

# Module Catalogue

for the Subject

# Quantum Engineering

as a Master's with 1 major  
with the degree "Master of Science"  
(120 ECTS credits)

Examination regulations version: 2024  
Responsible: Faculty of Physics and Astronomy

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## The subject is divided into

section / sub-section	ECTS credits	starting page
Electives Field	60	8
Subfield Quantum Engineering	min. 55	9
Advanced Laboratory Courses	min. 9	10
Advanced Seminar	min. 5	15
Specialization Quantum Engineering		18
Subfield Nontechnical Minors	0-5	73
Master Project Modules	60	94

## Learning Outcomes

German contents and learning outcome available but not translated yet.

After having successfully completed their studies the graduates fulfil the following

- The graduates have the ability to abstract, they are able to think analytically, they have a strong problem-solving competence and are able to structure complex issues.
- The graduates have a broad overview of the different areas of nanostructure engineering and of interdisciplinary synergies.
- They have profound knowledge of the physical and technical basics of nanostructure engineering as well as deep knowledge of the theoretical and experimental methods to gain new insights.
- They are able to apply their abilities and expertise to their own research projects and know the current state of research in at least one specialized field of nanostructure engineering.
- With the help of primary literature, especially in English, they are able to become acquainted with the current state of research in a specialist field and are able to apply physical and technical methods self-reliantly to concrete tasks, to develop solutions and to interpret and assess results.
- Even with incomplete information they are in a position to work self-reliantly on problems of nanostructure engineering, applying scientific methods and following the rules of good scientific practice, and to present and assess the results and consequences of their work.
- They are able to discuss physical and technical topics on the current state of research with other nanostructure engineers/scientists and also to explain physical correlations to non-They are able to work as responsible scientists in interdisciplinary and international teams with (natural) scientists and/or engineers in research, industry and economy.

### Scientific qualification

- The graduates have profound knowledge of the physical and technical basics of nanostructure engineering.
- The graduates can access profound knowledge of the theoretical and experimental methods to gain new insights.
- The graduates possess a broad overview of the complete area of nanostructure engineering.
- The graduates have an overview of the adjacent areas and interdisciplinary correlations.
- The graduates have the ability to abstract, they are able to think analytically, they have a high problem-solving competence and are able to structure complex correlations.
- The graduates transfer their abilities and expertise to their own research projects and know the current state of research in at least one specialist field of nanostructure engineering.
- The graduates are able to discuss physical and technical topics on the current state of research with other nanostructure engineers/scientists.
- The graduates are able to apply physical and technical methods self-reliantly to concrete experimental or theoretical tasks, to develop solutions and to interpret and assess the results.
- With the help of primary literature, especially in English, the graduates have the ability to become acquainted with the current state of research in a specialist field of nanostructure engineering.

### Qualification to start a job

- Even with incomplete information the graduates are in a position to work self-reliantly on physical and technical 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.
- The graduates are able to work as responsible scientists in interdisciplinary and international teams with (natural) scientists and/or engineers in research, industry and economy.
- The graduates have the ability to apply physical and technical methods self-reliantly to concrete tasks, to develop solutions and to interpret and assess the results.

- The graduates are in a position to transfer their abilities and expertise to their own research projects and know the current state of research in at least one specialist field of nanostructure engineering.

#### **Self-development**

- Even with incomplete information the graduates are able to work self-reliantly on problems of nanostructure engineering, applying scientific methods, and to present, assess and attend to the results and consequences of their work.
- The graduates know the rules of good scientific practice and take them into account.

#### **Qualification for social commitment**

- The graduates are able to critically reflect natural scientific and technical developments and to capture their impact on economy, society and environment. (technological impact assessment).
- The graduates have deepened 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 and technical topics on the current state of research with other nanostructure engineers/scientists and also to explain physical correlations to non-scientists.
- The graduates have developed 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)):

**o6-Sep-2023 (2023-71)**

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.

## Electives Field

(60 ECTS credits)



## Subfield Quantum Engineering

(min. 55 ECTS credits)

## Advanced Laboratory Courses

(min. 9 ECTS credits)

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 is creditable for 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		
--		
Additional information		
--		
Workload		
90 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
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 is creditable for 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		
--		
Additional information		
--		
Workload		
90 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
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 is creditable for 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		
--		
Additional information		
--		
Workload		
90 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
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 is creditable for 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		
--		
Additional information		
--		
Workload		
90 h		
Teaching cycle		
--		
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)		

## Advanced Seminar

(min. 5 ECTS credits)

Module title		Abbreviation
Advanced Seminar Quantum Engineering A		11-OSN-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	--
<b>Contents</b>		
Seminar on current issues in theoretical or experimental physics.		
<b>Intended learning outcomes</b>		
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.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
S (2) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)		
talk with discussion (30 to 45 minutes) Language of assessment: English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024)		



Module title		Abbreviation
Advanced Seminar Quantum Engineering B		11-OSN-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	--
<b>Contents</b>		
Seminar on current issues in theoretical or experimental physics.		
<b>Intended learning outcomes</b>		
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.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
S (2) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)		
talk with discussion (30 to 45 minutes) Language of assessment: English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024)		

# Specialization Quantum Engineering

( ECTS credits)

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	--
<b>Contents</b>		
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		
<b>Intended learning outcomes</b>		
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.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020)		
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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	--
<b>Contents</b>		
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.		
<b>Intended learning outcomes</b>		
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.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
--		
<b>Module appears in</b>		
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)		
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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		
<p>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.</p> <p>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.</p>		
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 is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>		
Allocation of places		
--		
Additional information		
--		
Workload		
180 h		
Teaching cycle		
--		
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)		
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exchange program Physics (2023)  
Master's degree (1 major) Quantum Engineering (2024)  
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	--
<b>Contents</b>		
<p>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.</p>		
<b>Intended learning outcomes</b>		
<p>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.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
<p>V (3) + R (1) Module taught in: English</p>		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes). If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English</p>		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
<p>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)</p>		
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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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) 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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)		
Master's with 1 major Quantum Engineering (2024)	JMU Würzburg • generated 19-Mär-2024 • exam. reg. data record Master (120 ECTS) Quantum Engineering - 2024	page 28 / 97

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	--
<b>Contents</b>		
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.		
<b>Intended learning outcomes</b>		
Familiarity with the properties and characterization methods of various groups of modern materials.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
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	
Preparation and safety briefing		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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)			

Module title		Abbreviation
<b>Sensor and Actor Materials - Functional Ceramics and Magnetic Particles</b>		o8-FU-SAM-161-mo1
Module coordinator		Module offered by
degree programme coordinator Funktionswerkstoffe (Functional Materials)		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	--
<b>Contents</b>		
Fabrication, effects and applications of sensory and actuator materials such as piezoelectrics, shape memory materials and magnetostrictive materials. Electrorheological and magnetorheological fluids, magnetofluids.		
<b>Intended learning outcomes</b>		
Students have developed fundamental knowledge in the area of sensory and actuator materials.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (2) + P (2)		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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) Assessment offered: Once a year, summer semester Language of assessment: German and/or English P: creditable for bonus		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
150 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
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			o8-PCM4-161-mo1
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 o8-PCM1a and o8-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 is creditable for 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)			
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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
Electrochemical Energy Storage and Conversion			o8-FU-EEW-222-mo1
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 like lead, nickel cadmium and nickel metal hydride, sodium sulfur, sodium nickel chloride, lithium ion accumulators), electrochemical double layer capacitors, redox-flow battery, fuel cell systems (AFC, PEMFC, DMFC, PAFC, SOFC), Solar cells (Si, CIS, CIGS, GaAs, organic and dye solar cell), thermoelectric devices.			
Intended learning outcomes			
The students gain comprehensive knowledge in the field of electrochemical energy storage and transformation and are able to apply this to scientific problems.			
Courses (type, number of weekly contact hours, language — if other than German)			
V (2) + S (2) 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 is creditable for bonus)			
a) written examination (approx. 90 minutes) or oral examination of one candidate each (approx. 30 minutes) and b) talk (approx. 30 minutes); (weighted 65:35) 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			
Master's degree (1 major) Functional Materials (2022) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)			

Module title			Abbreviation
Structure-Properties Correlations of Light Materials - Experiments and Numerical Simulations			o8-FU-MW-222-m01
Module coordinator		Module offered by	
degree programme coordinator Funktionswerkstoffe (Functional Materials)		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: Structure-property relationships through experiments and simulation.			
Intended learning outcomes			
The students gain fundamental knowledge about the properties of modern materials: aviation aluminum alloys and high performance ceramics. Analytical methods and predictions through numerical simulations will be presented. The relationship of mikro- and nanoscopic structure of materials and the resulting properties are emphasized.			
Courses (type, number of weekly contact hours, language — if other than German)			
V (2) + S (2) 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 is creditable for bonus)			
a) written examination (approx. 90 minutes) or oral examination of one candidate each (approx. 30 minutes) and b) talk (approx. 30 minutes); (weighted 60:40) 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			
Master's degree (1 major) Functional Materials (2022) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)			

Module title		Abbreviation
Current Topics in Quantum Engineering		11-EXN5-Int-241-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 or theoretical 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 theoretical or experimental physics on Master's level in the study programme Quantum Engineering. 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 (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 is creditable for 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) Quantum Engineering (2024)		

Module title		Abbreviation
Current Topics in Quantum Engineering		11-EXN6-Int-241-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 possesses advanced knowledge meeting the requirements of a module in theoretical or experimental physics on Master's level in the study programme Quantum Engineering. 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 is creditable for 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) Quantum Engineering (2024)		

Module title		Abbreviation
Current Topics in Quantum Engineering		11-EXN7-Int-241-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 or theoretical 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 theoretical or experimental physics on Master's level in the study programme Quantum Engineering. 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 is creditable for 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) Quantum Engineering (2024)		

Module title		Abbreviation
Current Topics in Quantum Engineering		11-EXN8-Int-241-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 or theoretical 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 theoretical or experimental physics on Master's level in the study programme Quantum Engineering. 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 (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 is creditable for 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) Quantum Engineering (2024)		

Module title		Abbreviation
Current Topics in Quantum Engineering		11-EXN6A-Int-241-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 possesses advanced knowledge meeting the requirements of a module in theoretical or experimental physics on Master's level in the study programme Quantum Engineering. 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 is creditable for 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		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
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Module appears in		
Master's degree (1 major) Quantum Engineering (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 is creditable for 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			
--			
Additional information			
--			
Workload			
180 h			
Teaching cycle			
--			
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 Topics in Quantum Engineering		11-CSNM-Int-241-mo1
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.
<b>Contents</b>		
This module allows lecturers of the Quantum Engineering study programme to give lectures on advanced topics that can not be covered by any other module. These lectures may either reflect new developments in research or deal with topics that are not included in the regular teaching cycle.		
<b>Intended learning outcomes</b>		
The students deepen their knowledge and understanding of an advanced topic in Quantum Engineering, thereby gaining insights into the interface between research and teaching.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
Master's degree (1 major) Quantum Engineering (2024)		

Module title		Abbreviation
<b>Solid State Physics 2</b>		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		
<p>1. Electrons in a periodic potential – the band structure</p> <p>a. Electrical and thermal transport</p> <p>b. Bloch theorem</p> <p>c. Electrons</p> <p>2. Semi-classical models of dynamic processes</p> <p>a. Electrical transport in partially and completely filled bands</p> <p>b. Fermi surfaces; measurement techniques</p> <p>c. Electrical transport in external magnetic fields</p> <p>d. Boltzmann-equations of transport</p> <p>3. The dielectric function and ferroelectrics</p> <p>a. Macroscopic electrodynamics and microscopic theory</p> <p>b. Polarizability of solids, of lattices, of valence electrons and quasi-free electrons; optical phonons, polaritons, plasmons, inter-band transitions, Wannier-Mott excitons</p> <p>c. Ferromagnetism</p> <p>4. Semiconductors</p> <p>a. Characteristics</p> <p>b. Intrinsic semiconductors</p> <p>c. Doped semiconductors</p> <p>d. Physics and applications of p-n junctions</p> <p>e. Heterostructures</p> <p>5. Magnetism</p> <p>a. Atomic dia- and paramagnetism</p> <p>b. Dia- and paramagnetism in metals</p> <p>c. Ferromagnetism</p> <p>6. Superconductivity</p> <p>a. Phenomena</p> <p>b. Models of superconductivity</p> <p>c. Tunnel experiments und applications</p>		
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 is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method</p>		

of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

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

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) 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 Topics in Physics		11-CSPM-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.
<b>Contents</b>		
This module allows lecturers of the physics study programme to give lectures on advanced topics that can not be covered by any other module. These lectures may either reflect new developments in research or deal with topics that are not included in the regular teaching cycle.		
<b>Intended learning outcomes</b>		
The students deepen their knowledge and understanding of an advanced topic in physics, thereby gaining insights into the interface between research and teaching.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
Master's degree (1 major) Quantum Engineering (2020)		
Master's degree (1 major) Quantum Engineering (2024)		

Module title		Abbreviation
Solid State Spectroscopy		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	--
<b>Contents</b>		
Single and many particle picture of electrons in solids, Light-matter interaction, Optical spectroscopy, Electron spectroscopy, X-ray spectroscopies.		
<b>Intended learning outcomes</b>		
Specific and in-depth knowledge of solid-state spectroscopy. Knowledge of different methods of spectroscopy and their applications. Understanding of the theoretical principles and modern developments in the related science.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
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
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. Z <sub>2</sub> 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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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) 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
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		
<p>This will usually be a course on quantum many particle physics approached by the perturbative methods using Green's functions</p> <p>An outline could be:</p> <ol style="list-style-type: none"> <li>1. Single-particle Green's function</li> <li>2. Review of second quantization</li> <li>3. Diagrammatic method using many particle Green's functions at temperature <math>T=0</math></li> <li>4. Diagrammatic method for finite <math>T</math></li> <li>5. Landau theory of Fermi liquids</li> <li>6. Superconductivity</li> <li>7. One-dimensional systems and bosonization</li> </ol>		
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 is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>		
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
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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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
<b>Magnetism</b>		11-MAG-Int-201-mo1
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	--
<b>Contents</b>		
Dia- and paramagnetism, Exchange interaction, Ferromagnetism, Antiferromagnetism, Anisotropy, Domain structure, Nanomagnetism, Superparamagnetism, Experimental methods to measure magnetic properties. Kondo effect.		
<b>Intended learning outcomes</b>		
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.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
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)		
Master's with 1 major Quantum Engineering (2024)	JMU Würzburg • generated 19-Mär-2024 • exam. reg. data record Master (120 ECTS) Quantum Engineering - 2024	page 52 / 97

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			
<p>„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:</p> <ol style="list-style-type: none"><li>1. Second quantization: fermions and bosons</li><li>2. Band structures of particles in a crystal</li><li>3. Angular momentum, symmetry operators, Lie Algebras</li><li>4. Scattering theory: potential scattering, partial wave expansion</li><li>5. Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation, Lorentz group, fine structure splitting of atomic spectra</li><li>6. Quantum entanglement</li><li>7. Canonical formalism</li></ol>			
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 is creditable for bonus)			
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>			
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 Quantum Optics		11-TQO-Int-221-mo1
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		
<ol style="list-style-type: none"> <li>1. Semi-classical atom-field interactions</li> <li>2. Interaction of atoms with quantized light fields and dressed-atom model</li> <li>3. Master equation and open systems</li> <li>4. Coherence and interference effects</li> <li>5. Coherent light propagation in resonant media</li> <li>6. Photon statistics and correlations</li> <li>7. Quantum optics of many-body systems</li> </ol>		
Intended learning outcomes		
<p>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.</p>		
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 is creditable for bonus)		
<p>written examination (approx. 90 to 120 minutes) or oral examination of one candidate each (approx. 30 minutes) or oral examination in groups (groups of 2, approx. 30 minutes per candidate) or project report (approx. 8 to 10 pages) or presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>		
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)



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		
<p>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).</p> <p>A possible syllabus may be:</p> <ol style="list-style-type: none"> <li>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)</li> <li>2. Electron–electron interactions in solids (path integral method for weakly interacting fermions, mean field theory, random phase approximation (RPA), density functional theory)</li> <li>3. Application of mean field theory and the RPA to magnetism</li> <li>4. BCS theory of superconductivity</li> </ol>		
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 is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>		
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
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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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)  
exchange program Physics (2023)  
Master's degree (1 major) Quantum Engineering (2024)  
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		
<ol style="list-style-type: none"> <li>1. Brief summary of classical information theory</li> <li>2. Quantum theory seen from the perspective of information theory</li> <li>3. Composite systems and the Schmidt decomposition</li> <li>4. Entanglement measures</li> <li>5. Quantum operations, POVMs, and the theorems of Kraus and Stinespring</li> <li>6. Quantum gates and quantum computers</li> <li>7. Elements of the theory of decoherence</li> </ol>		
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 is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>		
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
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	--
<b>Contents</b>		
<p>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</p> <ol style="list-style-type: none"> <li>1) the NMR signal theory and signal evolution (Bloch equations)</li> <li>2) the principles of spatial encoding, magnetic resonance imaging (MRI) and corresponding imaging sequences and measurement parameters,</li> <li>3) the concept of k-space and Fourier imaging,</li> <li>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.</li> </ol>		
<b>Intended learning outcomes</b>		
<p>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.</p>		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1)		
Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)		
<p>a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).</p> <p>If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.</p> <p>Assessment offered: In the semester in which the course is offered and in the subsequent semester</p> <p>Language of assessment: English</p>		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
Teaching cycle: In the semester in which the course is offered and in the subsequent semester		
<b>Referred to in LPO I</b> (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
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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester 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) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (2024)		
Master's with 1 major Quantum Engineering (2024)	JMU Würzburg • generated 19-Mär-2024 • exam. reg. data record Master (120 ECTS) Quantum Engineering - 2024	page 65 / 97

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
1-2 semester	graduate	Approval from examination committee required.
<b>Contents</b>		
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.		
<b>Intended learning outcomes</b>		
Familiarity with current research topics in experimental or theoretical physics. Within experimental physics, the ability to analyze and document scientific experiments.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
R (o) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)		
project report (10 to 20 pages) Language of assessment: English		
<b>Allocation of places</b>		
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<b>Additional information</b>		
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<b>Workload</b>		
300 h		
<b>Teaching cycle</b>		
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<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
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<b>Module appears in</b>		
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-EXP5-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 or theoretical 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 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 (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 is creditable for 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) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (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 possesses 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 is creditable for 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-EXP7-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 or theoretical 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 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 is creditable for 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) Quantum Engineering (2020)		
Master's degree (1 major) Quantum Engineering (2024)		

Module title		Abbreviation
Current Topics in Physics		11-EXP8-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 or theoretical 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 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 (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 is creditable for 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) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (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 possesses 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 is creditable for 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)		



## Subfield Nontechnical Minors

(0-5 ECTS credits)

Module title		Abbreviation
Advanced Analysis		10-M-VAN-222-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		
Continuation of analysis in several variables; Lebesgue measure and Lebesgue integral in $\mathbb{R}^n$ , integral theorems.		
Intended learning outcomes		
The student is acquainted with advanced topics in analysis. Taking the example of the Lebesgue integral, he or she is able to understand the construction of a complex mathematical concept		
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 is creditable for 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		
--		
Workload		
300 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
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Module appears in		
Bachelor' degree (1 major) Mathematical Data Science (2022) exchange program Mathematics (2023) Master's degree (1 major) Quantum Engineering (2024) Master's degree (1 major) Physics International (2024)		

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)			
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 is creditable for 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) Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English creditable for bonus			
Allocation of places			
--			
Additional information			
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Workload			
150 h			
Teaching cycle			
--			
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)			

Module title		Abbreviation
Quantum Communications		10-I=QC-221-m01
Module coordinator		Module offered by
holder of the Chair of Computer Science VII		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		
<ul style="list-style-type: none"> <li>• Introduction</li> <li>• Hilbert Spaces and Operators</li> <li>• Quantum Mechanics</li> <li>• Quantum States</li> <li>• Quantum Circuit Elements</li> <li>• Entanglement and Its Applications</li> <li>• Quantum Key Distribution</li> <li>• Quantum Channel</li> <li>• Quantum Error Correction Coding</li> <li>• Continuous-Variable Quantum Communications</li> <li>• Further Topics</li> </ul>		
Intended learning outcomes		
<p>Students will</p> <ul style="list-style-type: none"> <li>• develop a solid foundation in quantum information technology, including qubits, quantum gates, entanglement, and quantum measurements,</li> <li>• learn about secure communications using quantum mechanics, including protocols like Quantum Key Distribution (QKD),</li> <li>• gain familiarity with protocols such as quantum teleportation, superdense coding and error correction, and</li> <li>• understand the effects of noise and decoherence in quantum communications and learn strategies to mitigate their impact.</li> </ul>		
Courses (type, number of weekly contact hours, language — if other than German)		
V (2) + V (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 is creditable for bonus)		
<p>written examination (approx. 60 to 120 minutes).</p> <p>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).</p> <p>Language of assessment: English</p> <p>creditable for bonus</p>		
Allocation of places		
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Additional information		
Focuses available for students of the Master's programme Informatik (Computer Science, 120 ECTS credits): LR		
Workload		
150 h		

<b>Teaching cycle</b>
--
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)
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<b>Module appears in</b>
Master's degree (1 major) Computer Science (2021) Master's degree (1 major) Computer Science (2023) Master's degree (1 major) Aerospace Computer Science (2023) 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
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		
<p>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.</p>		
Intended learning outcomes		
<p>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.</p>		
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 is creditable for bonus)		
<p>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</p>		
Allocation of places		
--		
Additional information		
--		
Workload		
150 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
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Module appears in		
<p>Bachelor' degree (1 major) Computer Science (2017) Bachelor' 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)</p>		
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Bachelor' degree (1 major) Business Information Systems (2020)  
 Master's degree (1 major) Physics International (2020)  
 Master's degree (1 major) Quantum Engineering (2020)  
 Bachelor' degree (1 major) Computer Science und Sustainability (2021)  
 Master's degree (1 major) Quantum Technology (2021)  
 Bachelor' degree (1 major) Business Information Systems (2021)  
 Bachelor' degree (1 major) Artificial Intelligence and Data Science (2022)  
 Bachelor' degree (1 major) Artificial Intelligence and Data Science (2023)  
 Bachelor' degree (1 major) Business Information Systems (2023)  
 Master's degree (1 major) Quantum Engineering (2024)  
 Master's degree (1 major) Physics International (2024)  
 Bachelor' degree (1 major) Business Information Systems (2024)  
 Bachelor' degree (1 major) Artificial Intelligence and Data Science (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 is creditable for bonus)		
<p>written examination (approx. 60 to 120 minutes).</p> <p>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).</p> <p>Separate written examination for Master's students.</p> <p>Language of assessment: German and/or English</p> <p>creditable for bonus</p>		
Allocation of places		
--		
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		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
<p>Master's degree (1 major) Computer Science (2016)</p> <p>Master's degree (1 major) Physics (2016)</p> <p>Master's degree (1 major) Digital Humanities (2016)</p> <p>Master's degree (1 major) Computer Science (2017)</p> <p>Master's degree (1 major) Computer Science (2018)</p> <p>Master's degree (1 major) Physics (2020)</p> <p>Master's degree (1 major) Physics International (2020)</p> <p>Master's degree (1 major) Quantum Engineering (2020)</p> <p>Master's degree (1 major) Quantum Engineering (2024)</p>		
Master's with 1 major Quantum Engineering (2024)	JMU Würzburg • generated 19-Mär-2024 • exam. reg. data record Master (120 ECTS) Quantum Engineering - 2024	page 80 / 97



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

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 is creditable for 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		
--		
Additional information		
--		
Workload		
150 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Bachelor' degree (1 major) Computer Science (2019) Master's degree (1 major) Nanostructure Technology (2020) Master's degree (1 major) Physics (2020) Bachelor' degree (1 major) Business Information Systems (2020) Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020) Bachelor' degree (1 major) Aerospace Computer Science (2020) Bachelor' degree (1 major) Computer Science und Sustainability (2021) Master's degree (1 major) Quantum Technology (2021) Bachelor' degree (1 major) Business Information Systems (2021)		
Master's with 1 major Quantum Engineering (2024)	JMU Würzburg • generated 19-Mär-2024 • exam. reg. data record Master (120 ECTS) Quantum Engineering - 2024	page 82 / 97

Bachelor' degree (1 major) Artificial Intelligence and Data Science (2022)  
 Bachelor' degree (1 major) Artificial Intelligence and Data Science (2023)  
 Bachelor' degree (1 major) Mathematics (2023)  
 Bachelor' degree (1 major) Business Information Systems (2023)  
 Master's degree (1 major) Quantum Engineering (2024)  
 Master's degree (1 major) Physics International (2024)  
 Bachelor' degree (1 major) Artificial Intelligence and Data Science (2024)

Module title			Abbreviation
Artificial Intelligence 1			10-I=KI1-212-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 is creditable for 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). creditable for bonus Language of assessment: German and/or English			
Allocation of places			
--			
Additional information			
Focuses available for students of the Master's programme Informatik (Computer Science, 120 ECTS credits): AT,SE,KI,HCI			
Workload			
150 h			
Teaching cycle			
--			
Referred to in LPO I (examination regulations for teaching-degree programmes)			
--			
Module appears in			
Master's degree (1 major) Computer Science (2021) Master's degree (1 major) Aerospace Computer Science (2021) Master's degree (1 major) Computational Mathematics (2022) Master's degree (1 major) Information Systems (2022) Master's degree (1 major) Mathematics (2022) Master's degree (1 major) Computer Science (2023) Master's degree (1 major) Aerospace Computer Science (2023) 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 with 1 major Quantum Engineering (2024)		JMU Würzburg • generated 19-Mär-2024 • exam. reg. data record Master (120 ECTS) Quantum Engineering - 2024	
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Master's degree (1 major) Mathematics (2024)  
Master's degree (1 major) Information Systems (2024)

Module title			Abbreviation
Environmental Law			02-N-Ö-W2-05-152-m01
Module coordinator		Module offered by	
Dean of Studies Faculty of Law		Faculty of Law	
ECTS	Method of grading	Only after succ. compl. of module(s)	
3	numerical grade	--	
Duration	Module level	Other prerequisites	
1 semester	undergraduate	Prior completion of the following module is recommended: 02-N-Ö-V	
Contents			
German contents available but not translated yet.			
Gegenstand der Vorlesung sind sowohl das allgemeine als auch das besondere Umweltrecht in Deutschland und der EU. Neben den Grundzügen, den allgemeinen Prinzipien, der verfassungsrechtlichen Verortung sowie den verschiedenen Handlungsinstrumenten des Umweltrechts auf deutscher wie auf europäischer Ebene sollen insbesondere der Einfluss des europäischen Umweltrechts auf das deutsche Umweltrecht und das Zusammenspiel der beiden Rechtsordnungen behandelt werden.			
Intended learning outcomes			
German intended learning outcomes available but not translated yet.			
Die Studierenden haben einen umfassenden Überblick über die Entwicklung, die Systematik und die wesentlichen rechtlichen Bestimmungen des deutschen wie auch des europäischen Umweltrechts erhalten. Sie wissen Grundzüge, allgemeine Prinzipien, verfassungsrechtliche Vorgaben und Handlungsinstrumente des Umweltrechts zu verorten und haben sich darüber hinaus mit dem Einfluss des europäischen Umweltrechts auf die deutsche Rechtsordnung und das Zusammenspiel der beiden Rechtsordnungen im diesem Bereich auseinandergesetzt.			
Courses (type, number of weekly contact hours, language — if other than German)			
V (2)			
Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)			
a) written examination (approx. 120 minutes) or b) oral examination (approx. 15 minutes) Assessment offered: Usually every two years, winter semester			
Allocation of places			
--			
Additional information			
--			
Workload			
90 h			
Teaching cycle			
--			
Referred to in LPO I (examination regulations for teaching-degree programmes)			
--			
Module appears in			
Bachelor's degree (1 major, 1 minor) Public Law (Minor, 2015) Bachelor's degree (1 major, 1 minor) Public Law (Minor, 2017) Bachelor's degree (1 major, 1 minor) Public Law (Minor, 2019) Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024)			
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Module title		Abbreviation
Astrophysics		11-AP-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	undergraduate	--
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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
Allocation of places		
--		
Additional information		
--		
Workload		
180 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Master's degree (1 major) Quantum Engineering (2020) exchange program Physics (2023) Master's degree (1 major) Quantum Engineering (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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English			
Allocation of places			
--			
Additional information			
--			
Workload			
180 h			
Teaching cycle			
--			
Referred to in LPO I (examination regulations for teaching-degree programmes)			
--			
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 characterization 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 is creditable for 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. Assessment offered: In the semester in which the course is offered and in the subsequent semester Language of assessment: English		
Allocation of places		
--		
Additional information		
--		
Workload		
180 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Master's degree (1 major) Physics International (2020) Master's degree (1 major) Quantum Engineering (2020)		
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exchange program Physics (2023)  
Master's degree (1 major) Quantum Engineering (2024)  
Master's degree (1 major) Physics International (2024)

Module title		Abbreviation
Nontechnical Special Topics		11-EXZ5-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		
Additional qualifications for engineers. 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 on Master's level in the study program Nanostructure Technology. He/She commands knowledge qualifying him/her for a job in industry respective industrial research and development.		
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 is creditable for 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		
--		
Additional information		
--		
Workload		
150 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024)		

Module title		Abbreviation
Nontechnical Special Topics		11-EXZ6-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.
<b>Contents</b>		
Additional qualifications for engineers. Credited academic achievements, e.g. in case of change of university or study abroad.		
<b>Intended learning outcomes</b>		
The student possesses advanced knowledge meeting the requirements of a module on Master's level in the study program Nanostructure Technology. He/She commands knowledge qualifying him/her for a job in industry respective industrial research and development.		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
--		
<b>Module appears in</b>		
Master's degree (1 major) Quantum Engineering (2020)		
Master's degree (1 major) Quantum Engineering (2024)		

Module title		Abbreviation
Nontechnical Minor Subject		11-EXNT6-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.
<b>Contents</b>		
Non-technical minor. Crediting for academic achievements, e.g. from university change or study abroad		
<b>Intended learning outcomes</b>		
The student possesses 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, legal science, economics,...).		
<b>Courses</b> (type, number of weekly contact hours, language — if other than German)		
V (3) + R (1) Module taught in: English		
<b>Method of assessment</b> (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for 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		
<b>Allocation of places</b>		
--		
<b>Additional information</b>		
--		
<b>Workload</b>		
180 h		
<b>Teaching cycle</b>		
--		
<b>Referred to in LPO I</b> (examination regulations for teaching-degree programmes)		
--		
<b>Module appears in</b>		
Master's degree (1 major) Quantum Engineering (2020)		
Master's degree (1 major) Quantum Engineering (2024)		

## Master Project Modules

(60 ECTS credits)

Module title		Abbreviation
Professional Specialization Quantum Engineering		11-FS-N-Int-201-m01
Module coordinator		Module offered by
--		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	--	--
Contents		
--		
Intended learning outcomes		
--		
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 is creditable for bonus)		
talk with discussion (30 to 45 minutes) Language of assessment: English		
Allocation of places		
--		
Additional information		
--		
Workload		
450 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024)		

Module title		Abbreviation
Scientific Methods and Project Management Quantum Engineering		11-MP-N-Int-201-m01
Module coordinator		Module offered by
--		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	--	--
Contents		
--		
Intended learning outcomes		
--		
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 is creditable for bonus)		
talk with discussion (30 to 45 minutes) Language of assessment: English		
Allocation of places		
--		
Additional information		
--		
Workload		
450 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024)		



Module title		Abbreviation
Master Thesis Quantum Engineering		11-MA-N-Int-201-m01
Module coordinator		Module offered by
--		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		
--		
Intended learning outcomes		
--		
Courses (type, number of weekly contact hours, language — if other than German)		
no courses assigned Module taught in: English		
Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module is creditable for bonus)		
Master's thesis (750 to 900 hours total) Language of assessment: English		
Allocation of places		
--		
Additional information		
Time to complete: 6 months		
Workload		
900 h		
Teaching cycle		
--		
Referred to in LPO I (examination regulations for teaching-degree programmes)		
--		
Module appears in		
Master's degree (1 major) Quantum Engineering (2020) Master's degree (1 major) Quantum Engineering (2024)		