Subdivided Module Catalogue
for the Subject
Quantum Technology
as a Master’s with 1 major
with the degree "Master of Science"
(120 ECTS credits)

Examination regulations version: 2021
Responsible: Faculty of Physics and Astronomy
Course of Studies - Contents and Objectives

Not available
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)):

28-Apr-2021 (2021-53)
09-Jun-2021 (2021-65)
??-??-2022 (2022-??)

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

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**Thesis (60 ECTS credits)**

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### Advanced Magnetic Resonance Imaging

**Module title**: Advanced Magnetic Resonance Imaging  
**Abbreviation**: 11-MRI-171-m01

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<tr>
<td>6</td>
<td>numerical grade</td>
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**Module coordinator**: Managing Director of the Institute of Applied Physics  
**Module offered by**: Faculty of Physics and Astronomy

**Duration**: 1 semester  
**Module level**: graduate

**Contents**

Nuclear magnetic resonance (NMR) is a quantum mechanical phenomenon that, through magnetic resonance imaging (MRI), has played a major role in the revolution of medical imaging over the last 30 years. Based on the fundamental principles of nuclear magnetic resonance (resonance principle, relaxation times, chemical shift) this course covers:

1. the NMR signal theory and signal evolution (Bloch equations),
2. the principles of spatial encoding, magnetic resonance imaging (MRI) and corresponding imaging sequences and measurement parameters,
3. the concept of k-space and Fourier imaging, and
4. the physical, methodological and technical possibilities and limits of MRI. As a last point, exemplary application fields of MRI of biomedical research, clinical imaging and non-destructive testing are introduced.

**Intended learning outcomes**

The students have advanced knowledge of the mathematical-theoretical and physical principles of modern imaging magnetic resonance, image generation and processing. They gain a broad overview of the field of modern MRI and its interdisciplinary contexts and applications.

**Courses**

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<tr>
<th>Type</th>
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<th>Language</th>
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<tr>
<td>V</td>
<td>(3) + R (1)</td>
<td>English</td>
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In the semester in which the course is offered and in the subsequent semester

**Method of assessment**

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<tr>
<th>Type</th>
<th>Scope</th>
<th>Language</th>
<th>Exam offered</th>
<th>Information on whether module can be chosen to earn a bonus</th>
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<td>a)</td>
<td>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: German and/or English</td>
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**Allocation of places**

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**Additional information**

--

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

--
Module title: Current Topics in Physik  
Abbreviation: 11-EXP6-161-m01

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

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

Duration: 1 semester  
Module level: graduate  
Other prerequisites: 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 students have advanced competencies corresponding to the requirements of a module of Experimental or Theoretical Physics of the Master's programme of Nanostructure Technology. They have knowledge of a current subdiscipline of Physics and understand the measuring and/or calculation methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.

Courses: (type, number of weekly contact hours, language — if other than German)
V (3) + R (1)

Method of assessment: (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

Allocation of places: --

Additional information: --

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

--
Module title: Current Topics in Physik
Abbreviation: 11-EXP6A-161-m01

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

ECTS: 6
Method of grading: numerical grade
Duration: 1 semester
Module level: graduate
Other prerequisites: 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 students have advanced competencies corresponding to the requirements of a module of Experimental or Theoretical Physics of the Master's programme of Nanostructure Technology. They have knowledge of a current subdiscipline of Physics and understand the measuring and/or calculation methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.

Courses
(V (3) + R (1))

Method of assessment
(a) written examination (approx. 90 to 120 minutes) or (b) oral examination of one candidate each (approx. 30 minutes) or (c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or (d) project report (approx. 8 to 10 pages) or (e) presentation/talk (approx. 30 minutes).

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Language of assessment: German and/or English

Allocation of places
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Additional information
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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Module title | Abbreviation
---|---
Current Topics in Physik | 11-EXP5-161-m01

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

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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 students have advanced competencies corresponding to the requirements of a module of Experimental or Theoretical Physics of the Master's programme of Nanostructure Technology. They have knowledge of a current subdiscipline of Physics and understand the measuring and/or calculation methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.

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

V (2) + R (2)

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

written examination (approx. 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).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

Allocation of places

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Additional information

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

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**Contents**

Current topics of Experimental and Theoretical Physics. Accredited academic achievements, e.g. in case of change of university or study abroad.

**Intended learning outcomes**

The students have advanced competencies corresponding to the requirements of a module of Experimental or Theoretical Physics of the Master's programme of Nanostructure Technology. They have knowledge of a current subdiscipline of Physics and understand the measuring and/or calculation methods necessary to acquire this knowledge. They are able to classify the subject-specific contexts and know the application areas.

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

| V (3) + R (1) |

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

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Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

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**Contents**

Current topics of Experimental and Theoretical Physics. Accredited academic achievements, e.g. in case of change of university or study abroad.

**Intended learning outcomes**

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

V (4) + R (2)

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

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Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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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 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: German or English

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

- written examination (approx. 90 to 120 minutes) or
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Language of assessment: German and/or English

Allocation of places

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Additional information

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

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Subdivided Module Catalogue for the Subject Quantum Technology

Master's with 1 major, 120 ECTS credits

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**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 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: German or English

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

written examination (approx. 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
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Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

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### Subdivided Module Catalogue for the Subject Quantum Technology

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### 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 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

V (3) + R (1)
Module taught in: German or English

### Method of assessment

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

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Language of assessment: German and/or English

### Allocation of places

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### Additional information

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### Referred to in LPO I

(examination regulations for teaching-degree programmes)

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Module title: Current Topics in Quantum Technology
Abbreviation: 11-EXN8-212-m01

Module coordinator: Chairperson of examination committee
Module offered by: Faculty of Physics and Astronomy

ECTS: 8
Method of grading: Numerical grade
Only after successful completion of module(s)

Duration: 1 semester
Module level: Graduate
Other prerequisites: 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 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: German or English

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus):
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Language of assessment: German and/or English

Allocation of places:
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Additional information:
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Referred to in LPO I (examination regulations for teaching-degree programmes):
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Module title
Current Topics in Quantum Technology

Abbreviation
11-EXN6A-212-m01

Module coordinator
chairperson of examination committee

Module offered by
Faculty of Physics and Astronomy

ECTS
6

Method of grading
numerical grade

Only after succ. compl. of module(s)

Duration
1 semester

Module level
graduate

Other prerequisites
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 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
V (3) + R (1)
Module taught in: German or English

Method of assessment
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Language of assessment: German and/or English

Allocation of places
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Additional information
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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### Module title
Methods of Observational Astronomy

### Abbreviation
11-ASM-161-m01

### Module coordinator
Managing Director of the Institute of Theoretical Physics and Astrophysics

### Module offered by
Faculty of Physics and Astronomy

### ECTS
6

### Method of grading
numerical grade

### Only after succ. compl. of module(s)
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### Duration
1 semester

### Module level
graduate

### Other prerequisites
--

### Contents
Methods of observational astronomy across the electromagnetic spectrum. Evaluation of observational data from radio, optical, X-ray and gamma-ray telescopes.

### Intended learning outcomes
Overview of 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: German or English

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

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

Language of assessment: German and/or English

### Allocation of places
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### Additional information
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</table>

**Contents**

History of astronomy, coordinates and time measurement, the Solar System, exoplanets, astronomical scales, telescopes and detectors, stellar structure and atmospheres, stellar evolution and end stages, interstellar medium, molecular clouds, structure of the Milky Way, the local universe, the expanding universe, galaxies, active galactic nuclei, large-scale structures, cosmology.

**Intended learning outcomes**

The students are familiar with the modern world view of Astrophysics. They know methods and tools for astrophysical observations and evaluations. They are able to use these methods to plan and analyse own observations. They are familiar with the physics and development of the main astrophysical objects such as stars and galaxies.

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

- V (2) + R (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 can be chosen to earn a bonus)

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Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

- § 22 II Nr. 1 h)
- § 22 II Nr. 2 f)
- § 22 II Nr. 3 f)
### Module title
*Selected Topics of Theoretical Solid State Physics*

### Abbreviation
11-AKTF-201-m01

### Module coordinator
Managing Director of the Institute of Theoretical Physics and Astrophysics

### Module offered by
Faculty of Physics and Astronomy

### ECTS
6

### Method of grading
numerical grade

### Duration
1 semester

### Module level
graduate

### Other prerequisites
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### 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

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### Method of assessment

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Language of assessment: German and/or English

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

### Allocation of places
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### Additional information
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### Referred to in LPO I
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<td>Institute of Computer Science</td>
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**Contents**

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

**Intended learning outcomes**

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

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

V (2) + Ü (2)

Module taught in: English

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

written examination (approx. 60 to 120 minutes).

If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).

Language of assessment: German and/or English creditable for bonus

**Allocation of places**

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**Additional information**

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

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<thead>
<tr>
<th>Duration</th>
<th>Module level</th>
<th>Other prerequisites</th>
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</thead>
<tbody>
<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

### Contents
Periodic and aperiodic signals; principles of discreet and exact Fourier transformation; principles of digital signal and image processing; discretisation of signals/sampling theorem (Shannon); homogeneous and linear filters, convolution product; tapering functions and interpolation of images; the Parsival theorem, correlation and energetic observation; statistical signals, image noise, moments, stationary signals; tomography: Hankel and Radon transformation.

### Intended learning outcomes
The students have advanced knowledge of digital image and signal processing. They know the physical principles of image processing and are familiar with different methods of signal processing. They are able to explain different methods and to implement them, especially in the field of tomography.

### Courses
(V (2) + Ü (2)
Module taught in: German or English

### Method of assessment
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).
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: German and/or English

### Allocation of places
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### Additional information
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### Referred to in LPO I
(examination regulations for teaching-degree programmes)
--
Module title: Discrete Mathematics
Abbreviation: 10-M=VDIM-161-m01

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

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

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

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: German and/or English

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus):
a) written examination (approx. 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: German or English
Creditable for bonus: --

Allocation of places:
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Additional information:
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Referred to in LPO I (examination regulations for teaching-degree programmes):
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<table>
<thead>
<tr>
<th>Module title</th>
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<tbody>
<tr>
<td>Structure and Properties of Modern Materials: Experiments vs. Simulations</td>
<td>08-FU-MW-161-m01</td>
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<table>
<thead>
<tr>
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<tbody>
<tr>
<td>degree programme coordinator Funktionswerkstoffe (Functional Materials)</td>
<td>Chair of Chemical Technology of Material Synthesis</td>
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<th>Other prerequisites</th>
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</thead>
<tbody>
<tr>
<td>1 semester</td>
<td>graduate</td>
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</tbody>
</table>

### Contents

Material properties of metals and ceramics: Structur-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 micro- 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 (1)

### Method of assessment

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

a) talk (approx. 30 minutes) or b) oral examination of one candidate each (approx. 20 minutes) or c) oral examination in groups of 2 (approx. 30 minutes total)

Assessment offered: Once a year, winter semester

Language of assessment: German and/or English

### Allocation of places

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### Additional information

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### Referred to in LPO I

(examination regulations for teaching-degree programmes)

--
Module title | Abbreviation
--- | ---
Introduction to Law for Economists | 02-EReWi-G-161-m01

| Module coordinator | Module offered by |
--- | ---
Dean of the Faculty of Law | Faculty of Law |

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

| Duration | Module level | Other prerequisites |
--- | --- | ---
1 semester | undergraduate | -- |

**Contents**

German contents available but not translated yet.


**Intended learning outcomes**

German intended learning outcomes available but not translated yet.


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

V (3) + Ü (2)

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

written examination (approx. 120 minutes)

Assessment offered: Usually once a year, winter semester

**Allocation of places**

There are no restrictions with regard to available places for students of Rechtswissenschaft (Law) as well as Bachelor's students with the minor Privatrecht (Private Law). A total of 20 places will be allocated to students of other subjects. 10 of these will be allocated to students of the Master's degree programme Economics. Should the number of available places exceed the number of applications, the remaining places may be allocated to students of other subjects. Should there be more than 10 applications, the remaining places will be allocated as follows: Students applying after not having successfully completed assessment in past years will be given preferential consideration. The remaining places will be allocated by lot. A waiting list will be maintained and places re-allocated by lot as they become available.

**Additional information**

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

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<table>
<thead>
<tr>
<th>Module title</th>
<th>Abbreviation</th>
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</thead>
<tbody>
<tr>
<td>Introduction to Space Physics</td>
<td>11-ASP-161-m01</td>
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<table>
<thead>
<tr>
<th>Module coordinator</th>
<th>Module offered by</th>
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<tbody>
<tr>
<td>Managing Director of the Institute of Theoretical Physics and Astrophysics</td>
<td>Faculty of Physics and Astronomy</td>
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<tbody>
<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

### 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

The students acquire basic knowledge of Space Physics, in particular regarding the characterisation of the dynamics of charged particles in space and the heliosphere. They know relevant parameters and theoretical concepts and corresponding measuring methods.

### Courses

<table>
<thead>
<tr>
<th>Type</th>
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<th>Language</th>
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<tbody>
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<td>German or English</td>
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<tr>
<td>R</td>
<td>1</td>
<td>German or English</td>
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</tbody>
</table>

Module taught in: German or English

### Method of assessment

- 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).

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: German and/or English

### Allocation of places

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### Additional information

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### Referred to in LPO I

(examination regulations for teaching-degree programmes)

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<table>
<thead>
<tr>
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<td>Electrochemical Energy Storage and Conversion</td>
<td>08-FU-EEW-152-m01</td>
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<tr>
<td>holder of the Chair of Chemical Technology of Material Synthesis</td>
<td>Chair of Chemical Technology of Material Synthesis</td>
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<tbody>
<tr>
<td>1 semester</td>
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</table>

**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) + P (1) + E (1)

**Method of assessment**

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

a) assessment and b) Vortestate/Nachtestate (pre and post-experiment examination talks approx. 15 minutes each, log approx. 5 to 10 pages each) and assessment of practical assignments (2 to 4 random examinations), weighted 7:3

Assessment offered: Once a year, summer semester

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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**Referred to in LPO I**

(examination regulations for teaching-degree programmes)

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<table>
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<td>Electron and Ion Microscopy</td>
<td>11-EIM-211-m01</td>
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<th>Module offered by</th>
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<tbody>
<tr>
<td>Managing Director of the Institute of Applied Physics</td>
<td>Faculty of Physics and Astronomy</td>
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<tr>
<td>1 semester</td>
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</table>

**Contents**


**Intended learning outcomes**

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

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

V (3) + R (1)
Module taught in: German or English
Teaching cycle: annually, after announcement

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

a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English
Prüfungsturnus: im Semester der LV und im Folgesemester

**Allocation of places**

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**Additional information**

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

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<table>
<thead>
<tr>
<th>Module title</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Analysis and Design of Programs</td>
<td>10-I=PA-161-m01</td>
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<tr>
<td>holder of the Chair of Computer Science II</td>
<td>Institute of Computer Science</td>
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<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

**Contents**

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

**Intended learning outcomes**

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

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

V (2) + Ü (2)

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

written examination (approx. 60 to 120 minutes).

If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).

Language of assessment: German and/or English creditable for bonus

**Allocation of places**

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**Additional information**

Focuses available for students of the Master’s programme Informatik (Computer Science, 120 ECTS credits):

SE, IS, ES, GE

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

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<table>
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<td>Professional Specialization Quantum Technology</td>
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<tr>
<td>chairperson of examination committee</td>
<td>Faculty of Physics and Astronomy</td>
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<tbody>
<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

**Contents**

Introduction to current experimental, theoretical or engineering research topics within quantum technology research that are of particular relevance for the envisaged topic of the master thesis. A seminar talk summarizing the required underlying fundamental topics.

**Intended learning outcomes**

Thorough understanding of a current experimental, theoretical or engineering research topic in the field of quantum technology research chosen for the master thesis. In-depth knowledge of the current state of research and ability to present and convey this knowledge in a seminar talk.

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

S (4)
Module taught in: German or English

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

Talk with discussion (30 to 45 minutes)
Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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**Referred to in LPO 1** (examination regulations for teaching-degree programmes)

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<table>
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<td>Field Theory in Solid State Physics</td>
<td>11-FFK-201-m01</td>
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<td>Faculty of Physics and Astronomy</td>
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<th>Other prerequisites</th>
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<tbody>
<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

### Contents

This will usually be a course on quantum many particle physics approached by the perturbative methods using Green's functions.

An outline could be:
1. Single-particle Green's function
2. Review of second quantization
3. Diagrammatic method using many particle Green's functions at temperature T=0
4. Diagrammatic method for finite T
5. Landau theory of Fermi liquids
6. Superconductivity
7. One-dimensional systems and bosonization

### Intended learning outcomes

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

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

V (4) + R (2)
Module taught in: German or English

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

- written examination (approx. 90-120 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).
- If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.
- Language of assessment: German and/or English
- Assessment offered: In the semester in which the course is offered and in the subsequent semester

### Allocation of places

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### Additional information

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

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**Module title**: Solid State Physics 2  
**Abbreviation**: 11-FK2-201-m01

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

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

**Contents**

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

**Intended learning outcomes**

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

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

V (4) + R (2)  
Module taught in: German or English

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

Written examination (approx. 90-120 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).

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Master's with 1 major Quantum Technology (2021)  
JMU Würzburg • generated 19-Jul-2022 • exam. reg. data record Master (120 ECTS) Quantentechnologie - 2021
**Language of assessment:** German and/or English

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

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</table>
Module title
Solid State Spectroscopy

Abbreviation
11-FKS-161-m01

Module coordinator
Managing Director of the Institute of Applied Physics

Module offered by
Faculty of Physics and Astronomy

ECTS
6

Method of grading
Numerical grade

Only after succ. compl. of module(s)

Duration
1 semester

Module level
Graduate

Other prerequisites
None

Contents

Intended learning outcomes
The students have specific and advanced knowledge in the field of solid-state spectroscopy. They know different types of spectroscopy and their fields of application. They understand the theoretical principles and the current developments in research.

Courses

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<tr>
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Module taught in: German or English

Method of assessment

- 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).

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: German and/or English

Allocation of places

Additional information

Referred to in LPO I (examination regulations for teaching-degree programmes)
<table>
<thead>
<tr>
<th>Module title</th>
<th>Visiting Research</th>
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<tr>
<td>Abbreviation</td>
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<tr>
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</table>

**Contents**

Independent work on a current research topic of Experimental and Theoretical Physics. Implementation of scientific experiments including analysis and documentation of the results, especially in the context of research visits to other universities or research institutes.

**Intended learning outcomes**

The students are able to independently work on a current research area of Experimental or Theoretical Physics, to conduct and analyse scientific experiments and to document the results.

**Courses**

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

R (0)

<table>
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<tr>
<th>Method of assessment</th>
<th>(type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)</th>
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<td>project report (10 to 20 pages)</td>
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**Allocation of places**

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**Additional information**

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**Referred to in LPO I**

(examination regulations for teaching-degree programmes)

--
Module title
Advanced Topics in Solid State Physics

Abbreviation
11-CSFM-161-m01

Module coordinator
Managing Director of the Institute of Theoretical Physics and Astrophysics

Module offered by
Faculty of Physics and Astronomy

ECTS
6

Method of grading
numerical grade

Only after succ. compl. of module(s)

Duration
1 semester

Module level
graduate

Other prerequisites
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
The students advance their knowledge and understanding of an advanced topic of Condensed Matter Physics and acquire insights into the connections between research and teaching.

Courses (type, number of weekly contact hours, language — if other than German)
V (3) + R (1)

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

a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

Allocation of places
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Additional information
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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### Advanced Topics in Physics

**Module title:** Advanced Topics in Physics  
**Abbreviation:** 11-CSPM-161-m01

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**Contents**

This module will enable lecturers of 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**

The students advance their knowledge and understanding of an advanced topic of nanostructure technology and acquire insights into the connections between research and teaching.

**Courses**

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

V (3) + R (1)

**Method of assessment**

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

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).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

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### Module title
Advanced Topics in Quantum Technology

### Abbreviation
11-CSNM-212-m01

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### Contents
This module allows lecturers of the quantum technology study programme to give lectures on advanced topics that cannot 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.

### Intended learning outcomes
The students deepen their knowledge and understanding of an advanced topic in quantum technology, thereby gaining insights into the interface between research and teaching.

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

V (3) + R (1)
Module taught in: German or English

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

- 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).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

### Allocation of places
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### Additional information
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### Referred to in LPO I
(examination regulations for teaching-degree programmes)
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### Advanced Laboratory Course Master Part 1

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### Contents

Principles of Nuclear, Atomic and Molecular Physics, experiments on cryogenic temperatures and correlated systems, properties of solids, surfaces and interfaces. Experiments on the following topics: X-rays - nuclear magnetic resonance (NMR) - quantum Hall effect - optical pumping and spectroscopy in the field of optics - Hall effect - superconductivity - laser - solid-state optics

### Intended learning outcomes

Knowledge of conducting experiments, analysing and documenting experimental results, basic knowledge of issuing scientific publications, application of modern evaluation systems. The students are familiar with modern experimental methods. They are able to work on a task on the basis of publications, to conduct and evaluate an experiment and to present and discuss their results in a scientific publication.

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

| P (3) |

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

| practical examination |

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

Language of assessment: German and/or English

### Allocation of places

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### Additional information

--

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

--
### Module title
Advanced Laboratory Course Master Part 2

### Abbreviation
11-P-FM2-161-m01

### Module coordinator
Managing Director of the Institute of Applied Physics

### Module offered by
Faculty of Physics and Astronomy

### ECTS
3

### Method of grading
Only after succ. compl. of module(s)

### Duration
1 semester

### Module level
graduate

### Other prerequisites
Preparation and safety briefing.

### Contents
Principles of Nuclear, Atomic and Molecular Physics, experiments on cryogenic temperatures and correlated systems, properties of solids, surfaces and interfaces. Experiments on the following topics: X-rays - nuclear magnetic resonance (NMR) - quantum Hall effect - optical pumping and spectroscopy in the field of optics - Hall effect - superconductivity - laser - solid-state optics

### Intended learning outcomes
Knowledge of conducting experiments, analysing and documenting experimental results, basic knowledge of issuing scientific publications, application of modern evaluation systems. The students are familiar with modern experimental methods. They are able to work on a task on the basis of publications, to conduct and evaluate an experiment and to present and discuss their results in a scientific publication.

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

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

- **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: German and/or English

### Allocation of places

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### Additional information

--

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

--
### Module title
*Advanced Laboratory Course Master Part 3*

### Abbreviation
11-P-FM3-161-m01

### Module coordinator
Managing Director of the Institute of Applied Physics

### Module offered by
Faculty of Physics and Astronomy

### ECTS
3

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### Duration
1 semester

### Module level
graduate

### Other prerequisites
Preparation and safety briefing.

### Contents
Principles of Nuclear, Atomic and Molecular Physics, experiments on cryogenic temperatures and correlated systems, properties of solids, surfaces and interfaces. Experiments on the following topics: X-rays - nuclear magnetic resonance (NMR) - quantum Hall effect - optical pumping and spectroscopy in the field of optics - Hall effect - superconductivity - laser - solid-state optics

### Intended learning outcomes
Knowledge of conducting experiments, analysing and documenting experimental results, basic knowledge of issuing scientific publications, application of modern evaluation systems. The students are familiar with modern experimental methods. They are able to work on a task on the basis of publications, to conduct and evaluate an experiment and to present and discuss their results in a scientific publication.

### Courses
(type, number of weekly contact hours, language — if other than German)
P (3)

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

practical examination

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

Language of assessment: German and/or English

### Allocation of places
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### Additional information
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### Referred to in LPO I
(examination regulations for teaching-degree programmes)
--
### Advanced Laboratory Course Master Part 4

**Abbreviation**: 11-P-FM4-161-m01

**Module coordinator**: Managing Director of the Institute of Applied Physics

**Module offered by**: Faculty of Physics and Astronomy

**ECTS**: 3

**Method of grading**: Only after succ. compl. of module(s)

**Duration**: 1 semester

**Module level**: graduate

**Other prerequisites**: Preparation and safety briefing.

### Contents

Principles of Nuclear, Atomic and Molecular Physics, experiments on cryogenic temperatures and correlated systems, properties of solids, surfaces and interfaces. Experiments on the following topics: X-rays - nuclear magnetic resonance (NMR) - quantum Hall effect - optical pumping and spectroscopy in the field of optics - Hall effect - superconductivity - laser - solid-state optics

### Intended learning outcomes

Knowledge of conducting experiments, analysing and documenting experimental results, basic knowledge of issuing scientific publications, application of modern evaluation systems. The students are familiar with modern experimental methods. They are able to work on a task on the basis of publications, to conduct and evaluate an experiment and to present and discuss their results in a scientific publication.

### Courses

**Type, number of weekly contact hours, language** — if other than German

P (3)

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

Practical examination

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

Language of assessment: German and/or English

### Allocation of places

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### Additional information

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### Referred to in LPO 1

(examination regulations for teaching-degree programmes)

--
### Module title
Advanced Programming

### Abbreviation
10-I-APR-172-m01

### Module coordinator
holder of the Chair of Computer Science II

### Module offered by
Institute of Computer Science

### ECTS
5

### Method of grading
numerical grade

### Only after succ. compl. of module(s)
--

### Duration
1 semester

### Module level
undergraduate

### Other prerequisites
--

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

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

### Courses
(type, number of weekly contact hours, language — if other than German)
V (2) + Ü (2)

### Method of assessment
(type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
written examination (approx. 60 to 120 minutes).
If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
Language of assessment: German and/or English creditable for bonus

### Allocation of places
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### Additional information
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### Referred to in LPO I (examination regulations for teaching-degree programmes)
--
### Module Title

**Advanced Theory of Quantum Computing and Quantum Information**

| Abbreviation | 11-QIC-201-m01 |

### Module Coordinator

Managing Director of the Institute of Theoretical Physics and Astrophysics

### Module Offered by

Faculty of Physics and Astronomy

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### Duration

1 semester

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<th>Other Prerequisites</th>
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<tr>
<td>graduate</td>
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</table>

### Contents

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

### Intended Learning Outcomes

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

### Courses

<table>
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<th>Type</th>
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Module taught in: German or English

### Method of Assessment

written examination (approx. 90-120 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).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

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

### Allocation of Places

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### Additional Information

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### Referred to in LPO I

(examination regulations for teaching-degree programmes)

--
Subdivided Module Catalogue for the Subject Quantum Technology
Master's with 1 major, 120 ECTS credits

<table>
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<tr>
<th>Module title</th>
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<td>Semiconductor Physics</td>
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<tbody>
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</table>

**Contents**

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

**Intended learning outcomes**

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

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

V (3) + R (1)
Module taught in: German or English

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

written examination (approx. 90-120 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).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

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

**Allocation of places**

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**Additional information**

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

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<table>
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ECTS | Method of grading | Only after succ. compl. of module(s) |
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Duration | Module level | Other prerequisites |
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<tbody>
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Contents

German contents available but not translated yet.

Dieses Modul bietet eine Einführung in das deutsche und europäische Gesellschafts- und Handelsrecht.

Intended learning outcomes

German intended learning outcomes available but not translated yet.


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

V (3) + Ü (2)

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

written examination (approx. 120 minutes)
Assessment offered: Usually once a year, summer semester

Allocation of places

There are no restrictions with regard to available places for students of Rechtswissenschaft (Law) as well as Bachelor’s students with the minor Privatrecht (Private Law). A total of 20 places will be allocated to students of other subjects. 10 of these will be allocated to students of the Master’s degree programme Economics. Should the number of available places exceed the number of applications, the remaining places may be allocated to students of other subjects. Should there be more than 10 applications, the remaining places will be allocated as follows: Students applying after not having successfully completed assessment in past years will be given preferential consideration. The remaining places will be allocated by lot. A waiting list will be maintained and places reallocated by lot as they become available.

Additional information

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

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<table>
<thead>
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<th>Module title</th>
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<td>Institute of Computer Science</td>
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### Contents
Intelligent agents, uninformed and heuristic search, constraint problem solving, search with partial information, propositional and predicate logic and inference, knowledge representation.

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

### Courses
(type, number of weekly contact hours, language — if other than German)
V (2) + Ü (2)

### Method of assessment
(type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
- written examination (approx. 60 to 120 minutes).
  - If announced by the lecturer at the beginning of the course, the written examination may be replaced by an oral examination of one candidate each (approx. 20 minutes) or an oral examination in groups of 2 candidates (approx. 15 minutes per candidate).
- Language of assessment: German and/or English creditable for bonus

### Allocation of places
--

### Additional information
Focuses available for students of the Master’s programme Informatik (Computer Science, 120 ECTS credits):
- AT, SE, IS, HCI

### Referred to in LPO 1
(examination regulations for teaching-degree programmes)
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### Contents
Dia- and paramagnetism, exchange interaction, ferromagnetism, antiferromagnetism, anisotropy, domain structure, nanomagnetism, superparamagnetism, experimental methods to measure magnetic properties, Kondo effect.

### Intended learning outcomes
The students know basic terms, concepts and phenomena of magnetism and measuring methods for magnetic experiments; they are skilled in simple model building and in the formulation of mathematical-physical approaches and are able to apply them to tasks in the stated areas; they have competencies in independently working on problems of these areas; they are able to evaluate the accuracy of observations and analyses.

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

V (3) + R (1)
Module taught in: German or English

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

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).

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: German and/or English

### Allocation of places
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### Additional information
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### Referred to in LPO I (examination regulations for teaching-degree programmes)
--
Module title | Abbreviation
--- | ---
Trade Mark Law | 02-N-P-W06-182-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 | --

Contents

German contents available but not translated yet.


Intended learning outcomes

German intended learning outcomes available but not translated yet.

Die Studierenden können markenrechtliche Fragestellungen unter Gesichtspunkten des deutschen und europäischen Rechts analysieren.

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 can be chosen to earn a bonus)

a) written examination (approx. 120 minutes) or b) oral examination (approx. 15 minutes)

Assessment offered: Usually once a year, summer semester

Allocation of places

max. 10 places. There are no restrictions with regard to available places for students of the degree programme Rechtswissenschaft (Law) pursuing the degree Erste Juristische Staatsprüfung (first state examination in law) as well as Bachelor’s students with the minor Privatrecht (Private Law). A total of 10 places will be allocated to students of other subjects. Should there be more than 10 applications from students of other subjects, these places will be allocated as follows: Students applying after not having successfully completed assessment in the past two semesters will be given preferential consideration. The remaining places will be allocated by lot. A waiting list will be maintained and places re-allocated as they become available.

Additional information

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

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**Contents**

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

**Intended learning outcomes**

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

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

No courses assigned to module

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

Master's thesis (750 to 900 hours total)

Language of assessment: German and/or English

**Allocation of places**

--

**Additional information**

--

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

--
### Module title
Scientific Methods and Project Management Quantum Technology

### Abbreviation
11-MP-N-212-m01

### Module coordinator
chairperson of examination committee

### Module offered by
Faculty of Physics and Astronomy

### ECTS
15

### Method of grading
Only after succ. compl. of module(s)

### (not) successfully completed
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### Duration
1 semester

### Module level
graduate

### Other prerequisites
--

### Contents
Introduction to the scientific approach and practice, including project planning within a current experimental, engineering or theoretical research topic in the field of quantum technology research chosen for the master thesis. Establishment of a scientific project plan for the planned master thesis.

### Intended learning outcomes
Knowledge of the scientific approach and practice, including project planning in a current experimental, engineering or theoretical research topic in the field of quantum technology research chosen for the master thesis. Ability to establish a research plan for the master thesis, and to plan the required experimental or theoretical work. Ability to present the project in a seminar talk.

### Courses (type, number of weekly contact hours, language — if other than German)
R (4)
Module taught in: German or English

### Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
talk with discussion (30 to 45 minutes)
Language of assessment: German and/or English

### Allocation of places
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### Additional information
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### Referred to in LPO I (examination regulations for teaching-degree programmes)
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Nano-Optics

Nano-Optics

Module coordinator
Managing Director of the Institute of Applied Physics

Module offered by
Faculty of Physics and Astronomy

ECTS
6

Method of grading
Numerical grade

Duration
1 semester

Module level
Graduate

Other prerequisites
--

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

Intended learning outcomes
The students have specific and advanced knowledge in the field of nano-optics. They are familiar with the theoretical principles and application areas of nano-optics and with current developments in this field.

Courses
(V 3) + (R 1)

Module taught in: German or English

Method of assessment
(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: German and/or English

Allocation of places
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Additional information
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**Contents**

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

**Intended learning outcomes**

The students have advanced competencies on the Master's level which correspond to the requirements of a module in the field of a non-technical minor (mathematics, chemistry, informatics, law, business sciences...).

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

V (3) + R (1)

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

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).

If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

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**Contents**

Relevance of surfaces and interfaces, distinction between bulk phases, classical description, continuum models.

**Intended learning outcomes**

The students have gained an overview of the diverse aspects of surface physics and especially know the causes and contexts of physical peculiarities of surfaces and interfaces. Additionally, they know the most important experimental techniques and their specific application possibilities in the context of surface physics.

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

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

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

a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).

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

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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**Contents**

Seminar on current issues in theoretical or experimental physics.

**Intended learning outcomes**

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

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

S (2)

Module taught in: German or English

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

Talk with discussion (30 to 45 minutes)
Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

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**Contents**

Seminar on current issues in theoretical or experimental physics.

**Intended learning outcomes**

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

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

S (2)

Module taught in: German or English

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

Talk with discussion (30 to 45 minutes)

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

--
Optical Properties of Semiconductor Nanostructures

Managing Director of the Institute of Applied Physics
Faculty of Physics and Astronomy

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 by changing their size. The lecture addresses technological challenges in the preparation of semiconductor nanostructures of varying dimensions (2D, 1D, 0D). It provides the basic theoretical concepts to describe their properties, with a focus on optical properties and light-matter coupling. Moreover, it discusses the challenges and concepts of novel optoelectronic and quantum photonic devices based on such nanostructures, including building blocks for quantum communication and quantum computing architectures.

Intended learning outcomes

The students know the theoretical principles and characteristics of semiconductor nanostructures. They have knowledge of the technological methods to fabricate such structures, and of their applications to novel photonic devices. They are able to apply their knowledge to problems in this field of research.

Courses

V (3) + R (1)
Module taught in: German or English

Method of assessment

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).
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: German and/or English

Allocation of places

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Additional information

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**Contents**

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

**Intended learning outcomes**

The students have advanced knowledge of organic semiconductors.

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

V (3) + R (1)

Module taught in: German or English

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

- a) written examination (approx. 90 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: German and/or English

**Allocation of places**

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**Additional information**

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

---
Module title: Phenomenology and Theory of Superconductivity
Abbreviation: 11-PTS-201-m01

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

ECTS: 6
Duration: 1 semester
Module level: graduate
Other prerequisites: --

Contents

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: German or English

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
written examination (approx. 90-120 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).
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Language of assessment: German and/or English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

Allocation of places
--

Additional information
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Referred to in LPO I (examination regulations for teaching-degree programmes)
--
### Module title

**Physics of Advanced Materials**

| Abbreviation | 11-PMM-161-m01 |

### Module coordinator

Managing Director of the Institute of Applied Physics

### Module offered by

Faculty of Physics and Astronomy

### ECTS

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### Contents

General properties of various material groups such as liquids, liquid crystals and polymers; magnetic materials and superconductors; thin films, heterostructures and superlattices. Methods of characterising these material groups; two-dimensional layer materials.

### Intended learning outcomes

The students know the properties and characterization methods of some modern materials.

### Courses

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

V (3) + R (1)

Module taught in: German or English

### Method of assessment

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

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).

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

Language of assessment: German and/or English

### Allocation of places

--

### Additional information

--

### Referred to in LPO I

(examination regulations for teaching-degree programmes)

--
Subdivided Module Catalogue for the Subject
Quantum Technology
Master's with 1 major, 120 ECTS credits

<table>
<thead>
<tr>
<th>Module title</th>
<th>Abbreviation</th>
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<tbody>
<tr>
<td>Quantum Mechanics II</td>
<td>11-QM2-161-m01</td>
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<tr>
<td>Managing Director of the Institute of Theoretical Physics and Astrophysics</td>
<td>Faculty of Physics and Astronomy</td>
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<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</table>

**Contents**

The contents of this lecture build upon and will be chosen in accordance with the topics of the Bachelor's degree course "Quantum Mechanics I". Topics might include:

for QM:
1. Historical introduction
2. Single-particle states in a central potential
3. Principles of quantum mechanics
4. Spin and angular momentum
5. Approximations of energy eigenvalues
6. Approximations for time-dependent problems
7. Second quantisation
8. Potential scattering
9. General scattering theory
10. Canonical formalism
11. Charged particles in electromagnetic fields
12. Quantum theory of radiation
13. Quantum entanglement

**Intended learning outcomes**

The students acquire in-depth knowledge of advanced quantum mechanics. This knowledge is highly relevant to most of the theoretical Master's degree courses in Astrophysics, Particle Physics and Condensed Matter Physics. The completion of this course is highly recommended.

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

V (4) + R (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 can be chosen to earn a bonus)

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

**Allocation of places**

--

**Additional information**

--

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

--
Module title | Abbreviation
--- | ---
Quantum Transport | 11-QTR-201-m01

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

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Contents

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

Intended learning outcomes

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

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

V (3) + R (1)
Module taught in: German or English

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

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

Allocation of places
--

Additional information
--

Referred to in LPO I (examination regulations for teaching-degree programmes)
--
**Module title**
Scanning Probe Technologies

**Abbreviation**
11-SPT-211-m01

**Module coordinator**
Managing Director of the Institute of Applied Physics

**Module offered by**
Faculty of Physics and Astronomy

**ECTS**
6

**Method of grading**
Only after succ. compl. of module(s)

**Duration**
1 semester

**Module level**
graduate

**Other prerequisites**
--

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

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

**Courses** (type, number of weekly contact hours, language — if other than German)
V (3) + R (1)
Module taught in: German or English
Teaching cycle: annually, after announcement

**Method of assessment** (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
a) written examination (approx. 90 to 120 minutes) or b) oral examination of one candidate each (approx. 30 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate) or d) project report (approx. 8 to 10 pages) or e) presentation/talk (approx. 30 minutes).
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Language of assessment: German and/or English
Assessment offered: In the semester in which the course is offered and in the subsequent semester

**Allocation of places**
--

**Additional information**
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**Referred to in LPO I** (examination regulations for teaching-degree programmes)
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<tr>
<td></td>
<td>degree programme coordinator Funktionswerkstoffe (Functional Materials)</td>
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<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

**Contents**


**Intended learning outcomes**

The students acquire fundamental knowledge in sensoric and actoric materials.

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

V (2) + P (2)

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

a) written examination (approx. 90 minutes) or b) oral examination of one candidate each (approx. 20 minutes) or c) oral examination in groups (groups of 2, approx. 30 minutes per candidate)

Assessment offered: Once a year, summer semester

Language of assessment: German and/or English

P: creditable for bonus

**Allocation of places**

--

**Additional information**

--

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

--
Module title: Spintronics
Abbreviation: 11-SPI-161-m01

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

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

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

Contents
This lecture covers the basic principles of spin transport, with a particular emphasis on the phenomena of giant magnetoresistance and tunnel magnetoresistance. As a last point, we discuss new phenomena from the field of spin dynamics and current-induced spin phenomena.

Intended learning outcomes
The students know the basic principles of spin transport models and the applications of spin transport in information technology. They have gained an overview of current 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: German or English

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
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Assessment offered: In the semester in which the course is offered and in the subsequent semester
Language of assessment: German and/or English

Allocation of places
--

Additional information
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Referred to in LPO I (examination regulations for teaching-degree programmes)
--
**Module title**  
Theoretical Solid State Physics

**Abbreviation**  
11-TFK-161-m01

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</table>

**Contents**

The contents of this two-term course will depend on the choice of the lecturer, and may include parts of the syllabus which could alternatively be offered as "Quantum Many Body Physics" (11-QVTP).

A possible syllabus may be:

1. Band structure (Sommerfeld theory of metals, Bloch theorem, k.p approach and effective Hamiltonians for topological insulators (TIs), bulk-surface correspondence, general properties of TIs)
2. Electron-electron interactions in solids (path integral method for weakly interacting fermions, mean field theory, random phase approximation (RPA), density functional theory)
3. Application of mean field theory and the RPA to magnetism
4. BCS theory of superconductivity

**Intended learning outcomes**

During the two-semester lecture, the students acquire a basic understanding of many topics of Solid-State Physics, which are addressed in classical textbooks, and thereby advance their knowledge of the underlying concepts and the methods of description. The course builds upon the courses "Experimental Condensed Matter Physics" and "Quantum Mechanics".

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

V (4) + R (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 can be chosen to earn a bonus)

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

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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</table>

### Contents

1. Semi-classical atom-field interactions
2. Interaction of atoms with quantized light fields and dressed-atom model
3. Master equation and open systems
4. Coherence and interference effects
5. Coherent light propagation in resonant media
6. Photon statistics and correlations
7. Quantum optics of many-body systems

### Intended learning outcomes


### Courses

<table>
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Module taught in: German or English

### Method of assessment

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

Language of assessment: German and/or English

### Allocation of places

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### Additional information

--

### Referred to in LPO I

(examination regulations for teaching-degree programmes)
### Module title
Topological Effects in Solid State Physics

### Abbreviation
11-TEFK-201-m01

### Module coordinator
Managing Director of the Institute of Theoretical Physics and Astrophysics

### Module offered by
Faculty of Physics and Astronomy

### ECTS
8

### Method of grading
numerical grade

### Only after succ. compl. of module(s)
--

### Duration
1 semester

### Module level
graduate

### Other prerequisites
--

### Contents
1. Geometric phase in quantum systems
2. Mathematical basics of topology
3. Time-reversal symmetry
4. Hall conductance and Chern numbers
5. Bulk-boundary correspondence
6. Graphene (as a topological insulator)
7. Quantum Spin Hall insulators
8. Z2 invariants
9. Topological superconductors

### Intended learning outcomes
In-depth theoretical understanding of the topological concepts in quantum physics related to solid state systems. Ability to connect their knowledge with different research activities at the Department of Physics and Astronomy at Würzburg University.

### Courses (type, number of weekly contact hours, language — if other than German)
V (4) + R (1)

Module taught in: German or English

### Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
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Language of assessment: German and/or English

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

### Allocation of places
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### Additional information
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### Referred to in LPO I (examination regulations for teaching-degree programmes)
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<td>Ultrafast spectroscopy and quantum-control</td>
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<tbody>
<tr>
<td>lecturer of the seminar &quot;Nanoskalige Materialien&quot;</td>
<td>Institute of Physical and Theoretical Chemistry</td>
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<td>1 semester</td>
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<td>Prior completion of modules 08-PCM1a and 08-PCM1b recommended.</td>
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</table>

**Contents**

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

**Intended learning outcomes**

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

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

S (2) + Ü (1)

Module taught in: German or English

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

a) written examination (approx. 90 minutes) or b) oral examination of one candidate each (approx. 20 minutes) or c) talk (approx. 30 minutes)

Language of assessment: German and/or English

**Allocation of places**

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**Additional information**

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

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</table>

### Contents

German contents available but not translated yet.


### Intended learning outcomes

German intended learning outcomes available but not translated yet.

Die Studierenden haben grundlegende Kenntnisse des Gewerblichen Rechtsschutzes und des Urheberrechts erworben. Sie können Problematiken aus diesen Bereichen in den Kontext der deutschen und europäischen Regulatien einordnen.

### Courses

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

V (1)

### Method of assessment

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

a) written examination (approx. 120 minutes) or b) oral examination (approx. 15 minutes)

Assessment offered: Usually once a year, summer semester

### Allocation of places

max. 10 places. There are no restrictions with regard to available places for students of the degree programme Rechtswissenschaft (Law) pursuing the degree Erste Juristische Staatsprüfung (first state examination in law) as well as Bachelor’s students with the minor Privatrecht (Private Law). A total of 10 places will be allocated to students of other subjects. Should there be more than 10 applications from students of other subjects, these places will be allocated as follows: Students applying after not having successfully completed assessment in the past two semesters will be given preferential consideration. The remaining places will be allocated by lot. A waiting list will be maintained and places re-allocated as they become available.

### Additional information

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### Referred to in LPO I

(examination regulations for teaching-degree programmes)

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<td>Dean of Studies Mathematik (Mathematics)</td>
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**Contents**

Continuation of analysis in several variables, integration theorems.

**Intended learning outcomes**

The student is acquainted with advanced topics in analysis. Taking the example of the 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 can be chosen to earn a bonus)

a) written examination (approx. 90 to 180 minutes, usually chosen) or b) oral examination of one candidate each (15 to 30 minutes) or c) oral examination in groups (groups of 2, 10 to 15 minutes per candidate)

Language of assessment: German and/or English
creditable for bonus

**Allocation of places**

--

**Additional information**

--

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

--
Module title | Additional Qualifications | Abbreviation
---|---|---
11-EXZ5-161-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 skills for engineers. Accredited academic achievements, e.g. in case of change of university or study abroad.

Intended learning outcomes
The students have advanced competencies corresponding to the requirements of a module of the Master's degree programme of Nanostructure Technology. They have qualifying knowledge for an occupation in the industry or industrial research.

Courses (type, number of weekly contact hours, language — if other than German)
V (2) + R (2)

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
written examination (approx. 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).
If a written examination was chosen as method of assessment, this may be changed and assessment may instead take the form of an oral examination of one candidate each or an oral examination in groups. If the method of assessment is changed, the lecturer must inform students about this by four weeks prior to the original examination date at the latest.
Language of assessment: German and/or English

Allocation of places
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Additional information
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Referred to in LPO I (examination regulations for teaching-degree programmes)
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### Module title
Additional Qualifications

<table>
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### Module coordinator

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<td>Faculty of Physics and Astronomy</td>
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### ECTS

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### Duration

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Additional skills for engineers. Accredited academic achievements, e.g. in case of change of university or study abroad

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

| V (3) + R (1) |

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

- 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).
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### Allocation of places

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### Additional information

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

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