on scientific questions.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Selected Topics of Theoretical Solid State Physics				11-AKTF-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

In this lecture, selected topics of condensed matter theory are addressed. We intend to present new developments to bring the students in touch with actual research topics. Possible subjects are many-body localization and dynamic quantum matter.

Intended learning outcomes

The students learn how to describe condensed matter systems in presence of disorder and interactions from a theoretical point of view. This happens on the basis of analytical and numerical methods. Therefore, we envisage a smooth crossover of these students to the next step of becoming a researcher.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
High-Energy Astrophysics				11-APL-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Astrophysical sources of high-energy emission, radiative processes, interaction of light with matter, particle-acceleration processes, pair creation, nuclear processes, pion production, astrophysical shock waves, kinetic equations

Intended learning outcomes

The student gains knowledge in fundamentals of high-energy astrophysics, such as particle acceleration and non-thermal radiative processes in astrophysical

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Astrophysics				11-APM-Int-241-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

History of Astronomy, Coordinates and Time Measurement, the Solar System, Exoplanets, Astronomical Scales, Telescopes and Detectors, Stellar Structure and Atmospheres, Stellar Evolution and their 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.

Intended learning outcomes

The student is familiar with the modern astrophysical world view. He/She knows the methods and instruments of astrophysical research. He/She is able to plan and interpret his/her own observations. He/She is familiar with the physics and evolution of the most important astrophysical objects, e.g., stars and galaxies.

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

V (2) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Methods of Observational Astronomy				11-ASM-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Methods of observational Astronomy across the electromagnetic spectrum; Extraction and reduction of observational data from radio, optical, X-ray and gamma-ray telescopes.

Intended learning outcomes

Overview over the methods used in observational astronomy in various parts of the electromagnetic spectrum (radio, optical, X-ray and gamma-ray energies). Knowledge of principles and applications of these methods and ability to conduct astronomical observations.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Introduction to Space Physics				11-ASP-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Overview
2. Dynamics of charged particles in magnetic and electric fields
3. Elements of space physics
4. The sun and heliosphere
5. Acceleration and transport of energetic particles in the heliosphere
6. Instruments to measure energetic particles in extraterrestrial space

Intended learning outcomes

Basic knowledge in space physics, in particular of the characterzation of the dynamics of charged particles in space and the heliosphere. Knowledge of the relevant parameters, the theoretical concepts and the methods of their measurements.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)

Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

<table>
<tr><td colspan="3">Module title</td><td>Abbreviation</td></tr>
<tr><td colspan="3">Theoretical Astrophysics</td><td>11-AST-Int-201-m01</td></tr>
<tr><td colspan="3">Module coordinator</td><td>Module offered by</td></tr>
<tr><td colspan="3">Managing Director of the Institute of Theoretical Physics and Astrophysics</td><td>Faculty of Physics and Astronomy</td></tr>
<tr><td>ECTS</td><td>Method of grading</td><td colspan="2">Only after succ. compl. of module(s)</td></tr>
<tr><td>6</td><td>numerical grade</td><td colspan="2">--</td></tr>
<tr><td>Duration</td><td>Module level</td><td colspan="2">Other prerequisites</td></tr>
<tr><td>1 semester</td><td>graduate</td><td colspan="2">--</td></tr>
<tr><td colspan="4">Contents</td></tr>
<tr><td colspan="4">Topics in theoretical astrophysics such as e.g. white dwarfs, neutron stars and black holes, supernovae, pulsars, accretion and jets, shock waves, radiation transport, and gravitational lensing.</td></tr>
<tr><td colspan="4">Intended learning outcomes</td></tr>
<tr><td colspan="4">Knowledge of basic processes and methods of theoretical astrophysics. Ability to formulate theoretical models.</td></tr>
<tr><td colspan="4">Courses (type, number of weekly contact hours, language — if other than German)</td></tr>
<tr><td colspan="4">V (2) + R (2)
Module taught in: English</td></tr>
<tr><td colspan="4">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)</td></tr>
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester</td></tr>
<tr><td colspan="4">Allocation of places</td></tr>
<tr><td colspan="4">--</td></tr>
<tr><td colspan="4">Additional information</td></tr>
<tr><td colspan="4">--</td></tr>
<tr><td colspan="4">Workload</td></tr>
<tr><td colspan="4">180 h</td></tr>
<tr><td colspan="4">Teaching cycle</td></tr>
<tr><td colspan="4">--</td></tr>
<tr><td colspan="4">Referred to in LPO I (examination regulations for teaching-degree programmes)</td></tr>
<tr><td colspan="4">--</td></tr>
<tr><td colspan="4">Module appears in</td></tr>
<tr><td colspan="4">Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)</td></tr>
</table>

Module title				Abbreviation
Atmospheric Physics				11-ATP-Int-241-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Formation of atmospheres. Planetary atmospheres in the solar system: chemical composition and thermodynamics. Radiative transfer and radiative balance. Fluid mechanics. Greenhouse effect. Climate Models: Equilibrium and Runaway. Physics of clouds. Electric and magnetic fields. Solar wind and interplanetary medium. Meteorites, asteroids, cosmic rays. Atmospheres of exoplanets.

Intended learning outcomes

Students have knowledge of the physics of planetary atmospheres, especially the Earth's atmosphere and near-Earth space. They are able to use the acquired knowledge in the planning of space missions and in the exploration of exoplanets. They are able to model the physical mechanisms of the terrestrial climate and interpret the effects of global warming.

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

V (2) + R (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title			Abbreviation
Selected Topics of Theoretical Elementary Particle Physics			11-ATTP-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

A selection of topics from the following fields will be covered:
1. Advanced Techniques for Precision Calculations of Scattering Amplitudes
2. Phenomenology of Collider Experiments
3. Higgs Physics
4. Top-Quark Physics

Intended learning outcomes

Ability to apply advanced computational tools and methods for the description of particle physics phenomenology. Knowledge of current trends in particle physics phenomenology.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Basic Imaging Concepts				11-BIC-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Introduction to generic imaging concepts and physical imaging methods covering the most central aspects across all imaging modalities, including 1) the concept of Fourier imaging, 2) tomography (Radon-Transformation, central-slice- theorem), 3) the system theory of imaging systems, and 4) issues of image quality (point-spread function, modulation transfer function, spatial resolution, contrast, noise). During the course different advanced methods for image acquisition will be covered and a comprehensive overview of modern imaging modalities in biomedicine, material science and astrophysics will be given.

Intended learning outcomes

The students know the physical foundations of imaging methods and their applications. They understand the principles of image formation and are able to explain the different methods and to interpret simple images.

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

V (3) + R (1)
Module taught in: 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)

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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: every year, after announcement

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Models Beyond the Standard Model of Elementary Particle Physics				11-BSM-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Basics of the Standard Model of Particle Physics
2. Tests of the Standard Model in Low Energy Experiments and at High Energy Colliders
3. Neutrino Physics
4. Higgs Physics

A selection of topics from the following fields will covered:

- Phenomenology of Experiments at the LHC
- Particle Cosmology
- Extended Gauge Theories
- Models with Extended Higgs Sectors
- Supersymmetry
- Models with Extra Dimension of Space-Time

Intended learning outcomes

Familiarity with tests of the standard model and their limitations. Knowledge in the description of elementary particle phenomenology, in particular Higgs and neutrino physics. Ability to construct extensions of the standard model and understand how to test these extensions in low energy experiments, at high energy colliders and in cosmology.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title					Abbreviation
Image and Signal Processing in Physics					11-BSV-Int-201-m01
Module coordinator				**Module offered by**	
Managing Director of the Institute of Applied Physics				Faculty of Physics and Astronomy	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**		
6	numerical grade		--		
Duration		**Module level**	**Other prerequisites**		
1 semester		graduate	--		

Contents

Periodic and aperiodic signals; basic principles of the discrete and exact Fourier transformation; basic principles of the digital signal and image processing; discretization of signals/Shannon sampling theorem; Parsival theorem, correlation and energy consideration; statistical signals, image noise, moments, stationary signals; tomography: Hankel and Radon transformation.

Intended learning outcomes

Advanced knowledge about digital image and signal processing. Familiarity with the physical principles of image processing and various methods of signal processing. Capability of describing the various methods and in particular of applying them to tomography.

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

V (2) + Ü (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)

Master's degree (1 major) Physics International (2024)

Module title			Abbreviation
Bosonisation and Interactions in One Dimension			11-BWW-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

1. Instability of Fermi systems in one dimension (1D)
2. Abelian bosonisation and Luttinger liquids (spinless fermions, correlation functions, models with spin, renormalization group, and the sine-Gordon model).

The below mentioned topics will be presented in different years:
3. Interacting fermions on a lattice (Hubbard model, t/J model, transport properties)
4. Bethe ansatz
5. Spin-1/2 chains
6. Disordered systems
7. Non-abelian bosonisation and the WZW model (Kac-Moody algebras, Sugawara construction, Knizhnik-Zamolodchikov equation, applications of the WZW model)

Intended learning outcomes

Familiarity with the peculiarities of one-dimensional (1D) electron systems. Acquisition of the theoretical tools to understand experimentally relevant features including disorder effects and transport in 1D.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title			**Abbreviation**
Contemporary Astrophysics			11-CAP-Int-201-m01
Module coordinator		**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics		Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**	
6	numerical grade	--	
Duration	**Module level**	**Other prerequisites**	
1 semester	graduate	--	

Contents

History of Astronomy, Coordinates and Time Measurement, the Solar System, Exoplanets, Astronomical Scales, Telescopes and Detectors, Stellar Structure and Atmospheres, Stellar Evolution and their 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.

Intended learning outcomes

The student is familiar with the modern astrophysical world view. He/She knows the methods and instruments of astrophysical research. He/She is able to plan and interpret his/her own observations. He/She is familiar with the physics and evolution of the most important astrophysical objects, e.g., stars and galaxies.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: every year, after announcement

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title			Abbreviation
Computational Materials Science (DFT)			11-CMS-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
8	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

1. Density functional theory (DFT)
2. Wannier functions and localized basis functions
3. Numerical evaluation of topological invariants
4. Hartree-Fock and static mean-field theory
5. Many-body methods for solid state physics
6. Anderson impurity model (AIM) and Kondo physics
7. Dynamical mean-field theory (DMFT)
8. DFT + DMFT methods for realistic modeling of solids
9. Strongly correlated electrons

Intended learning outcomes

Theoretical treatment of the above topics complemented by hands-on tutorials to be held in the CIP-Pool. Familiarity with DFT software packages such as VASP or Wien2k and construction of maximally localized Wannier functions by projecting DFT results onto atomic orbitals using wannier90. Knowledge how to obtain many-body solutions of the AIM and explore some of its limiting cases such as the Kondo regime. Ability to use impurity solvers based on exact diagonalization or continuous-time quantum Monte Carlo for the solution of the DMFT self-consistency equations.

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

V (4) + R (2)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Renormalization Group and Critical Phenomena				11-CRP-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Phase transitions
2. Mean field theory
3. The concept of the renormalization group (RG)
4. Phase diagrams and fixed points
5. Perturbation-theoretical renormalization group
6. Low-dimensional systems
7. Conformal symmetry

Intended learning outcomes

Profound knowledge of the principles of scale invariance and the renormalization group (RG) in statistical physics. Understanding of the concept of the RG flow with respect to effective field theories in both statistical and quantum field theory.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Topics in Astrophysics				11-CSAM-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

An in-depth study of particular current topics in astrophysics. Concepts of astrophysics will be conveyed which are relevant to the following topics: Stellar structure, star formation and development, radiation transport, gas dynamics, heating and cooling processes of the interstellar medium, astrochemistry, accretion and jets, galaxy formation, as well as related topics.

Intended learning outcomes

Acquisition of advanced skills in current topics of astrophysics.
Capability to independently get acquainted with current research topics in astrophysics.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Topics in Solid State Physics				11-CSFM-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

This module will enable the lecturers of condensed matter physics to teach advanced courses on topics not covered in any of the other modules. These topics may relate either to recent research developments or to subjects not included in the regular curriculum.

Intended learning outcomes

In-depth knowledge and understanding of an advanced topic in condensed matter physics. Insight into the interface between teaching and research.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Computer Tomography				11-CTA-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

This advanced course focuses on the details of modern computed tomography (CT), which is employed both in medical and industrial imaging applications. In addition to the technicalities of CT systems and their application to various tasks in engineering and medical science, this lecture emphasizes on the mathematics of "inverting the Radon transform". Starting with the simple Filtered Back Projection method which is applied to a variety of standard recording geometries (parallel, fan, cone, helix) the advanced course lays out the strategies for algebraic reconstruction techniques (ART) along with many types of regularization schemes which may accompany these methods. Students will have the opportunity to see how Radon data is recorded and how different error sources as well as the corresponding correction schemes influence the outcome of the reconstructed volume images. Finally the most common tools for volume image analysis are presented, such as distance transforms, watersheds, labelling and fiber orientation analysis.

Intended learning outcomes

The student know the concept of Computed tomography (CT) and its applications. From the formulation of the basic inverse problem posed by this technique the students are able to derive strategies for different numerical solutions, based on Fourier analysis and/or based on probability theory. Most importantly the students have a firm impression (first-hand experience) of the various sources of measurement errors in CT which can impede any well-prepared reconstruction.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: every year, after announcement

Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Electron and Ion Microscopy				11-EIM-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Applied Physics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Theoretical Foundations. Electron and ion sources, optics of charged particles, interaction of matter with electrons and charged particles, detectors, measurement principles: SEM, STEM, TEM, sample preparation, advanced contrast mechanisms: EBSD, EELS, EDS, cathodoluminescence.

Intended learning outcomes

The student has specific and immersed knowledge in electron and ion microscopy. He/she knows the theoretical and instrumental basics and principles of detectors and contrast mechanisms. He/she knows different modi of electron microscopy and their applications. He/she knows ongoing developments in this field.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: annually, after announcement

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title	Abbreviation
Introduction to Plasma Physics	11-EPP-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Plasma Astrophysics: Dynamics of charged particles in electric and magnetic fields, Magnetohydrodynamics, Transport equations for energetic particles, Properties of magnetic turbulence, Propagation of solar particles within the solar wind, Particle acceleration via shock waves and via interaction with plasma turbulence, Particle acceleration and transport in galaxies and other astrophysical objects, Cosmic radiation.

Intended learning outcomes

Knowledge of fundamental processes in plasma astrophysics.

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

V (2) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics in Experimental Physics				11-EXE5-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
5	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Current topics in experimental physics, Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses advanced knowledge meeting the requirements of a module in experimental physics on Master's level. He/She commands knowledge in a current field in experimental physics and insight into the measuring and evaluation methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (2) + R (2)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics in Experimental Physics				11-EXE6A-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
6	numerical grade		--	
Duration		**Module level**	**Other prerequisites**	
1 semester		graduate	Approval from examination committee required.	

Contents

Current topics in experimental physics, credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student possesses advanced knowledge meeting the requirements of a module in experimental physics on Master's level. He/She commands knowledge in a current field in experimental physics and insight into the measuring and evaluation methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title			**Abbreviation**
Current Topics in Experimental Physics			11-EXE6-Int-201-m01
Module coordinator		**Module offered by**	
chairperson of examination committee		Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**	
6	numerical grade	--	
Duration	**Module level**	**Other prerequisites**	
1 semester	graduate	Approval from examination committee required.	

Contents

Current topics in experimental physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses advanced knowledge meeting the requirements of a module in experimental physics on Master's level. He/She commands knowledge in a current field in experimental physics and insight into the measuring and evaluation methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics in Experimental Physics				11-EXE7-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
7	numerical grade		--	
Duration	**Module level**		**Other prerequisites**	
1 semester	graduate		Approval from examination committee required.	

Contents

Current topics in experimental physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses advanced knowledge meeting the requirements of a module in experimental physics on Master's level. He/She commands knowledge in a current field in experimental physics and insight into the measuring and evaluation methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

210 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics in Experimental Physics				11-EXE8-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Current topics in experimental physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses advanced knowledge meeting the requirements of a module in experimental physics on Master's level. He/She commands knowledge in a current field in experimental physics and insight into the measuring and evaluation methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (4) + R (2)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Nonphysical Minor Subject				11-EXNP6-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Non-technical minor. Crediting for academic achievements, e.g. from university change or study abroad

Intended learning outcomes

The student posseses advanced knowledge on Master's level meeting the requirements of a module in the field of a non physical minor subject (mathematics, chemistry, computer science, ...).

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics in Physics				11-EXP6A-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Current topics in experimental or theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses advanced knowledge meeting the requirements of a module in theoretical or experimental physics on Master's level in the study programme Nanostructure Technology. He/She commands knowledge in a current field in physics and insight into the measuring and calculating methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title			**Abbreviation**
Current Topics in Physics			11-EXP6-Int-201-m01

Module coordinator	**Module offered by**
chairperson of examination committee	Faculty of Physics and Astronomy

ECTS	**Method of grading**	**Only after succ. compl. of module(s)**
6	numerical grade	--

Duration	**Module level**	**Other prerequisites**
1 semester	graduate	Approval from examination committee required.

Contents

Current topics in experimental or theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses advanced knowledge meeting the requirements of a module in theoretical or experimental physics on Master's level in the study programme Nanostructure Technology. He/She commands knowledge in a current field in physics and insight into the measuring and calculating methods which are necessary to acquire this knowledge. He/She is able to classify and to link the learnt. He/She knows about fields of application.

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

V (3) + R (1)

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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics of Theoretical Physics				11-EXT5-Int-201-m01

Module coordinator	Module offered by
chairperson of examination committee	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
5	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	Approval from examination committee required.

Contents

Current topics in theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses deepened knowledge meeting the requirements of a module in theoretical physics on Master's level. He/She commands advanced technical knowledge in a current field in theoretical physics and masters the respective methods. He/She is able to apply these methods to current problems in theoretical physics.

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

V (2) + R (2)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics of Theoretical Physics				11-EXT6A-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Current topics in theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses deepened knowledge meeting the requirements of a module in theoretical physics on Master's level. He/She commands advanced technical knowledge in a current field in theoretical physics and masters the respective methods. He/She is able to apply these methods to current problems in theoretical physics.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics of Theoretical Physics				11-EXT6-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Current topics in theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses deepened knowledge meeting the requirements of a module in theoretical physics on Master's level. He/She commands advanced technical knowledge in a current field in theoretical physics and masters the respective methods. He/She is able to apply these methods to current problems in theoretical physics.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title					Abbreviation
Current Topics of Theoretical Physics					11-EXT7-Int-201-m01
Module coordinator				Module offered by	
chairperson of examination committee				Faculty of Physics and Astronomy	
ECTS	Method of grading		Only after succ. compl. of module(s)		
7	numerical grade		--		
Duration		Module level	Other prerequisites		
1 semester		graduate	Approval from examination committee required.		

Contents

Current topics in theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses deepened knowledge meeting the requirements of a module in theoretical physics on Master's level. He/She commands advanced technical knowledge in a current field in theoretical physics and masters the respective methods. He/She is able to apply these methods to current problems in theoretical physics.

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

V (3) + R (1)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

210 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Current Topics of Theoretical Physics				11-EXT8-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

Current topics in theoretical physics. Credited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes

The student posseses deepened knowledge meeting the requirements of a module in theoretical physics on Master's level. He/She commands advanced technical knowledge in a current field in theoretical physics and masters the respective methods. He/She is able to apply these methods to current problems in theoretical physics.

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

V (4) + R (2)
Module taught in: 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)

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: English

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Field Theory in Solid State Physics				11-FFK-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

This will usually be a course on quantum many particle physics approached by the perturbative methods using Green's functions
An outline could be:
1. Single-particle Green's function
2. Review of second quantization
3. Diagrammatic method using many particle Green's functions at temperature T=0
4. Diagrammatic method for finite T
5. Landau theory of Fermi liquids
6. Superconductivity
7. One-dimensional systems and bosonization

Intended learning outcomes

Working knowledge of the methods of quantum field theory in a non-relativistic context. Ability to study properties of Fermi liquids (and bosonic systems) beyond the one-particle picture. Acquisition of methods which are essential for the understanding the effects of interactions, including superconductivity and the Kondo effect.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Solid State Physics 2				11-FK2-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

1. Electrons in a periodic potential – the band structure
a. Electrical and thermal transport
b. Bloch theorem
c. Electrons
2. Semi-classical models of dynamic processes
a. Electrical transport in partially and completely filled bands
b. Fermi surfaces; measurement techniques
c. Electrical transport in external magnetic fields
d. Boltzmann-equations of transport
3. The dielectric function and ferroelectrics
a. Macroscopic electrodynamics and microscopic theory
b. Polarizability of solids, of lattices, of valence electrons and quasi-free electrons; optical phonons, polaritons, plasmons, inter-band transitions, Wannier-Mott excitons
c. Ferromagnetism
4. Semiconductors
a. Characteristics
b. Intrinsic semiconductors
c. Doped semiconductors
d. Physics and applications of p-n junctions
e. Heterostructures
5. Magnetism
a. Atomic dia- and paramagnetism
b. Dia- and paramagnetism in metals
c. Ferromagnetism
6. Superconductivity
a. Phenomena
b. Models of superconductivity
c. Tunnel experiments und applications

Intended learning outcomes

Knowledge of effects, concepts and models in advanced solid state physics. Familiarity with the theoretical principles and with applications of experimental methods.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Solid State Spectrocopy				11-FKS-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Single and many particle picture of electrons in solids, Light-matter interaction, Optical spectroscopy, Electron spectroscopy, X-ray spectroscopies.

Intended learning outcomes

Specific and in-depth knowledge of solid-sate spectroscopy. Knowledge of different methods of spectroscopy and their applications. Understanding of the theoretical principles and modern developments in the related science.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Visiting Research				11-FPA-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
10	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
	graduate	Approval from examination committee required.		
Contents				
Independent work in a current research topic in experimental or theoretical physics. Experimental work including analysis and documentation of the results, especially in the context of research visits to other universities or research institutes.				
Intended learning outcomes				
Familiarity with current research topics in experimental or theoretical physics. Within experimental physics, the ability to analyze and document scientific experiments.				
Courses (type, number of weekly contact hours, language — if other than German)				
R (0) Module taught in: 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)				
project report (approx. 10 to 20 pages) Language of assessment: English				
Allocation of places				
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Additional information				
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Workload				
300 h				
Teaching cycle				
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Referred to in LPO I (examination regulations for teaching-degree programmes)				
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Module appears in				
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)				

Module title				Abbreviation
Professional Specialization Physics International				11-FS-P-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
15	(not) successfully completed	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		
Contents				
Introduction to current experimental or theoretical research topics within physics that are of particular relevance for the envisaged topic of the master thesis. A seminar talk summarizing the required underlying fundamental topics.				
Intended learning outcomes				
Thorough understanding of a current experimental or theoretical research topic of relevance to the topic chosen for the master thesis. In-depth knowledge of the current state of research and ability to present and convey this knowledge in a seminar talk.				
Courses (type, number of weekly contact hours, language — if other than German)				
S (4) Module taught in: 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)				
talk with discussion (30 to 45 minutes) Language of assessment: English				
Allocation of places				
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Additional information				
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Workload				
450 h				
Teaching cycle				
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Referred to in LPO I (examination regulations for teaching-degree programmes)				
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Module appears in				
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Physics International (2024)				

Module title				Abbreviation
Introduction to Gauge/Gravity Duality				11-GGD-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Elements of quantum field theory:
   - Quantisation of the free field
   - Interactions
   - Renormalisation Group
   - Gauge Fields
   - Conformal Symmetry
   - Large N expansion
   - Supersymmetry
2. Elements of gravity
   - Manifolds, coordinate covariance and metric
   - Riemann curvature
   - Maximally symmetric spacetimes
   - Black holes
3. Elements of string theory
   - Open and closed strings
   - Strings in background fields
   - Type IIB String Theory
   - D-Branes
4. The AdS/CFT correspondence
   - Statement of the correspondence
   - Near-horizon limit of D3-Branes
   - Field-operator correspondence
   - Tests of the correspondence: Correlation functions
   - Tests of the correspondence: Conformal anomaly
   - Holographic principle
5. Extensions to non-conformal theories
   - Holographic renormalisation group
   - Holographic C-Theorem
6. Applications I: Thermo- and hydrodynamics
   - Quantum field theory at finite temperature
   - Black holes
   - Holographic linear response formalism
   - Transport coefficients: Shear viscosity and conductivities
7. Applications II: Condensed matter physics
   - Finite charge density and Reissner-Nordström black holes
   - Quantum critical behaviour
   - Holographic fermions
   - Holographic superconductors
   - Entanglement entropy
8. Applications III: Particle physics
   - Gravity dual of confinement
   - Gravity dual of chiral symmetry breaking
   - Quark-gluon plasma

Intended learning outcomes
Thorough understanding of the foundations of gauge/gravity duality and the ability to carry out basic tests. Working knowledge of essential applications. Knowledge of quantum mechanics and classical electrodynamics is a prerequisite for this course. Knowledge of quantum field theory and general relativity will be useful, however is not a prerequisite.
Courses (type, number of weekly contact hours, language — if other than German)
V (4) + R (2) Module taught in: 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)
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: English Assessment offered: In the semester in which the course is offered and in the subsequent semester
Allocation of places
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Additional information
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Workload
240 h
Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title			Abbreviation
Group Theory			11-GRTM-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	Approval from examination committee required.

Contents

German contents available but not translated yet.

Gruppentheorie. Endliche Gruppen. Lie-Gruppen. Lie-Algebren. Darstellungen. Tensoren. Klassifikationstheorem. Anwendungen

Intended learning outcomes

German intended learning outcomes available but not translated yet.

Die Studierenden beherrschen die Grundlagen der Gruppentheorie, insbesondere der Lie-Gruppen. Sie sind in der Lage, Problemstellungen der Gruppentheorie zu erkennen und mit Hilfe der erlernten Methoden zu lösen. Sie können die Gruppentheorie zur Formulierung und Bearbeitung physikalischer Probleme anwenden.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)

exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Optical Properties of Semiconductor Nanostructures				11-HNS-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Semiconductor Nanostructures are frequently referred to as 'artificial materials'. In contrast to atoms, molecules or macroscopic crystals, their electronic, optical and magnetic properties can be systematically tailored via changing their size. The lecture addresses technological challenges in the preparation of semiconductor nanostructures of varying dimensions (2D, 1D, 0D). It provides the basic theoretical concepts to describe their properties, with a focus on optical properties and light-matter coupling. Moreover, it discusses the challenges and concepts of novel optoelectronic and quantum photonic devices based on such nanostructures, including building blocks for quantum communication and quantum computing architectures

Intended learning outcomes

Familiarity with the fundamental properties of semiconductor nanostructures as well as with their theoretical foundations. Knowledge of the technological methods to fabricate such structures, and of their applications to novel photonic devices.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)

Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Semiconductor Physics				11-HPH-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

The lecture deals with the fundamental properties of semiconductors. It begins with an analysis of the crystal structure, leading to methods for describing band structures. These form a basis for discussing optical and electronic properties of monolithic semiconductors. It then turns to examining semiconductor heterostructures, and studies how these can be used to modify and design optical and electrical properties, especially in the case of lowered dimensionality systems. Examples are selected from current research activities.

Intended learning outcomes

To provide the student with a working knowledge semiconductors pertaining to crystal structure, symmetries, and band structures, as well as electrical and optical properties. This establishes a solid basis preparing him for the more targeted specially lectures in the program.

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

V (3) + R (1)
Module taught in: 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)

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).
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)

Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Basic Imaging Reconstruction and Processing				11-IRP-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

This training course uses the fundamentals of modern signal processing and imaging concepts, which are introduced in the corresponding lecture. Starting with the different categories of signals and transferring them to imaging applications, the students can test Fourier transform properties first hand by developing Matlab or Python code. Image convolution and de-convolution techniques are addressed in particular with respect to image processing tasks in modern physics (e.g. denoising). The Radon-Transform, which takes an outstanding im-portance in the field of computed tomography is demonstrated by the three-dimensional image reconstruction from real CT data whereby different sources of error can be tested. The theoretical part on discrete signals and their Fourier transform properties as well as different ways of image compression will also be further developed during this course.

Intended learning outcomes

Students who attended the course are firm with the theoretical concepts of signal processing in particular with respect to imaging applications. They are able to devise a strategy /toolchain for basic and advanced imaging problems, such as image reconstruction, denoising, Fourier analysis and frequency decomposition. By using Matlab or Python they are able to calculate appropriate figures of merit from scientific images, such as SNR.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: every year, after announcement

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

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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023)

Module title				Abbreviation
Conformal Field Theory 2				11-KFT2-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

5 Minimal models (critical statistical mechanics models (Ising, tricritical Ising, 3 state Potts model, restricted solid-on-solid models), correlation functions of the critical Ising model, fusion rules and the Verlinde algebra, Landau-Ginzburg description of minimal models, modified Coulomb gas method and its application to the Ising model, superconformal models)
6 Free bosons and fermions (mode expansions, twist fields, fermionic zero modes and fermion parity)
7 Free fermions on the torus (operator implementation of the partition function, vacuum energies, representations of Virasoro algebra, the modular group and fermionic spin structures, Virasoro characters, critical Ising model on the torus, Jacobi theta function identities)
8 Free bosons on the torus (Lagrangian formulation of the partition function, fermionization, orbifolds in general, S1/Z2 orbifold, Gaussian and Askhin-Teller models, duality between original and orbifold theories, marginal operators, the space of c=1 theories)

Intended learning outcomes

Acquisition of both practical and conceptional familiarity with the methods of conformal field theory. Basic understanding of critical phenomena, quantum field theory, and functional integration. Enhanced level of understanding in particular for students of theoretical physics by exposure to an ambitious method with significant applications in contemporary condensed matter physics.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Conformal Field Theory				11-KFT-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Conformal field theory (CFT), as developed in the 1980s, finds immediate applications in string theory and two-dimensional statistical mechanics, where critical exponents and correlation functions for many models (Ising, tricritical Ising, 3-state Potts, etc.) can be calculated exactly. The physical idea is that the principle of scale invariance is elevated from a global to a local invariance, which for reasons of consistency amounts to invariance under conformal transformations. This, in turn, yields a rich and fascinating mathematical structure for two dimensional systems (either two space or one time and one space dimension). CFT has become relevant to many interesting areas of condensed matter physics, including Abelian and non-Abelian bosonization, quantized Hall states (where the bulk wave function is described in terms of conformal correlators, and the edge in terms 1+1 dimensional CFTs), the two-channel Kondo effect, fractional topological insulators, and in particular fault-tolerant topological quantum computing involving non-Abelian anyons (Ising and Fibonacci anyons, for example, owe their names to the fusion rules of the associated conformal fields.) A potential syllabus for the first term of the course is:
0 Introduction (scale and conformal invariance, critical exponents, the transverse Ising model at the self-dual point)
1 Conformal theories in D dimensions (conformal group, conformal algebra in 2D, constraints on correlation functions)
2 Conformal theories in D=2 (primary fields and correlation functions, quantum field theory, canonical quantization and Noether's theorem, radial quantization and Polyakov's theorem, time ordering and functional integration, the free boson and vertex operators, conformal Ward identities)
3 The central charge and the Virasoro algebra (central charge, the Schwarzian derivative, the free fermion, (Abelian) bosonization, mode expansions and the Virasoro algebra, the cylinder geometry and the Casimir effect, in- and out-states, highest weight states, descendant fields and operator product expansions, conformal blocks, duality and the bootstrap)
4 Kac determinant and unitarity (Verma modules and null states, Kac determinant formula, non-unitarity proof, conformal grids, minimal models in general)

Intended learning outcomes

Acquisition of both practical and conceptional familiarity with the methods of conformal field theory. Basic understanding of critical phenomena, quantum field theory, and functional integration. Enhanced level of understanding in particular for students of theoretical physics by exposure to an ambitious method with significant applications in contemporary condensed matter physics.

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

V (3) + R (1)
Module taught in: 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)

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: English Assessment offered: In the semester in which the course is offered and in the subsequent semester
Allocation of places
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Additional information
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Workload
180 h
Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Magnetism				11-MAG-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Dia- and paramagnetism, Exchange interaction, Ferromagnetism, Antiferromagnetism, Anisotropy, Domain structure, Nanomagnetism, Superparamagnetism, Experimental methods to measure magnetic properties. Kondo effect.

Intended learning outcomes

Knowledge of the basic terminology, concepts and phenomena of magnetism and the experimental methods to measure them. Skills in constructing simple models and describing the mathematical formalism, and the ability to apply these skills to the mentioned fields of magnetism. Competence to independently solve problems in these fields. Capability of assessing the precision of observations and of their analysis.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)

Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Master Thesis Physics International				11-MA-P-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
30	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Independent work on an experimental or theoretical research task within physics, in particular using state-of-the-art methods and according to scientific aspects. Writing of the master thesis.

Intended learning outcomes

Ability to independently work on an experimental or theoretical task in physics, in particular according to state-of-the-art methods and scientific aspects, and to discuss and present it in a written final thesis.

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

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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)

Master's thesis (750 to 900 hours total)
Language of assessment: English

Allocation of places

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Additional information

Time to complete: 6 months

Workload

900 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Multi-wavelength Astronomy				11-MAS-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Phenomenology of active galactic nuclei and extragalactic jets
2. Jet-emission processes
3. VLBI observations of jets
4. High-energy observations of jets
5. Multimessenger signatures of jets

Intended learning outcomes

Knowledge in multiwavelength astronomy by studying the observations of active galactic nuclei and their extragalactic jets. Insight into a new not-yet solved astrophysical question. Practice in writing an observing proposal.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Scientific Methods and Project Management Physics International				11-MP-P-Int-201-m01
Module coordinator			**Module offered by**	
chairperson of examination committee			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
15	(not) successfully completed	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Introduction to the scientific approach and practice, including project planning within a current experimental or theoretical research topic in physics. Establishment of a scientific project plan for the planned master thesis.

Intended learning outcomes

Knowledge of the scientific approach and practice, including project planning in a current experimental or theoretical research topic of relevance to the topic chosen for the master thesis. Ability to establish a research plan for the master thesis, and to plan the required experimental or theoretical work. Ability to present the project in a seminar talk.

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

R (4)
Module taught in: 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)

talk with discussion (30 to 45 minutes)
Language of assessment: English

Allocation of places

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Additional information

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Workload

450 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Magnetic Resonance Imaging				11-MRI-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Nuclear magnetic resonance (NMR) is a quantum mechanical phenomenon that, through magnetic resonance imaging (MRI), has played a major role in the revolution in medical imaging over the last 30 years. Starting from the fundamentals of nuclear magnetic resonance (resonance principle, relaxation times, chemical shift) this course covers
1) the NMR signal theory and signal evolution (Bloch equations)
2) the principles of spatial encoding, magnetic resonance imaging (MRI) and corresponding imaging sequences and measurement parameters,
3) the concept of k-space and Fourier imaging,
4) the physical, methodological and technical possibilities and limitations of MRI. Finally, typical application fields of MRI in biomedical research, clinical imaging and non-destructive testing will be covered.

Intended learning outcomes

The students are familiar with the basics and the deepened aspects of NMR and MRI including the mathematical-theoretical description and the physical basics of modern MRI, MRI-instrumentation and image-formation/image-processing principles. The students gain a deep insight into the area of modern MRI and its interdisciplinary relations and applications.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: In the semester in which the course is offered and in the subsequent semester

Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)

Module title	Abbreviation
Computational Astrophysics	11-NMA-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Various methods used in astrophysical simulations with special emphasis on their applications. N-body algorithms (tree- and polynomial codes). Particle-mesh methods (particle-in-cell methods). Vlasow methods (e.g., Lattice-Boltzmann). Hyperbolic conservation laws (fluid dynamics, finite difference method, Riemann solver, ENO). Methods of high-performance computing. Message-passing interface (MPI). GPGPU programming (OPEN-CL).

Intended learning outcomes

Ability to solve problems and equations typical in astrophysics and other fields of physics with the aid of numerical simulations. Capability to choose adequate strategies to approach such problems and to validate the results.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Nano-Optics				11-NOP-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

The lecture conveys theoretical fundamentals, experimental techniques, and applications of nano-optics starting from the discussion of the focusing of light. Based on this, the fundamentals of modern far-field optical microscopy are discussed. In the following, the near-field optical microscopy is introduced and discussed. As a further basis, quantum emitters are introduced and their light emission in nano-environments is derived. Plasmons in 2D, 1D and 0 dimensions are introduced and discussed in detail. This finally leads to the concept of optical antennas.

Intended learning outcomes

Specific and in-depth knowledge of the topic of nano-optics. Familiarity with the basic theoretical description and applications of nano-optics as well as the current developments of the topic.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)

Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Organic Semiconductors				11-OHL-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Fundamentals of organic semiconductors, molecular and polymer electronics and sensor technology, applications.

Intended learning outcomes

In-depth knowledge of the properties of organic semiconductor materials and their applications.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Open Quantum Systems				11-OQS-Int-241-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		
Contents				
density matrix theory, stochastic processes in Hilbert space, non-Markovian processes, relativistic quantum processes				
Intended learning outcomes				
development of a theoretical understanding of quantum system coupled to their environment				
Courses (type, number of weekly contact hours, language — if other than German)				
V (3) + R (1) Module taught in: 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)				
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: English Assessment offered: In the semester in which the course is offered and in the subsequent semester				
Allocation of places				
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Additional information				
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Workload				
180 h				
Teaching cycle				
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Referred to in LPO I (examination regulations for teaching-degree programmes)				
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Module appears in				
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Physics International (2024)				

Module title				Abbreviation
Advanced Seminar Physics A				11-OSP-A-Int-201-m01

Module coordinator	**Module offered by**
Managing Director of the Institute of Applied Physics	Faculty of Physics and Astronomy

ECTS	**Method of grading**	**Only after succ. compl. of module(s)**
5	numerical grade	--

Duration	**Module level**	**Other prerequisites**
1 semester	graduate	--

Contents

Seminar on current topics in theoretical and experimental physics

Intended learning outcomes

In-depth knowledge about a current topic in experimental or theoretical physics. Ability to read scientific publications, summarizing them and presenting them to a peer audience.

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

S (2)
Module taught in: 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)

talk with discussion (30 to 45 minutes)
Language of assessment: English

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Seminar Physics B				11-OSP-B-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**		**Only after succ. compl. of module(s)**	
5	numerical grade		--	
Duration		**Module level**	**Other prerequisites**	
1 semester		graduate	--	

Contents

Seminar on current topics in theoretical and experimental physics.

Intended learning outcomes

In-depth knowledge about a current topic in experimental or theoretical physics. Ability to read scientific publications, summarizing them and presenting them to a peer audience.

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

S (2)
Module taught in: 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)

talk with discussion (30 to 45 minutes)
Language of assessment: English

Allocation of places

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Additional information

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Workload

150 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Laboratory Course Master Part 1				11-P-FM1-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
3	(not) successfully completed	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Preparation and safety briefing.		

Contents

Foundations of particle, atomic and molecular physics, low-temperature experiments and correlated systems, solid state properties, surfaces and interfaces. Experiments covering the topics x-ray radiation, nuclear magnetic resonance (NMR), quantum Hall effect, optical pumping and spectroscopy with visible light, Hall effect, superconductivity, lasers, solid state optics

Intended learning outcomes

Solid skills in performing an experiment and analyzing and documenting the experimental outcome. Basic knowledge of how to prepare a scientific publication and use state-of-the-art analysis systems and software. Knowledge of experimental methods, of using scientific publications, of performing and evaluating an experiment, and presenting and discussing the results in the form of a scientific publication.

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

P (3)
Module taught in: 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)

practical examination
Students must successfully prepare, perform, document (lab notebook) and evaluate (in the form of a scientific publication) an experiment to be considered to have successfully completed this experiment. Students must successfully complete two experiments to be considered to have successfully completed this module. Detailed regulations are laid down in the respective module description.
Language of assessment: English

Allocation of places

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Additional information

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Workload

90 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title	Abbreviation
Advanced Laboratory Course Master Part 2	11-P-FM2-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Applied Physics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
3	(not) successfully completed	--

Duration	Module level	Other prerequisites
1 semester	graduate	Preparation and safety briefing.

Contents

Foundations of particle, atomic and molecular physics, low-temperature experiments and correlated systems, solid state properties, surfaces and interfaces. Experiments covering the topics x-ray radiation, nuclear magnetic resonance (NMR), quantum Hall effect, optical pumping and spectroscopy with visible light, Hall effect, superconductivity, lasers, solid state optics

Intended learning outcomes

Solid skills in performing an experiment and analyzing and documenting the experimental outcome. Basic knowledge of how to prepare a scientific publication and use state-of-the-art analysis systems and software. Knowledge of experimental methods, of using scientific publications, of performing and evaluating an experiment, and presenting and discussing the results in the form of a scientific publication

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

P (3)
Module taught in: 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)

practical examination
Students must successfully prepare, perform, document (lab notebook) and evaluate (in the form of a scientific publication) an experiment to be considered to have successfully completed this experiment. Students must successfully complete two experiments to be considered to have successfully completed this module. Detailed regulations are laid down in the respective module description.
Language of assessment: English

Allocation of places

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Additional information

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Workload

90 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Laboratory Course Master Part 3				11-P-FM3-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
3	(not) successfully completed	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Preparation and safety briefing.		

Contents

Foundations of particle, atomic and molecular physics, low-temperature experiments and correlated systems, solid state properties, surfaces and interfaces. Experiments covering the topics x-ray radiation, nuclear magnetic resonance (NMR), quantum Hall effect, optical pumping and spectroscopy with visible light, Hall effect, superconductivity, lasers, solid state optics

Intended learning outcomes

Solid skills in performing an experiment and analyzing and documenting the experimental outcome. Basic knowledge of how to prepare a scientific publication and use state-of-the-art analysis systems and software. Knowledge of experimental methods, of using scientific publications, of performing and evaluating an experiment, and presenting and discussing the results in the form of a scientific publication.

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

P (3)
Module taught in: 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)

practical examination
Students must successfully prepare, perform, document (lab notebook) and evaluate (in the form of a scientific publication) an experiment to be considered to have successfully completed this experiment. Students must successfully complete two experiments to be considered to have successfully completed this module. Detailed regulations are laid down in the respective module description.
Language of assessment: English

Allocation of places

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Additional information

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Workload

90 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Laboratory Course Master Part 4				11-P-FM4-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
3	(not) successfully completed	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Preparation and safety briefing.		

Contents

Foundations of particle, atomic and molecular physics, low-temperature experiments and correlated systems, solid state properties, surfaces and interfaces. Experiments covering the topics x-ray radiation, nuclear magnetic resonance (NMR), quantum Hall effect, optical pumping and spectroscopy with visible light, Hall effect, superconductivity, lasers, solid state optics

Intended learning outcomes

Solid skills in performing an experiment and analyzing and documenting the experimental outcome. Basic knowledge of how to prepare a scientific publication and use state-of-the-art analysis systems and software. Knowledge of experimental methods, of using scientific publications, of performing and evaluating an experiment, and presenting and discussing the results in the form of a scientific publication.

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

P (3)
Module taught in: 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)

practical examination
Students must successfully prepare, perform, document (lab notebook) and evaluate (in the form of a scientific publication) an experiment to be considered to have successfully completed this experiment. Students must successfully complete two experiments to be considered to have successfully completed this module. Detailed regulations are laid down in the respective module description.
Language of assessment: English

Allocation of places

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Additional information

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Workload

90 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title	Abbreviation
Physics of Complex Systems	11-PKS-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

1. Theory of critical phenomena in thermal equilibriumt
2. Introduction into the physics out of equilibriumt
3. Entropy production and fluctuationst
4. Phase transitions away from equilibriumt
5. Universalityt
6. Spin glasses
7. Theory of neural networks

Intended learning outcomes

In-depth knowledge of concepts and methods essential for a thorough understanding of collective phenomena in complex many-body systems. Thorough understanding of the concepts of entropy, entropy production and universality. Ability to appreciate the central importance of symmetries. Ability to perform research tasks in the field of complex systems.

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

V (2) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Physics of Advanced Materials				11-PMM-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

General properties of various material groups such as liquids, liquid crystals and polymers; magnetic materials and superconductors; thin films, heterostructures and superlattices. Methods to characterize these material groups. Two-dimensional layered structures.

Intended learning outcomes

Familiarity with the properties and characterization methods of various groups of modern materials.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Phenomenology and Theory of Superconductivity				11-PTS-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics and Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Basic Properties of Superconductors and their Applications, Development of technological platforms, Methods of material science for calculating temperature profiles in superconductors. Overview of the phenomenology of conventional and unconventional superconductivity. Review of BCS theory and its applicability for different types of superconductors. Extension of Ginzburg-Landau theory to a quantum field theory formalism using Feynman diagrams and functional integrals. Theoretical formalism of Ward identities and response functions. Goldstone modes, phase fluctuations, and coupling to the electromagnetic field. Interpretation of the Meissner effect in terms of the Higgs mechanism. Interplay of magnetism and conventional/unconventional superconductivity. Discussion of current research topics and perspective on room-temperature superconductivity.

Intended learning outcomes

Acquisition of basic knowledge about superconductivity as a macroscopic quantum phenomenon. Profound understanding of unconventional superconductivity and its interplay with magnetism in the context of current research. Knowledge of BCS mean-field theory, the quantum-field theory methods necessary to extend BCS theory, as well as the Meissner effect and the Higgs mechanism. Basic understanding of unconventional superconductors and their fascinating connection with competing magnetic phases.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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d) project report (approx. 8 to 10 pages) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)

Module title				**Abbreviation**
Quantum Field Theory I				11-QFT1-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

1. Symmetries.
2. Lagrange formalism for fields.
3. Field quantisation.
4. Asymptotic states, scattering theory and S-matrix
5. Gauge principle and interaction.
6. Perturbation theory.
7. Feynman rules.
8. Quantum elektrodynamical processees in Born approximation.
9. Radiative corrections (optional)
10. Renormalisation (optional).

Intended learning outcomes

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 basics processes in the framework of quantum electrodynamics in leading order. Moreover, they have a basic understanding of radiative corrections and renormalisation.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Quantum Field Theory II				11-QFT2-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
8	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

1. Generating Functionals
2. Path Integrals
3. Renormalization
4. Renormalization group
5. Gauge theories
6. Spontaneous Symmetry Breaking
7. Effective Field Theory (optional)

Intended learning outcomes

In-depth knowledge of the concepts and methods of quantum field theory, including the principles of renormalization and of gauge theories. Ability to formulate problems in quantum field theory and to solve them using the acquired calculational methods.

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

V (4) + R (2)
Module taught in: 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)

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).
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Advanced Theory of Quantum Computing and Quantum Information				11-QIC-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

1. Brief summary of classical information theory
2. Quantum theory seen from the perspective of information theory
3. Composite systems and the Schmidt decomposition
4. Entanglement measures
5. Quantum operations, POVMs, and the theorems of Kraus and Stinespring
6. Quantum gates and quantum computers
7. Elements of the theory of decoherence

Intended learning outcomes

Comprehensive understanding of quantum states and identity matrix beyond the usual textbook interpretation. Knowledge of handling tensor products and dealing with quantum effects in multipartite quantum systems. In-depth understanding of the phenomenon of entanglement. Knowledge of the fundamental mathematical concepts of quantum information theory. Ability to assess the limitations of quantum computing arising from decoherence.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Quantum Mechanics II				11-QM2-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	undergraduate	--		

Contents

„Quantum mechanics 2“ constitutes the central theoretical course to be taken within the international Master's program in physics. While the specific emphasis can be adjusted individually, the core topics that are supposed to be covered should include:
1. Second quantization: fermions and bosons
2. Band structures of particles in a crystal
3. Angular momentum, symmetry operators, Lie Algebras
4. Scattering theory: potential scattering, partial wave expansion
5. Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation, Lorentz group, fine structure splitting of atomic spectra
6. Quantum entanglement
7. Canonical formalism

Intended learning outcomes

In-depth knowledge of advanced quantum mechanics. Thorough understanding of the mathematical and theoretical concepts of the listed topics. Ability to describe or model problems of modern theoretical quantum physics mathematically, to solve problems analytically or using approximation methods and to interpret the results physically. The course is pivotal to subsequent theory courses in astrophysics, high energy physics and condensed matter/solid state physics. The course is mandatory for all Master's students.

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

V (4) + R (2)
Module taught in: 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)

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).
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Quantum Transport				11-QTR-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

The lecture addresses the fundamental transport phenomena of electrons in solids where Electron-electron interaction and the wave nature are the determining factors. This includes the diffusive and ballistic transport regime as well as the Coulomb blockade. Observations of electron interference effects, conductance quantization and the quantum Hall effect will be discussed. Thermoelectric properties of electronic system and the phenomenon of superconductivity will be examined as well.
Low dimensional electron systems and its quantum mechanical description are the basis of this lecture. Relevant material systems are semiconductor heterostructures as well as topological insulators, topological semimetals, and topological superconductors. The content will be guided by actual research results.

Intended learning outcomes

Working knowledge of basic transport experiments, its analysis and its interpretation which enables the student to discuss results critical.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)

Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Radio Astronomical Interferometry				11-RAI-Int-211-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1) Motivation and Background
a) History of radio astronomy
b) The role and development of radio interferometry
c) Applications of radio interferometry and scientific topics of special interest
d) Summary of important concepts in radio astronomy
II) Fundamental Concepts
1. Fourier optics
a) The concept of telescope aperture
b) Convolution and Fourier Theorems
c) (Radio) telescopes as spatial filters
2. lnterferometry
a) The Michelson interferometer
b) The two-element interferometer
c) The visibility function
d) The influence of limited bandwidth e) Spatial frequencies in interferometry
f) Coordinate systems
3.Aperture Synthesis by Radio lnterferometric Arrays
a) The concept of (u ,v) coverage
b) Simple configurations and transit arrays
c) Tracking arrays and Earth-rotation synthesis
d) VLBI arrays
e) Antenna separations and geometry
4.Receiver Response
a) Heterodyne frequency conversion
b) Interferometer sensitivity
c) Sampling, weighting, gridding
d) Bandwidth smearing
c) Calibration
5.lmage reconstruction
a) CLEAN and alternative imaging algorithms
b) Image defects
c) Seif calibration
6. Digital Beamforming
II I. Special Applications and Challenges
a) s.urveys and Wide-Field lmaging
b) Very Long Baseline lnterferometry
c) Spectroscopy in Radio lnterferometry
d) Polarisation in Radio lnterferometry
e) Time-Domain Science in Radio lnterferometry
f) Low-frequency Challenges lnterferometry
g) Big Data in Radio lnterferometry
h) lnterferometry and Geodesy
IV) Technical realization: Current and Upcoming Radio Interferometers
1. Low-frequency arrays: LOFAR, GMRT, ASKAP, APERTIF/WSRT, LWA, MWA

2. Centimeter-Band Arrays: JVLA, MERLIN, ATCA, MeerKAT, VLBA, EVN, LBA, JVN, VERA, AVN
3. (Sub-) Mill imeter Arrays: ALMA, NOEMA, GMVA, EHT
4. The Future: SKA

Intended learning outcomes

The goal of the course is the transfer of knowwledge and competence in the radio interferometrical method, providing a foundation for independent research.
Concepts are taught in connection to practical examples from modern astronomy including recent measurements of radio interferometers.
Students shall gain the following specific competences: Understanding of the concept of radio interferometrical observations and their calibration.
Processing and interpretation of raw data. data reduction and analysis, applications and understanding of established algorithms.
Handling of large data volumes. The course makes use of general concepts and teaches special programming concepts that are of wide use beyond astronomy.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: every year, after announcement

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Renormalization Group Methods in Field Theory				11-RMFT-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

This course is complementary to the discussion of Wilson's renormalizationg group (RG) as covered in the course „Renormalization Group and Critical Phenomena" (11-CRP). This course focuses on the diagrammatic formulation of RG flow equations and its relation to diagrammatic perturbation expansions. For interacting fermion systems, this is of particular relevance in the context of the functional renormalization group. A possible outline of the course is:
1. Wilson's RG
2. Path integral formulation of interacting fermions
3. Bethe-Salpeter-equation
4. RG flow equations for the one-particle and the two-particle vertex
5. Comparison of flow equations with diagrammatic resummation schemes (such as the „random phase approximation")
6. RG flow equations for spin systems

Intended learning outcomes

Familiarity with modern diagram based techniques for interacting many-body systems. In-depth understanding of the theoretical framework addressing a range of phenomena in correlated electron systems including superconductivity, charge and spin density waves, and nematic instabilities.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: Once a year as announced

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title	**Abbreviation**
Theory of Relativity	11-RTT-Int-201-m01

Module coordinator	**Module offered by**
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	**Method of grading**	**Only after succ. compl. of module(s)**
6	numerical grade	--

Duration	**Module level**	**Other prerequisites**
1 semester	graduate	--

Contents

1. Mathematical Foundations
2. Differential forms
3. Brief Summary of the special relativity
4. Elements of differential geometry
5. Electrodynamics as an example of a relativistic gauge theory
6. Field equations of the fundamental structure of general relativity
7. Stellar equilibrium and other astrophysical applications
8. Introduction to cosmology

Intended learning outcomes

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.

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

V (3) + R (1)
Module taught in: 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)

a) written examination (approx. 90 to 120 minutes) or
b) oral examination of one candidate each (approx. 30 minutes) or
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Black Holes				11-SLQ-Int-241-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

PART 1 - Classical solutions

1. Vacuum solutions of Einstein's equation - the Schwarzschild solution, Birkhoff's theorem, the Eddington-Finkelstein coordinates, Kruskal extension and eternal black holes, the Penrose diagram, conformal compactification and Carter-Penrose diagram
2. Gravitational collapse - the Oppenheimer-Snyder solution
3. Charged and rotating black holes - Cauchy horizons, ergosphere
4. ADM formalism - energy and angular momentum
5. Black hole thermodynamics

PART 2 - Astrophysical observations of black holes

1. Spin and mass measurements of black holes
2. Black hole electromagnetism
3. Gravitational waves and their measurement

PART 3 – Quantum aspects of black hole

1. Introduction to QFT on curved spacetime: Rindler spacetime, Unruh effect
2. Derivation of Hawking radiation
3. Hawking's original formulation of the information paradox
4. The "holography of information" - information paradox in AdS/CFT, the Page curve and Islands
5. Firewall, fuzzball, complementarity - possible resolutions of information paradox
6. Wormholes and the factorization puzzle

Intended learning outcomes

This course plays a bridging role joining the basics on GR learnt in the GR I course and the active research directions in the fields of Astronomy, Astrophysics, General Relativity, String Theory and Gauge/Gravity Duality. Through this course, the students will gain sufficient commands over the applications of general relativity in connection with research directions in this area. This in turn will motivate them to pursue careers as a researcher in the aforementioned directions and help them to successful begin their Master and PhD projects.

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

V (3) + R (1)
Module taught in: 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)

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
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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: English

Assessment offered: In the semester in which the course is offered and in the subsequent semester
Allocation of places
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Additional information
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Workload
180 h
Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Spintronics				11-SPI-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

In this lecture, the basic principles of spin transport are taught, with a particular emphasis on the phenomena of giant magnetoresistance and tunnel magnetoresistance. New phenomena from the fields of spin dynamics and current-induced spin phenomena are discussed.

Intended learning outcomes

Knowledge of basic principles of spin transport models and of applications of spin transport in information technology. Overview over the state-of-the-art findings in this field (giant magnetoresistance, tunnel magnetoresistance).

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Scanning Probe Technologies				11-SPT-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Basic theoretical principles of scanning force, tunneling, and near-field optical microscopy; basic principles of surface science; tip-sample interactions; design principles and material considerations; fundamentals of control engineering; measurement modes, e.g., contact and non-contact, Kelvin probe, friction force microscopy, etc; basic principles of processing and presenting microcopy data; measurement techniques and their application: lock-in, phase-lock loop, etc.

Intended learning outcomes

Student acquires specific knowledge in scanning probe microscopy. He/she knows the basic theoretical principles, is aware of basic design principles, knows pros and cons of various materials, and is familiar of measurement modes, contrast mechanisms, and their application. He/she is aware of recent development in the field.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

Teaching cycle: every year, after announcement

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title	Abbreviation
Surface Science	11-SSC-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Applied Physics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Relevance of surfaces and interfaces, distinction from bulk phases, classical description, continuum models, Atomic structure: reconstructions and adsorbates, surface orientation and symmetries, Microscopic processes at surface, thermodynamics, adsorption and desorption, Experimental characterization, Electronic structure of surfaces, chemical bonding, surface states, spin-orbit coupling, Rashba effects, topological surface states, magnetism

Intended learning outcomes

The students have an overview over the diverse aspects of surface science and they are familiar with the physical characteristic of surfaces and interfaces. The students know the most important experimental techniques for the investigation of surfaces, as well as their specific fields of application.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)

Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title			**Abbreviation**
String Theory 1			11-STRG1-Int-201-m01

Module coordinator	**Module offered by**
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	**Method of grading**	**Only after succ. compl. of module(s)**
8	numerical grade	--

Duration	**Module level**	**Other prerequisites**
1 semester	graduate	--

Contents

Classical and quantum theory of the relativistic bosonic string, in particular the Nambu-Goto action and Polyakov action, Quantization of the closed bosonic string and emergent graviton, Quantum Lorentz invariance and critical dimension, Quantization of the open bosonic string, D-Branes, Gauge Fields and Yang-Mills Theories, Relativistic Conformal Field Theory, String Path Integral, BRST Quantization, String Interactions, Effective Actions and Gravity.

Intended learning outcomes

Familiarity with the classical and quantum theory of relativistic bosonic strings, in particular with the two classical actions for relativistic bosonic strings, the Nambu-Goto action and the Polyakov action. Ability to quantize the closed bosonic string and to understand the emergence of the massless graviton in the spectrum of the closed bosonic string. Knowledge of the the quantum Lorentz anomaly and the derivation of the critical dimension of the bosonic string. Understanding of the boundary conditions for the open string and its connection to D-branes. Knowledge of open string quantization and the spectrum of massless gauge fields, as well as of Yang-Mills fields for coincident branes. In-depth knowledge of relativistic conformal field theory, the string path integral and its BRST quantization and the calculation of string interactions. Thorough understanding of the low-energy effective actions in target space and the emergence of Einstein gravity.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title			Abbreviation
String Theory 2			11-STRG2-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
6	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

Superstring Theories and M Theory, in particular a short introduction to bosonic string theory, the theory of fermionic fields and representations of clifford algebra in diverse dimensions, a review of supersymmetry in two and higher dimensions, the classical and quantum version of the Ramond-Neveau-Schwarz Superstring, type 2 A/B Superstrings, the Gliozzi-Scherck-Olive Projection and Space-Time Supersymmetry in 10 dimensions, the type 1 Superstring, heterotic string theories, anomaly cancellation and restrictions on gauge groups, dualities between the five superstring theories as well as their relation to M Theory in 11D, D-Branes and supersymmetric gauge theories, supergravity and the AdS/CFT Correspondence.

Intended learning outcomes

In-depth knowledge of supersymmetric string theories and M Theory. Familiarity with the main features of bosonic string theory, as well as withthe theory of fermionic fields and representations of Clifford algebra in different dimensions. Knowledge of supersymmetry in two and higher dimensions, as relevant for the understanding of superstring theory. Working knowledge of the classical and quantum version of the Ramond-Neveau-Schwarz Superstring. Understanding of the emergence of type II A/B Superstrings upon imposing the Gliozzi-Scherck-Olive Projection, which in particular enforces Space-Time Supersymmetry in 10D. Familiarity with the type 1 and heterotic superstring theories, as well as with anomaly cancellation in these theories and the restrictions it imposes on the allowed gauge groups. Knowledge of dualities between the five superstring theories as well as their relation to M Theory in 11D. Knowledge of the properties of D-Branes in type I and II superstring theories and the supersymmetric gauge theories they carry, of the supergravity actions in ten and eleven dimensional space-time and of the AdS/CFT Correspondence.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload
180 h
Teaching cycle
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Topological Effects in Solid State Physics				11-TEFK-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Geometric phase in quantum systems
2. Mathematical basics of topology
3. Time-reversal symmetry
4. Hall conductance and Chern numbers
5. Bulk-boundary correspondence
6. Graphene (as a topological insulator)
7. Quantum Spin Hall insulators
8. Z2 invariants
9. Topological superconductors

Intended learning outcomes

In-depth theoretical understanding of the topological concepts in quantum physics related to solid state systems. Ability to connect their knowledge with different research activities at the Department of Physics and Astronomy at Würzburg University.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Theoretical Elementary Particle Physics				11-TEP-Int-201-m01

Module coordinator	Module offered by
Managing Director of the Institute of Theoretical Physics and Astrophysics	Faculty of Physics and Astronomy

ECTS	Method of grading	Only after succ. compl. of module(s)
8	numerical grade	--

Duration	Module level	Other prerequisites
1 semester	graduate	--

Contents

1. Fundamental Forces and Particles
2. Groups and Symmetries
3. Quark Model of Hadrons
4. Parton Model and Deep Inelastic Scattering
5. Basics of Quantum Field Theory
6. Gauge Theories
7. Spontaneous Symmetry Breaking
8. Electro-Weak Standard Model
9. Quantum Chromo Dynamics
10. Extensions of the Standard Model

Intended learning outcomes

Familiarity with the mathematical methods of elementary particle physics. Understanding of the structure of the standard model and its construction from symmetry principles and experimental observations. Knowledge of the calculational methods for scattering and decay processes, tests of the standard models and there are limitations. Familiarity with the basics of extended theories.

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

V (4) + R (2)
Module taught in: 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)

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).
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Theoretical Solid State Physics 2				11-TFK2-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

A possible continuation of „11-TFK“ is the following syllabus:
5. Advanced topics of the theory of superconductivity (Bogoliubov-de Gennes equations, effective field theory, Anderson-Higgs description of the Meissner effect)
6. Unconventional superconductors (e.G. copper-oxide high-Tc superconductors)
7. Green's function methods and Feynman diagrammatic technique
8. The Kondo Effect (Anderson's “poor mans scaling“, renormalization group)

Intended learning outcomes

Advanced knowledge of the topics listed above. In-depth understanding of both the concepts involved and ability to apply the methods listed. This provides a thorough working knowledge of a large number of topics treated in the standard textbooks on theoretical solid state physics.

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

V (4) + R (2)
Module taught in: 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)

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).
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)

exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Theoretical Solid State Physics				11-TFK-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

The contents of this two-term course will depend on the choice of the lecturer, and may include parts of the syllabus which could alternatively be offered as „Quantum Many Body Physics" (11-QVTP).
A possible syllabus may be:
1. Band structure (Sommerfeld theory of metals, Bloch theorem, k.p approach and effective Hamiltonians for topological insulators (TIs), bulk-surface correspondence, general properties of TIs)
2. Electron–electron interactions in solids (path integral method for weakly interacting fermions, mean field theory, random phase approximation (RPA), density functional theory)
3. Application of mean field theory and the RPA to magnetism
4. BCS theory of superconductivity

Intended learning outcomes

In-depth knowledge of the topics listed above. In-depth understanding of the concepts involved and ability to apply the methods listed. This provides a thorough working knowledge of a large number of topics treated in the standard textbooks on theoretical solid state physics.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020)
Master's degree (1 major) Quantum Engineering (2020)
exchange program Physics (2023)
Master's degree (1 major) Quantum Engineering (2024)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Experimental Particle Physics				11-TPE-Int-201-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Applied Physics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

Physics with modern particle physics detectors at the LHC and at the Tevatron. Discovery of the Higgs Boson. Determination of the W boson and Top Quark mass. Measurement of standard model parameters. Search for physics beyond the standard model.

Intended learning outcomes

Familiarity with the basic questions studied with a modern particle physics detector, and with modern data analysis techniques in particle physics. Ability to put results into context and to assess their systematic uncertainties.

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

V (3) + R (1)
Module taught in: 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)

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).
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Language of assessment: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in

Master's degree (1 major) Physics International (2020)
exchange program Physics (2023)
Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Particle Physics (Standard Model)				11-TPSM-Int-201-m01
Module coordinator			**Module offered by**	
Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
6	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

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

Intended learning outcomes

Students know the theoretical fundamental laws of the standard model of particle and the key experiments that have established and confirmed the standard model. They have basic knowledge in order to interpret experimental or theoretical results in the framework of the standard model can and knows its significance and limitations.

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

V (3) + R (1)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

180 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020) exchange program Physics (2023)

Module title				Abbreviation
Particle Physics (Standard Model)				11-TPSM-Int-211-m01
Module coordinator			**Module offered by**	
Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	Approval from examination committee required.		

Contents

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

Intended learning outcomes

Students know the theoretical fundamental laws of the standard model of particle and the key experiments that have established and confirmed the standard model. They have basic knowledge in order to interpret experimental or theoretical results in the framework of the standard model can and knows its significance and limitations.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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

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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Physics International (2024)

Module title				Abbreviation
Theoretical Quantum Optics				11-TQO-Int-221-m01
Module coordinator			**Module offered by**	
Managing Director of the Institute of Theoretical Physics and Astrophysics			Faculty of Physics and Astronomy	
ECTS	**Method of grading**	**Only after succ. compl. of module(s)**		
8	numerical grade	--		
Duration	**Module level**	**Other prerequisites**		
1 semester	graduate	--		

Contents

1. Semi-classical atom-field interactions
2. Interaction of atoms with quantized light fields and dressed-atom model
3. Master equation and open systems
4. Coherence and interference effects
5. Coherent light propagation in resonant media
6. Photon statistics and correlations
7. Quantum optics of many-body systems

Intended learning outcomes

Comprehensive understanding of phenomena involving light and its interaction with atoms at the microscopical level. Knowledge of density matrix formalism for quantum systems and the related mathematical concepts. In-depth understanding of quantum properties of light and their experimental signatures, including photon statistics and correlations. Knowledge of the theory of open systems and master equation description involving Lindblad superoperators. Understanding and modeling the role of coherence and interference in light propagation effects in resonant atomic media. Knowledge of cooperative effects in many-body systems: super- and subradiance, collective light shifts and their applications.

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

V (4) + R (2)
Module taught in: 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)

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: English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places

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Additional information

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Workload

240 h

Teaching cycle

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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module appears in
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)