Subdivided Module Catalogue
for the Subject

Physics
as a Bachelor’s with 1 major
with the degree "Bachelor of Science"
(180 ECTS credits)

Examination regulations version: 2015
Responsible: Faculty of Physics and Astronomy
Course of Studies - Contents and Objectives

The goal of the studies is to mediate knowledge on the most important subsections of physics and to make the students familiar with the methods of physical scientific and physical thinking and working. By training of analytic thinking abilities the students acquire the ability to deal later with the various fields of applications and to compile the basic knowledge in particular necessary for a consecutive Bachelor and Master course of studies. Therefore the main emphasis is put on the understanding of the fundamental experimental and theoretical physical terms and laws as well as on basic scientific methods and the development of the typical scientific thinking and working structures. During the Bachelor thesis the student should work on a thematic and temporally limited experimental or theoretical engineeringscientific task in the field of experimental or theoretical physics using well-known procedures and scientific criteria under guidance to a large extent independently.
Abbreviations used

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

Term: \text{SS} = \text{summer semester}, \text{WS} = \text{winter semester}

Methods of grading: \text{NUM} = \text{numerical grade}, \text{B/NB} = \text{(not) successfully completed}

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

Other: \text{A} = \text{thesis}, \text{LV} = \text{course(s)}, \text{PL} = \text{assessment(s)}, \text{TN} = \text{participants}, \text{VL} = \text{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:

\text{ASPO2015}

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

\text{22-Jul-2015 (2015-40) except for mandatory elective 11-KDS-152 added in Fast Track procedure at a later time}

\text{14-Mar-2018 (2018-16)}

\text{12-Dec-2018 (2018-63)}

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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<td>11-T-SE-152-m01</td>
<td>Statistical Physics and Electrodynamics</td>
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<td>11-P-PC-152-m01</td>
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<td><strong>Compulsory Electives (21 ECTS credits)</strong></td>
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In the area of mandatory electives, students must achieve no less than 12 ECTS credits in graded modules. In the area of mandatory electives, students must complete modules worth a total of no less than 21 ECTS credits.

### Modules Chemistry, Computer Science, Mathematics

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<td>08-ACP-NF-152-m01</td>
<td>General and Analytical Chemistry for students of natural sciences (lab)</td>
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<td>08-OC-NF-152-m01</td>
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<td>10-M-COM-152-m01</td>
<td>Computational Mathematics</td>
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<td>10-M-NUM1af-152-m01</td>
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<td>10-M-PRG-152-m01</td>
<td>Programming course for students of Mathematics and other subjects</td>
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### Modules Applied Physics

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<td>11-EL-152-m01</td>
<td>Electronic Circuits</td>
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<td>11-LMT-152-m01</td>
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<td>Laboratory and Measurement Technology in Biophysics</td>
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<td>Imaging Methods at the Synchrotron</td>
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### Modules Astrophysics

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### Modules Particle Physics

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<td>11-DTS-152-m01</td>
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### Modules Semiconductor Physics

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<tr>
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<td>Physics of Semiconductor Devices</td>
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### Modules Solid State and Nanostructure Physics

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<td>Principles of Energy Technologies</td>
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**Key Skills Area (20 ECTS credits)**

**General Key Skills (5 ECTS credits)**

In addition to the modules listed below, students may also take modules offered by JMU as part of the pool of general transferable skills (ASQ).

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**Subject-specific Key Skills (15 ECTS credits)**

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<td>Seminar Experimental/Theoretical Physics</td>
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<td>11-P-FR1-152-m01</td>
<td>Data and Error Analysis</td>
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<td>11-P-FR2-152-m01</td>
<td>Advanced and Computational Data Analysis</td>
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**Thesis (10 ECTS credits)**

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<td>11-BA-P-152-m01</td>
<td>Bachelor Thesis Physics</td>
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Module title: Laboratory Course Physics A (Mechanics, Heat, Electromagnetism)
Abbreviation: 11-P-PA-152-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: undergraduate
Other prerequisites: --

Contents:
Measurement tasks in mechanics, thermodynamics and electricity theory, e.g. measurement of voltages and currents, heat capacity, calorimetry, density of bodies, dynamic viscosity, elasticity, surface tension, spring constant, drafting of graphics and drafting of measurement protocols.

Intended learning outcomes:
The students know and have mastered physical measuring methods and experimenting techniques. They are able to independently plan and conduct experiments, to cooperate with others, and to document the results in a measuring protocol.

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

practical assignment with talk (approx. 30 minutes)
Preparing, performing and evaluating (record of readings or lab report) the experiments will be considered successfully completed if a Testat (exam) is passed. Exactly one experiment that was not successfully completed can be repeated once. After completion of all experiments, talk (with discussion; approx. 30 minutes) to test the candidate's understanding of the physics-related contents of the module. Talks that were not successfully completed can be repeated once. Both components of the assessment have to be successfully completed.

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>Data and Error Analysis</td>
<td>11-P-FR1-152-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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<th>Duration</th>
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<th>Other prerequisites</th>
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<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
<td>Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.</td>
</tr>
</tbody>
</table>

**Contents**

Types of errors, error approximation and propagation, graphic representations, linear regression, mean values and standard deviation.

**Intended learning outcomes**

The students are able to evaluate measuring results on the basis of error propagation and of the principles of statistics and to draw, present and discuss the conclusions.

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

<table>
<thead>
<tr>
<th>V (x) + Ü (y)</th>
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<tbody>
<tr>
<td>Module taught in: Ü: German or English</td>
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</tbody>
</table>

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

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

**Allocation of places**

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**Additional information**

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

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

§ 53 I Nr. 1 c)
§ 77 I Nr. 1 d)
<table>
<thead>
<tr>
<th>Module title</th>
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<tbody>
<tr>
<td>Numerical Mathematics 1 for students of other subjects</td>
<td>10-M-NUM1af-152-m01</td>
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<table>
<thead>
<tr>
<th>Module coordinator</th>
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<tbody>
<tr>
<td>Dean of Studies Mathematik (Mathematics)</td>
<td>Institute of Mathematics</td>
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<th>Method of grading</th>
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<tr>
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<th>Other prerequisites</th>
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<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</tbody>
</table>

**Contents**

Solution of systems of linear equations and curve fitting problems, nonlinear equations and systems of equations, interpolation with polynomials, splines and trigonometric functions, numerical integration.

**Intended learning outcomes**

The student is acquainted with the fundamental concepts and methods in numerical mathematics, applies them to practical problems and knows about their typical fields of application.

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

V (4) + Ü (2)

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

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

Language of assessment: German and/or English

creditable for bonus

**Allocation of places**

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**Additional information**

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**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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<tr>
<td>Numerical Mathematics 2 for students of other subjects</td>
<td>10-M-NUM2af-152-m01</td>
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<td>Dean of Studies Mathematik (Mathematics)</td>
<td>Institute of Mathematics</td>
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<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</table>

**Contents**

Eigenvalue problems, linear programming, methods for initial value problems for ordinary differential equations, boundary value problems.

**Intended learning outcomes**

The student is able to draw a distinction between the different concepts of numerical mathematics and knows about their advantages and limitations concerning the possibilities of application in different fields of natural and engineering sciences and economics.

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

V (4) + Ü (2)

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

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

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

**Allocation of places**

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**Additional information**

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

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Module title: Astrophysics
Abbreviation: 11-AP-152-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: Only after succ. compl. of module(s)
Numerical grade: --

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

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):
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):
§ 22 II Nr. 1 h)
§ 22 II Nr. 2 f)
§ 22 II Nr. 3 f)
<table>
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<tr>
<th>Module title</th>
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<tbody>
<tr>
<td>Introduction to Computer Science for Students of all Faculties</td>
<td>10-I-EIN-152-m01</td>
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**Module coordinator**
Dean of Studies Informatik (Computer Science)

**Module offered by**
Institute of Computer Science

<table>
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<tr>
<th>ECTS</th>
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<tr>
<th>Duration</th>
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<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</table>

**Contents**
Foundations of computer science including representation of information and websites (HTML, XML, EBNF), databases, algorithms and data structures, programming (Java).

**Intended learning outcomes**
The students are familiar with the fundamentals of computer science, e.g. in the areas of representation of information and websites (HTML, XML, EBNF), databases, algorithms and data structures, programming in Java.

**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)

Written examination (approx. 60 to 120 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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Module title: Classical Physics 1 (Mechanics)
Abbreviation: 11-E-M-152-m01

Module coordinator: Managing Director of the Institute of Applied Physics
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: undergraduate
Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.

Contents:
1. Principles: Physical quantities, prefactors, derived quantities, dimensional analysis, time / length / mass (definition, measurement procedures, SI), importance of metrology;
2. Point Mechanics: Kinematics, motion in 2D and 3D / vectors, special cases: Uniform and constant accelerated motion, free fall, slate litter; circular motion in polar coordinates;
3. Newton's laws: Forces and momentum definition, weight vs. mass forces on the pendulum, forces on an atomic scale, isotropic and anisotropic friction. Preparation of the equations of motion and solutions;
4. Work and energy: (Kinetic) performance, examples;
5. Elastic, inelastic and super-elastic collision: Energy and momentum conservation, surges in centre of mass and balance system, rocket equation;
6. Conservative and non-conservative force fields: Potential, potential energy; law, weight scale, field strength and potential of gravity (general relations);
7. Rotational motion: Angular momentum, angular velocity, torque, rotational energy, moment of inertia, analogies to linear translation, applications, satellites (geostationary and interstellar), escape velocities, trajectories in the central potential;
8. Tidal forces: Inertial system, reference systems, apparent forces, Foucault pendulum, Coriolis force, centrifugal force;
9. Galilean transformation: Brief digression to Maxwell’s equations, ether, Michelson interferometer, Einstein’s postulates, problem of simultaneity, Lorentz transformation, time dilation and length contraction, relativistic impulse;
10. Rigid body and gyroscope: Determining the centre of mass, inertia tensor and -ellipsoid, principal axes and their stability, tensor on the example of the elasticity tensor, physics of the bike; gyroscope: Precession and nutation, the Earth as a spinning top;
11. Friction: Static and dynamic friction, stick-slip motion, rolling friction, viscous friction, laminar flow, eddy formation;
12. Vibration: Representation by means of complex e-function, equation of motion (DGL) on forces, torque and power approach, Taylor expansion, harmonic approximation; spring and pendulum, physical pendulum, damped vibration (resonant case, Kriechfall, aperiodic limit), forced vibration, Fourier analysis;
13. Coupled vibrations: Eigenvalues and eigenfunctions, double pendulum, deterministic vs. chaotic motion, non-linear dynamics and chaos;
14. Waves: Wave equation, transverse and longitudinal waves, polarisation, principle of superposition, reflection at the open and closed end, speed of sound; interference, Doppler effect; phase and group velocity, dispersion relation;
15. Elastic deformation of solid bodies: Elastic modulus, general Hooke’s law, elastic waves;
16. Fluids: Hydrostatic pressure and buoyancy, surface tension and contact angle, capillary forces, steady flows, Bernoulli equation; Boyle-Mariotte, gas laws, barometric height formula, air pressure, compressibility and compressive modulus;
17. Kinetic theory of gases: ideal and real gas, averages, distribution functions, equipartition theorem, Brownian motion, collision cross section, mean free path, diffusion and osmosis, degrees of freedom, specific heat
### Intended learning outcomes

The students understand the basic contexts and principles of mechanics, vibration, waves and kinetic theory of gases. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.

### Courses

<table>
<thead>
<tr>
<th>Type</th>
<th>Number of Weekly Contact Hours</th>
<th>Language — if other than German</th>
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<tbody>
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<td>Ü: German or English</td>
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Module taught in: Ü: German or English

### Method of assessment

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<th>Type</th>
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<th>Language — if other than German</th>
<th>Examination Offered — if not every semester, information on whether module can be chosen to earn a bonus</th>
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<td>written examination (approx. 120 minutes)</td>
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### Allocation of places

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### Additional information

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

### Referred to in LPO I

<table>
<thead>
<tr>
<th>Paragraph</th>
<th>Section</th>
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<tbody>
<tr>
<td>§ 53 I Nr. 1 a)</td>
<td></td>
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<tr>
<td>§ 77 I Nr. 1 a)</td>
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</tbody>
</table>
Module title: Classical Physics 2 (Heat and Electromagnetism)
Abbreviation: 11-E-E-152-m01

Module coordinator: Managing Director of the Institute of Applied Physics
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: Undergraduate
Other prerequisites: Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.

Contents:
1. Thermodynamics (linked to 11-E-M); temperature and quantity of heat, thermometer, Kelvin scale;
2. Heat conduction, heat transfer, diffusion, convection, radiant heat;
3. Fundamental theorems of thermodynamics, entropy, irreversibility, Maxwell’s demon;
4. Heat engines, working diagrams, efficiency, example: Stirling engine;
5. Real gases and liquids, states of matter (also solids), van der Waals, critical point, phase transitions, critical phenomena (opalescence), coexistence region, Joule-Thomson;
6. Electrostatics, basic concepts: Electrical charge, forces; electric field, repulsive field concept, field lines, field of a point charge;
7. Gaussian sentence, related to Coulomb’s law, definition of “river”; Gaussian surface, divergence theorem; special symmetries; divergence and GS in differential form;
8. Electrical potential, working in the E-box, electric potential, potential difference, voltage; potential equation, equipotential surfaces; several important examples: Sphere, hollow sphere, capacitor plates, electric dipole; laces effects, Segner wheel;
9. Matter in the E-field, charge in a homogeneous field, Millikan experiment, Braun tube; electron: Field emission, thermionic emission, dipole in homogeneous and inhomogeneous field; induction, Faraday cage;
10. Capacitor, mirror charge, definition, capacity; plate and spherical capacitor; combination of capacitors; medium in the capacitor; electrical polarisation, displacement and orientation polarisation, microscopic image; dielectric displacement; electrolytic capacitor; Piezoelectric effect;
11. Electricity, introduction, current density, drift velocity, conduction mechanisms;
12. Resistance and conductivity, resistivity, temperature dependence; Ohm’s law; realisations (resistive and non-ohmic, NTC, PTC);
13. Circuits, electrical networks, Kirchhoff’s rules (meshes, nodes); internal resistance of a voltage source, measuring instruments; Wheatstone bridge;
14. Power and energy in the circuit; Capacitor charge; galvanic element; thermovoltage;
15. Transfer mechanisms, conduction in solids: Band model, semiconductor; line in liquids and gases;
16. Magnetostatics, fundamental laws; permanent magnet, field properties, definitions and units; Earth’s magnetic field; Amper’s Law, analogous to e-box, magn. river, swirl;
17. Vector potential, formal derivation, analogous to electric scalar potential; calculation of fields, examples, Helmholtz coils;
18. Moving charge in the static magnetic field, current balance, Lorentz force, right-hand rule, electric motor; dipole field; movement paths, mass spectrometer, Wien filters, Hall effect; electron: e / m determination;
19. Matter in the magnetic field, effects of the field on matter, relative permeability, susceptibility; para-, dia-, ferromagnetism; magn. moment of the electron, behaviour at interfaces;
20. Induction, Faraday’s law of induction, Lenz’s rule, flux change, eddy electric field, Waltenhofen’s pendulum; inductance, self-induction; applications: Transformer, generator;
21. Maxwell’s displacement current, choice of integration area, displacement current; Maxwell’s extension, wave equation; Maxwell equations;
22. AC: Fundamentals, sinusoidal vibrations, amplitude, period and phase; power and RMS value, ohmic resistance; Capacitive & inductive resistor, capacitor and coil, phase shift and frequency dependence; impedance: Complex resistance; performance of the AC;
23. Resonant circuits, combinations of RLC; series and parallel resonant circuit; forced vibration, damped harmonic oscillator (related to 11-E-M);
24: Hertz dipole, characteristics of irradiation, near field, far field; Rayleigh scattering; accelerated charge, synchrotron radiation, X-rays; 25. Electromagnetic waves: Principles, Maxwell’s determination to electromagnetism, radiation pressure (Poynting vector, radiation pressure).

### Intended learning outcomes

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

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

<table>
<thead>
<tr>
<th>Type</th>
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<td>V (4) + Ü (2)</td>
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Module taught in: Ü: German or English

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

- **written examination** (approx. 120 minutes)

Language of assessment: German and/or English

### Allocation of places

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### Additional information

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

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

§ 53 I Nr. 1 a)
§ 77 I Nr. 1 a)
# Theoretical Mechanics

**Abbreviation:** 11-T-M-152-m01

<table>
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<th>ECTS</th>
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<th>Other prerequisites</th>
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<tbody>
<tr>
<td>8</td>
<td>numerical grade</td>
<td>Only after succ. compl. of module(s)</td>
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</table>

**Duration:** 1 semester

**Module level:** undergraduate

Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.

## Contents

1. Newton’s formulation: Inertial systems, Newton’s laws of motion, equations of motion; one-dimensional motion, energy conservation; Harmonic oscillator; Movement in space of intuition, conservative forces;
2. Lagrangian formulation: Variational principles, Euler-Lagrange equation; constraints; coordinate transformations, mechanical gauge transformation; symmetries, Noether theorem, cyclic coordinates; accelerated reference systems and apparent forces;
3. Hamiltonian formulation: Legendre transformation, phase space; Hamilton function, canonical equations; Poisson brackets, canonical transformations; generator of symmetries, conservation laws; minimal coupling; Liouville theorem; Hamilton-Jacobi formulation [optional];
4. Applications: Central-force problems; mechanical similarity, Virial theorem; minor vibrations; particles in an electromagnetic field; rigid bodies, torque and inertia tensor, centrifugal and Euler equations [optional]; scattering, cross section [optional];
5. Relativistic dynamics: Lorentz Transformation; Minkowski space; equations of motion; 6. Non-linear dynamics: Stability theory; KAM theory [optional]; deterministic chaos [optional]

## Intended learning outcomes

The students have gained first experiences concerning the working methods of Theoretical Physics. They are familiar with the principles of theoretical mechanics and their different formulations. They are able to independently apply the acquired mathematical methods and techniques to simple problems of Theoretical Physics and to interpret the results. They have especially acquired knowledge of basic mathematical concepts.

## Courses

**V (4) + Ü (2)**

Module taught in: Ü: German or English

## Method of assessment

written examination (approx. 120 minutes)

Language of assessment: German and/or English
<table>
<thead>
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<th>Referred to in LPO I  (examination regulations for teaching-degree programmes)</th>
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</table>
## Module title
Quantum Mechanics

### Abbreviation
11-T-Q-152-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)
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## Duration
1 semester

## Module level
Undergraduate

## Other prerequisites
Admission prerequisite to assessment: completion of exercises (approx. 13 exercise sheets per semester). Students who successfully completed approx. 50% of exercises will qualify for admission to assessment. The lecturer will inform students about the respective details at the beginning of the semester.

## Contents
1. History and basics: Limits of classical physics; fundamental historical experiments; from classical physics to quantum mechanics (QM);
2. Wave function and Schrödinger equation (SG): SG for free particles; superposition; probability distribution for pulse measurement; correspondence principles: postulates of QM; Ehrenfest theorem; continuity equation; stationary solutions of SG
3. Formalisation of QM: Eigenvalue equations; Physical significance of the eigenvalues of an operator; state space and Dirac notation; representations in state space; tensor products of state spaces
4. Postulates of QM (and their interpretation): State; measurement; chronological development; energy-time uncertainty;
5. One-Dimensional problems: The harmonic oscillator; potential level; potential barrier; potential well; symmetry properties;
6. Spin-1/2 systems I: Theoretical description in Dirac notation; Spin 1/2 in the homogeneous magnetic field; two-level systems (qubits);
7. Angular momentum: Commutation and rotations; eigenvalues of the angular momentum operators (abstract); solution of the eigenvalue equation in polar coordinates (concrete);
8. Central potential - hydrogen atom: Bonding states in 3D; Coulomb potential;
9. Motion in an electromagnetic field: Hamiltonian; Normal Zeeman effect; canonical and kinetic momentum; Gauge transformation; Aharonov-Bohm effect; Schrödinger, Heisenberg and interaction representation; motion of a free electron in a magnetic field;
10. Spin-1/2 systems II: Formulation using angular momentum algebra;
11. Addition of angular momenta:
12. Approximation methods: Stationary perturbation theory (with examples); variational method; WKB method; time-dependent perturbation theory;
13. Atoms with several electrons: Identical particles; Helium atom; Hartree and Hartree-Fock approximation; atomic structure and Hund’s rules

## Intended learning outcomes
The students have gained first experiences concerning the working methods of Theoretical Physics. They are familiar with the principles of quantum theory. They are able to apply the acquired mathematical methods and techniques to simple problems of quantum theory and to interpret the results. They have especially acquired knowledge of advanced mathematical concepts.

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

V (4) + Ü (2)

Module taught in: Ü: German or English

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

written examination (approx. 120 minutes)
Language of assessment: German and/or English
### Allocation of places

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### Additional information

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

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

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### Module title

| Statistical Physics and Electrodynamics |

### Abbreviation

| 11-T-SE-152-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

| Only after succ. compl. of module(s) |

### Duration

| 2 semester |

### Module level

| undergraduate |

### Other prerequisites

| -- |

### Contents

**A. Statistical Physics;**

0. Principles of statistics: Elements of statistics (central limit theorem and statistics of extremes); Micro- and macro-states; probability space (conditional probability, statistical independence);

1. Statistical Physics: Entropy and probability theory; entropy in classical physics; thermodynamic equilibrium in closed and open systems (with energy and / or particle exchange);

2. Ideal systems: Spin systems; linear oscillators; ideal gas;

3. Statistical Physics and thermodynamics: The 1st law; quasi-static processes; entropy and temperature; generalised forces; the second and third law; reversibility; transition from Statistical Physics to thermodynamics;

4. Thermodynamics: Thermodynamic fundamentals relationship; thermodynamic potentials; changes of state; thermodynamic machines (Carnot engine and efficiency); chemical potential;

5. Ideal Systems II, quantum statistics: Systems of identical particles; ideal Fermi gas; ideal Bose gas and Bose-Einstein condensation; grids and normal modes: Phonons;

6. Systems of interacting particles: Approximation methods (mean-field theory, Sommerfeld expansion); computer simulation (Monte Carlo method); interacting phonons (Debye approximation); Ising models (particularities in 1 and 2 dimensions); Yang-Lee-theorems; Van der Waals equation for real interacting gases;

7. Critical phenomena: Scaling laws, critical slowing down, fast variable as Bad (electron-phonon interaction and BCS superconductor); magnetism (quantum criticality at low temperatures, quantum phase transitions at $T = 0$); problems of the thermodynamic limit;

**B. Electrodynamics;**

0. Mathematical tools: Gradient, divergence, curl; curve, surface, volume integrals; Stokes and Gaussian sentence; Delta function; Fourier transform; full functional systems; solving PDEs;

1. Maxwell equations;

2. Electrostatics: Coulomb’s law; electrostatic potential; charged interface; electrostatic field energy (capacitor); multipole expansion; Boundary value problems; numerical solution; Image charges; Green’s functions; development according to orthogonal functions;

3. Magnetostatics: Current density; continuity equation; vector potential; Biot-Savart law; magnetic moment; analogies to electrostatics;

4. Maxwell equations in matter: Electrical and magnetic susceptibility; interfaces;

5. Dynamics of electromagnetic fields: Faraday induction; RCL-circuits; field energy and pulse; potentials; plane waves; wave packets; plane waves in matter; cavity resonators and wave guides; inhomogeneous wave equation; temporally oscillating sources and dipole radiation; accelerated point charges;

6. Special Theory of Relativity: Lorentz transform; simultaneity; length contraction and time dilation; light cone; effect, energy and momentum; co- and contra-variant tensors; covariant classical mechanics;

7. Covariant electrodynamics: Field strength tensor and Maxwell’s equations; transformation of the fields; Doppler effect; Lorentz force

### Intended learning outcomes

The students have advanced knowledge of the methods of Theoretical Physics. They know the principles of electrodynamics, thermodynamics and statistical mechanics. They are able to discuss the acquired theoretical concepts and to attribute them to bigger physical contexts.

### Courses

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

<p>| V (4) + V (4) |</p>
<table>
<thead>
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<th><strong>Method of assessment</strong> (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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<th><strong>Additional information</strong></th>
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<tr>
<td>Module title</td>
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<tr>
<td>Statistical Physics - Exercises</td>
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<td>Managing Director of the Institute of Theoretical Physics and Astrophysics</td>
<td>Faculty of Physics and Astronomy</td>
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<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</table>

**Contents**

Exercises in Statistical Physics and theoretical thermodynamics according to the content of 11 T-SEV content. Among others Principles of statistics, Statistical Physics, ideal systems, fundamental theorems, thermodynamic potentials, quantum statistics, Fermi and Bose gas, systems of interacting particles, approximation methods, Ising models, critical phenomena, etc.

**Intended learning outcomes**

The students are familiar with the mathematical methods of theoretical thermodynamics and Statistical Physics and are able to independently apply them to the description and solution of problems of Statistical Physics and to interpret the results in a physical manner.

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

| Ú (2) | Module taught in: Ú: German or English |

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

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

**Allocation of places**

- 

**Additional information**

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

-
**Module title** | **Abbreviation**  
---|---  
Electrodynamics - Exercises | 11-T-EA-152-m01  

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

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

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

**Contents**

Exercises in electrodynamics according to the content of 11 T-SEV. Among others, Mathematical tools, Maxwell’s equations, electrostatics, magnetostatics, Maxwell equations in matter, dynamic electromagnetic fields, electromagnetic waves, special relativity, covariant electrodynamics etc.

**Intended learning outcomes**

The students are familiar with the mathematical methods of theoretical electrodynamics and are able to independently apply them to the description and solution of problems of electrodynamics and to interpret the results in a physical manner.

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

Ü (2)
Module taught in: Ü: German or English

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

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

**Allocation of places**

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**Additional information**

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

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<tr>
<td>Advanced and Computational Data Analysis</td>
<td>11-P-FR2-152-m01</td>
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**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**
undergraduate

**Other prerequisites**
Students are highly recommended to complete module 11-P-FR1 prior to completing module 11-P-FR2.

**Contents**
Advanced methods of data analysis and error calculation. Distribution function, significance tests, modelling. Computerised data analysis.

**Intended learning outcomes**
The students have advanced knowledge of the analysis of measuring data and error calculation. They have mastered methods of computerised data analysis are able to apply them to self-obtained measuring data and to discuss the results.

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

V (1) + Ü (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)

Exercises (successful completion of approx. 50% of approx. 10 exercise sheets)
Assessment offered: Once a year, summer 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>Modelling and Computational Science</td>
<td>10-M-MWR-152-m01</td>
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<tr>
<td>Dean of Studies Mathematik (Mathematics)</td>
<td>Institute of Mathematics</td>
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</table>

**Contents**


**Intended learning outcomes**

The student masters the fundamental mathematical methods and techniques to simulate processes from natural and engineering sciences on a computer.

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

V (4) + Ü (2)

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

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

**Allocation of places**

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**Additional information**

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

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### Module title

**Introduction to Solid State Physics**

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<td>11-E-F-152-m01</td>
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### Module coordinator

Managing Director of the Institute of Applied Physics

### Module offered by

Faculty of Physics and Astronomy

### ECTS

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### Duration

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</table>

### Contents

1. The free-electron gas (FEG), free electrons; density of states; Pauli principle; Fermi-Dirac statistics; spec. heat, Sommerfeld coefficient; electrons in fields: Drude-Lorentz-Sommerfeld; electrical and thermal conductivity, Wiedemann-Franz law; Hall effect; limitations of the model
2. Crystal structure, periodic lattice; types of lattices; Bravais lattice; Miller indices; simple crystal structures; lattice defects; polycrystals; amorphous solids; group theoretical approaches, the importance of symmetry for electronic properties
3. The reciprocal lattice (RG), motivation: Diffraction; Bragg condition; definition; Brillouin zones; diffraction theory; Scattering; Ewald construction; Bragg equation; Laue’s equation; structure and form factor
4. Structure determination, probes: X-ray, electron, neutron; methods: Laue, Debye-Scherrer, rotating crystal; electron diffraction, LEED
5. Lattice vibrations (phonons), equations of motion; dispersion; group velocity; diatomic base: optical, acoustic branch; quantisation: Phonon momentum; optical properties in the infrared; dielectric function (Lorentz model); examples of dispersion curves (occ. Kramers-Kronig), measurement methods
6. Thermal properties of insulators, Einstein and Debye model; phonon density of states; anharmonicity and thermal expansion; thermal conductivity; Umklapp processes; crystal defects
7. Electrons in a periodic potential, Bloch theorem; band structure; approximation of nearly free electrons (NFE); strongly bound electrons (tight binding, LCAO); examples of band structures, Fermi surfaces, spin-orbit interaction
8. Superconductivity, BCS theory, pairing, coupling of bosonic and fermionic modes, band structure, many-particle aspects (quasiparticle concept)

### Intended learning outcomes

The students understand the basic contexts and principles of Solid-State Physics (bonding and structure, lattice dynamics, thermal properties, principles of electronic properties (free electron gas)). They understand the structure of solids and know the experimental methods and theoretical models for the description of phenomena of Solid-State Physics. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.

### Courses

<table>
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<th>(type, number of weekly contact hours, language — if other than German)</th>
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<td>V (4) + Ü (2)</td>
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Module taught in: Ü: German or English

### Method of assessment

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<td>written examination (approx. 120 minutes) Language of assessment: German and/or English</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
Nuclear and Elementary Particle Physics

### Abbreviation
11-E-T-152-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
undergraduate

### Other prerequisites
--

### Contents
1. Overview, historical introduction, history and significance of Nuclear and Particle Physics
2. Methods of Nuclear Physics, scattering and spectroscopy, nuclear radius, composition of matter, mass and charge distribution in the nucleus, the discovery of the proton and neutron
3. Nuclear models, the mass of the atomic nuclei, droplet model, bonding energy, nuclear shell model
4. Structure of cores, angular momentum, spin, parity, mag. and electr. moments, collective excitation forms, spin-orbit interaction
5. Radioactivity and spectroscopy, radioactive decay, natural and civilisational sources of ionising radiation
6. Nuclear energy, nuclear fission, nuclear reactors, nuclear fusion, star power, star development, formation of the chemical elements of hydrogen
7. Radiation and matter, interaction of radiation and matter, Bethe-Bloch formula, photoelectric effect, pair production
8. Instruments, accelerators and detectors
9. Electromagnetic interaction, differential cross section, virtual photons, Feynman graphs, exchange interaction
10. Strong interaction, quarks, gluons, colour and degree of freedom, deep-inelastic electron-proton scattering, confinement, asymptotic freedom, particle zoo, isospin, strangeness, SU (3) symmetry, antiprotons
11. Weak interaction, cracked mirror symmetries, Wu experiment, charge conjugation, time reversal, CP invariance, exchange particles, W and Z, neutrinos, neutrino vibrations
12. Standard model, three families of leptons and quarks, quark-lepton symmetry, Higgs boson, free parameters

### Intended learning outcomes
The students understand the basic connections between fundamental Nuclear and Elementary Particle Physics. They have an overview of the experimental observations of Particle Physics and the theoretical models which describe them.

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

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

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

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

### Allocation of places
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### Additional information
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### Referred to in LPO I
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<td>Group Theory</td>
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<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

**Contents**


**Intended learning outcomes**

The students know the basics of group theory, especially of Lie groups. They are able to identify problems of group theory and to solve them by using the acquired methods. They are able to apply group theory to the formulation and processing of physical problems.

**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 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)

--
### Module title
Computational Physics

### Abbreviation
11-CP-152-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
undergraduate

### Other prerequisites
--

### Contents
- Introduction to programming on the basis of C++ / Java /Mathematica
- numerical solution of differential equations
- simulation of chaotic systems
- generation of random numbers
- random walk
- many-particle processes and reaction-diffusion model

### Intended learning outcomes
The students have knowledge of two major programming languages and know algorithms important for Physics. They have knowledge of numerical standard methods and are able to apply computer-assisted processes to the solution of physical problems, e.g. algorithms for solving numerical problems of Physics.

### 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: 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)

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<td>Statistics, Data Analysis and Computer Physics</td>
<td>11-SDC-152-m01</td>
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<tbody>
<tr>
<td>1 semester</td>
<td>graduate</td>
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</table>

### Contents
Statistics, data analysis and computer physics.

### Intended learning outcomes
The students have specific and advanced knowledge in the field of statistics, data analysis and Computational Physics.

### Courses (type, number of weekly contact hours, language — if other than German)
V (2) + 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: 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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<td>Particle Physics (Standard Model)</td>
<td>11-TPS-152-m01</td>
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</table>

**Contents**

- Theoretical description of the Standard Model
- Electroweak symmetry breaking through the Higgs mechanism
- Parity Violation
- Bhabha scattering
- Z-Line Shape and forward / reverse asymmetry
- Higgs production and decay
- Experimental setup and results of key experiments to test the Standard Model and for determining its parameters
- Search for the Higgs boson

**Intended learning outcomes**

The students know the theoretical fundamental laws of the standard model of Particle Physics and the key experiments that have established and confirmed the standard model. They are able to interpret experimental or theoretical results in the framework of the standard model and know its validity and limits.

**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 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**

- --

**Additional information**

- --

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

- --
Module title          | Abbreviation
Preparatory Course Mathematics | 11-P-VKM-152-m01

Module coordinator | Module offered by
Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics | Faculty of Physics and Astronomy

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

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

Contents
Principles of mathematics and elementary calculation methods from school and partially beyond, especially for the introduction to and preparation for the modules of Experimental and Theoretical Physics.
1. Basic geometry and algebra
2. Coordinate systems and complex numbers
3. Vectors - vectored values
4. Differential calculus
5. Integral calculus

Intended learning outcomes
The students know the principles of mathematics and elementary calculation methods which are required for successfully studying Theoretical and Experimental Physics.

Courses (type, number of weekly contact hours, language — if other than German)
T (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) exercises (successful completion of approx. 50% of approx. 6 exercise sheets) or b) talk (approx. 15 minutes)
Assessment offered: Once a year, winter semester

Allocation of places
--

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)
## Computational Mathematics

<table>
<thead>
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<th>Module title</th>
<th>Abbreviation</th>
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<tbody>
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<td>Computational</td>
<td>10-M-COM-152-m01</td>
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<tr>
<td>Mathematics</td>
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<thead>
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<th>Module offered by</th>
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<tr>
<td>Dean of Studies Mathematik (Mathematics)</td>
<td>Institute of Mathematics</td>
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<th>Module level</th>
<th>Other prerequisites</th>
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<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</table>

### Contents

Introduction to modern mathematical software for symbolic computation (e.g. Mathematica or Maple) and numerical computation (e.g. Matlab) to supplement the basic modules in analysis and linear algebra (10-M-ANA-G and 10-M-LNA-G). Computer-based solution of problems in linear algebra, geometry, analysis, in particular differential and integral calculus; visualisation of functions.

### Intended learning outcomes

The student learns the use of advanced modern mathematical software packages, and is able to assess their fields of application to solve mathematical problems.

### Courses

<table>
<thead>
<tr>
<th>(type, number of weekly contact hours, language — if other than German)</th>
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<tr>
<td>V (1) + Ü (2)</td>
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### Method of assessment

- **project in the form of programming exercises (approx. 20 to 25 hours)**
- **Assessment offered**: Once a year, winter semester
- **Language of assessment**: German and/or English

### Allocation of places

- --

### Additional information

- --

### Referred to in LPO I

- (examination regulations for teaching-degree programmes)
- § 22 II Nr. 3 f)
<table>
<thead>
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<th>Module title</th>
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<td>Programming course for students of Mathematics and other subjects</td>
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<td>1 semester</td>
<td>undergraduate</td>
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</table>

**Contents**
Basics of a modern programming language (e.g. C).

**Intended learning outcomes**
The student is able to work independently on small programming exercises and standard programming problems in mathematics.

**Courses** (type, number of weekly contact hours, language — if other than German)
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)
Project in the form of programming exercises (approx. 20 to 25 hours)
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)
§ 22 II Nr. 3 f)
<table>
<thead>
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<th>Module title</th>
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<td>Mathematical Methods of Physics</td>
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<tbody>
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<td>Managing Director of the Institute of Theoretical Physics and Astrophysics</td>
<td>Faculty of Physics and Astronomy</td>
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<tr>
<td>2 semester</td>
<td>undergraduate</td>
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</table>

**Contents**

Principles of mathematics and basic calculation methods beyond the school curriculum, especially for the introduction to and preparation of the modules of Theoretical Physics and Classical or Experimental Physics.

**Intended learning outcomes**

The students have knowledge of the principles of mathematics and elementary calculation methods which are required in Theoretical and Experimental Physics.

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

- V (2) + Ü (1) + V (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) exercises (successful completion of approx. 50% of approx. 13 exercise sheets) or b) talk (approx. 15 minutes)

**Allocation of places**

- --

**Additional information**

- --

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

- § 53 I Nr. 1 a)
- § 77 I Nr. 1 a)
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<td>Electronic Circuits</td>
<td>11-EL-152-m01</td>
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<td>Faculty of Physics and Astronomy</td>
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<td>1 semester</td>
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**Contents**

Principles of electronic components and circuits. Analogous circuit technology: Passive (resistors, capacitors, coils and diodes) and active components (bipolar and field-effect transistors, operational amplifiers). Digital circuits: different types of gates and CMOS circuits. Microcontroller

**Intended learning outcomes**

The students have knowledge of the practical setup of electronic circuits from the field of analogous and digital circuit technology.

**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: 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)

--
**Module title**  
Laboratory and Measurement Technology

**Abbreviation**
11-LMT-152-m01

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

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

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<th>ECTS</th>
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<tr>
<td>1 semester</td>
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</table>

**Contents**

Introduction to electronic and optical measuring methods of physical metrology, vacuum technology and cryogenics, cryogenics, light sources, spectroscopic methods and measured value acquisition.

**Intended learning outcomes**

The students have competencies in the field of electronic and optical measuring methods of physical metrology, vacuum technology and cryogenics, cryogenics, light sources, spectroscopic methods and measured value acquisition.

**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: Once a year, winter 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 Catalogue for the Subject Physics

**Bachelor's with 1 major, 180 ECTS credits**

<table>
<thead>
<tr>
<th>Module title</th>
<th>Abbreviation</th>
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<tbody>
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<td>Seminar Experimental/Theoretical Physics</td>
<td>11-HS-152-m01</td>
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<th>Module coordinator</th>
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<td>Managing Directors of the Institute of Applied Physics and the Institute of Theoretical Physics and Astrophysics</td>
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<th>Other prerequisites</th>
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<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
<td>Admission prerequisite to assessment: regular attendance (minimum 85% of sessions).</td>
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</table>

**Contents**

Current issues of Theoretical/Experimental Physics.

**Intended learning outcomes**

The students have advanced knowledge of a specialist field of Experimental or Theoretical Physics. They are able to independently acquire this knowledge and to summarise it in an oral presentation.

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

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<tr>
<td>Module taught in:</td>
<td>German or English</td>
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</table>

**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)

**Allocation of places**

--

**Additional information**

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

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

--
Module title | Abbreviation
---|---
Experimental Chemistry | 08-AC-ExChem-152-m01

Module coordinator | Module offered by
lecturer of lecture "Experimentalchemie" (Experimental Chemistry) | Institute of Inorganic Chemistry

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<th>ECTS</th>
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Duration | Module level | Other prerequisites
1 semester | undergraduate | --

Contents
Basics of general and anorganic chemistry.

Intended learning outcomes
German intended learning outcomes available but not translated yet.
Kenntnis der Grundlagen der Allgemeinen und Anorganischen Chemie

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

Method of assessment (type, scope, language — if other than German, examination offered — if not every semester, information on whether module can be chosen to earn a bonus)
written examination (approx. 90 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>
<thead>
<tr>
<th>Module title</th>
<th>Abbreviation</th>
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<tr>
<td>General and Analytical Chemistry for students of natural sciences (lab)</td>
<td>08-ACP-NF-152-m01</td>
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<tbody>
<tr>
<td>holder of the Chair of Anorganic Chemistry</td>
<td>Institute of Inorganic Chemistry</td>
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<tr>
<td>1 semester</td>
<td>undergraduate</td>
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**Contents**

The module provides the opportunity to apply the knowledge of the introductory lectures in a practical course. After a safety introduction the students experiment independently in the laboratory. Focuses are laboratory safety, basic laboratory techniques, synthesis of basic compounds and analysis of an unknown compound.

**Intended learning outcomes**

The student is able to identify basic chemical issues and to solve them experimentally. Therefor he/she can carry out the necessary stoichiometric calculations and correctly outline the chemical processes written and verbal.

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

P (4)

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

Vortestate/Nachtestate (pre and post-experiment examination talks approx. 15 minutes each, log approx. 5 to 10 pages each) and assessment of practical performance (2 to 4 random examinations)

Assessment offered: Once a year, summer 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)

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<table>
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<tr>
<th><strong>Module title</strong></th>
<th><strong>Abbreviation</strong></th>
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<tbody>
<tr>
<td>Organic Chemistry for students of medicine, biomedicine, dental medicine and natural sciences</td>
<td>08-OC-NF-152-m01</td>
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<tbody>
<tr>
<td>lecturer of lecture &quot;Organische Chemie für Studierende der Medizin, Biomedizin, Zahnmedizin, Ingenieur- and Naturwissenschaften&quot;</td>
<td>Institute of Organic Chemistry</td>
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<td>1 semester</td>
<td>undergraduate</td>
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</table>

**Contents**

This module will provide students with an overview of organic chemistry.

**Intended learning outcomes**

German intended learning outcomes available but not translated yet.

Der/Die Studierende verfügt über grundlegendes Wissen im Bereich der Organischen Chemie.

**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)

written examination (approx. 60 minutes)
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
---|---
Optics and Quantum Physics | 11-E-OAV-152-m01

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

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

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

Contents

A. optics and quanta

1. Light (linked to 11-E-E): basic concepts, the speed of light, Huygens-Fresnel principle: reflection, refraction.
2. Light in matter: propagation velocity in the medium; dispersion, complex and frequency-dependent dielectric constant; absorption, Kramers-Kronig relation, interfaces, Fresnel equations, polarization, generation by absorption, birefringence, optical activity (dipole)
3. Geometrical optics: basic concepts, Fermat’s principle, optical path, planar interfaces, Snell’s law, total reflection, optical tunneling, evanescent waves, prism; normal and anomalous dispersion, curved interfaces, thin and thick lenses, lens systems, lens grinder formula, aberrations, imaging errors (spherical & chromatic aberration, astigmatism, coma, distortion, correction approaches).
4. Optical instruments: characteristics; camera, eye, magnifying glass, microscope, telescope types, bundle beam vs. image construction (electron lenses, electron microscope), confocal microscopy.
5. Wave optics: spatial and temporal coherence, Young’s double slit experiment, interference pattern (intensity profile), thin films, parallel layers, wedge-shaped layers, phase shift, Newton rings, interferometer (Michelson, Mach-Zender, Fabry-Perot).
6. Diffraction in the far field: Fraunhofer diffraction, single slit, intensity distribution, apertures, resolving power, Rayleigh & Abbé criterion, Fourier optics, optical grating, n-fold slit, intensity distribution, grating spectrometer and resolution, diffraction off atomic lattices, convolution theorem.
7. Diffraction in the near field: Fresnel, near-field diffraction at circular apertures/disks, Fresnel grating spectrometer and resolution, diffraction off atomic lattices, convolution theorem.
8. Failure of classical physics I - from light wave to photon: black body radiation and Planck’s quantum hypothesis; photoelectric effect and Einstein’s explanation, Compton effect, light as a particle, wave-particle duality, quantum structure of nature
9. Failure of classical physics II - particles as waves: de Broglie’s matter wave concept; diffraction of particle waves (Davison-Germer-experiment, double slit interference).
10. Wave mechanics: wave packets, phase and group velocity (recap of 11-EM), uncertainty principle, Nyquist-Shannon theorem, wave function as probability amplitude, probability of residence, measurement process in quantum mechanics (double-slit experiment & which-way information, collapse of the wave function, Schrödinger’s cat).
11. Mathematical concepts of quantum mechanics: Schrödinger equation as wave equation, conceptual comparison to wave optics, free particle and particles in a potential, time-independent Schrödinger equation as eigenvalue equation, simple examples in 1D (potential step, potential barrier and tunnel effect, box potential and energy quantization, harmonic oscillator), box potential in higher dimensions and degeneracy, formal theory of QM (states, operators, observables).

B. atomic and molecular physics

1. Structure of atoms: experimental evidence for the existence of atoms, size of the atom, charges and masses in the atom, isotopes, internal structure, Rutherford experiment, instability of the “classical” Rutherford atom


5. Fine and hyperfine structure: electronic spin and magnetic spin moment, Stern-Gerlach experiment, Einstein-de Haas effect, glimpse of the Dirac equation (spin as relativistic phenomenon and existence of antimatter), electron spin resonance (ESR), spin-orbit coupling, relativistic fine structure, Lamb shift (quantum electrodynamics), nuclear spin and hyperfine structure.


7. Light-matter interaction: time-dependent perturbation theory (Fermi’s Golden Rule) and optical transitions, matrix elements and dipole approximation, selection rules and symmetry, line broadening (lifetime, Doppler effect, collision broadening), atomic spectroscopy.

8. LASER: elementary optical processes (absorption, spontaneous and stimulated emission), stimulated emission as light amplification, Einstein’s rate equations, thermal equilibrium, non-equilibrium character of a laser: rate equations, population inversion, and laser condition, principle structure of a laser, optical pumping, 2-, 3- and 4-level lasers, examples (ruby laser, He-Ne laser, semiconductor laser).


11. Molecular rotations and vibrations: Born-Oppenheimer approximation, rigid rotator (symmetric and asymmetric molecules), centrifugal splitting/expansion, molecule as (an)harmonic oscillator, Morse potential, normal vibrational modes, vibrational-rotational interaction.


**Intended learning outcomes**

The students understand the basic principles and contexts of radiation, wave and quantum optics and quantum phenomena as well as Atomic and Molecular Physics. They understand the theoretical concepts and know the structure and application of important optical instruments and measuring methods. They understand the ideas and concepts of quantum theory and Astrophysics and the relevant experiments to observe and measure quantum phenomena. They are able to discuss their knowledge and to integrate it into a bigger picture.

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

V (4) + V (4)

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

oral examination of one candidate each (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>
<thead>
<tr>
<th>Module title</th>
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<tbody>
<tr>
<td>Optics and Waves - Exercises</td>
<td>11-E-OA-152-m01</td>
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<td>Managing Director of the Institute of Applied Physics</td>
<td>Faculty of Physics and Astronomy</td>
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<td>1 semester</td>
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</table>

**Contents**

Exercises in Optics according to the content of 11-E-OAV. Among others Basic concepts, Fermat's principle, optical path, light in matter, polarization, Geometrical Optics, Optical instruments, wave optics, interference, thin films, interferometers, Fraunhofer diffraction optical grating, Fresnel diffraction, holography, wave packets, wave equation and Schrödinger equation, quantum structure of nature, etc.

**Intended learning outcomes**

The students understand the basic principles and contexts of radiation, wave and quantum optics. They are able to apply mathematical methods to the formulation of physical contexts and autonomously apply their knowledge to the solution of mathematical-physical tasks.

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

Ü (2)
Module taught in: Ü: German or English

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

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

**Allocation of places**

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**Additional information**

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

§ 53 I Nr. 1 a)
§ 77 I Nr. 1 a)
## Module: Atoms and Quanta - Exercises

**Abbreviation:** 11-E-AA-152-m01

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

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

**ECTS:** 5

**Method of grading:** Numerical grade

**Duration:** 1 semester

**Module level:** Undergraduate

### Contents

Exercises in Atomic and Quantum Physics according to the contents of 11-E-OAV. Among others Structure of atoms, experimental fundamental laws of Quantum Physics, the Schrödinger equation, quantum mechanics of the hydrogen atom, atoms in external fields, multi-electron atoms, optical transitions and spectroscopy, laser, molecules and chemical bonding, molecular rotations and vibrations, etc.

### Intended learning outcomes

The students understand the basic principles and contexts of quantum phenomena as well as Atomic and Molecular Physics. They are able to mathematically formulate physical contexts of Atomic and Quantum Physics and to autonomously apply their knowledge to the solution of mathematical-physical tasks.

### Courses

- **Ü (2)**
  - Module taught in: Ü: German or English
  - **Method of assessment**: Written examination (approx. 120 minutes)
  - 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)

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Bachelor’s with 1 major Physics (2015)
### Module title
Mathematics 1 for Students of Physics and Nanostructure Technology

### Abbreviation
10-M-PHY1-152-m01

### Module coordinator
Dean of Studies Mathematik (Mathematics)

### Module offered by
Institute of Mathematics

### ECTS
<table>
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</table>

### Contents
Fundamentals on numbers and functions, sequences and series, differential and integral calculus in one variable, vector spaces, simple differential equations.

### Intended learning outcomes
The student gets acquainted with basic concepts of mathematics. He/She learns to apply these methods to simple problems in natural and engineering sciences, in particular in the fields of physics and nanostructure technology, and is able to interpret the results.

### Courses (type, number of weekly contact hours, language — if other than German)
V (5) + Ü (2)  
Module taught in: Ü: 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, usually chosen) or b) oral examination of one candidate each (approx. 20 minutes) or c) oral examination in groups (groups of 2, 15 minutes per candidate)
Language of assessment: 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**

Linear maps and systems of linear equations, matrix calculus, eigenvalue theory, differential and integral calculus in several variables, differential equations, Fourier analysis.

**Intended learning outcomes**

The student gets acquainted with fundamental concepts of advanced mathematics. He/She learns to apply these methods to simple problems in natural and engineering sciences, in particular in the field of physics and nanostructure technology, and is able to interpret the results.

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

V (5) + Ü (2)

Module taught in: Ü: 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, usually chosen) or b) oral examination of one candidate each (approx. 20 minutes) or c) oral examination in groups (groups of 2, 15 minutes per candidate)

Language of assessment: 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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# Module Catalogue for the Subject

## Physics

### Bachelor's with 1 major, 180 ECTS credits

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<td>Mathematics 3 for Students of Physics and related Disciplines (Differential Equations)</td>
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## Contents


1. Ordinary differential equations;
   1.1. Solution methods
   1.2 Existence and uniqueness theorem
   1.3 Systems of differential equations
2. Partial differential equations
   2.1 Non-linear partial differential equations of the 1st and 2nd order
   2.2 1D and 3D wave equation
   2.3 Helmholtz equation and potential theory
   2.4 Parabolic differential equations

## Intended learning outcomes

The students have basic mathematical knowledge of dynamic equations and solution methods for common and partial differential equations and have mastered the necessary calculation methods.

## Courses

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

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

## Method of assessment

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

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

## Allocation of places

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## Additional information

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

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Module title: Physics of Semiconductor Devices
Abbreviation: 11-SPD-152-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
Duration: 1 semester
Module level: undergraduate
Other prerequisites: --

Contents
Based on the fundamentals of Semiconductor Physics, the lecture provides an insight into semiconductor key technologies and discusses the main components in the fields of electronics and photonics on the basis of examples. The basic part introduces the crystal structures and band and phonon dispersions of technologically relevant semiconductors. The following part discusses the principles of charge transport involving non-equilibrium effects based on the charge carrier density of the thermal equilibrium. The part on technology gives an insight into the methods of production of semiconductor materials and presents the most important methods of planar technology. It discusses the way of functioning of the following components, sorted according to volume components, interface components and application fields: Rectifier diodes, Zener diodes, varistor, varactor, tunnel diodes, IMPATT, Baritt- and Gunn diodes, photodiode, solar cell, LED, semiconductor injection laser, transistor, JFET, Thyristor, Diac, Triac, Schottky diode, MOSFET, MESFET, HFET. It highlights the importance of low-dimensional charge carrier systems for technology and basic research and shows recent developments in the components sector.

Intended learning outcomes
The students know the characteristics of semiconductors, they have gained an overview of the electronic and phonon band structures of important semiconductors and the resulting electronic, optical and thermal properties. They know the principles of charge transport as well as the Poisson, Boltzmann and continuity equation for the solution of questions. They have gained insights into the methods of semiconductor production and are familiar with the theories of planar technology and recent developments in this field, they have a basic understanding of component production. They understand the structure and way of functioning of the main components of electronics (diode, transistor, field-effect transistor, thyristor, diac, triac), of microwave applications (tunnel, IMPATT, Baritt or Gunn diode) and of optoelectronics (photo diode, solar cell, light-emitting diode, semiconductor injection laser), they know the realisation possibilities of low-dimensional charge carrier systems on the basis of semiconductors and their technological relevance, they are familiar with current developments in the field of components.

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: 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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<tr>
<td>Module title</td>
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<tr>
<td>Semiconductor Lasers and Photonics</td>
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<td>Managing Director of the Institute of Applied</td>
<td>Faculty of Physics</td>
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<tr>
<td>Physics</td>
<td>and Astronomy</td>
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</table>

### Contents

This lecture discusses the principles of laser physics, based on the example of semiconductor lasers, and current developments regarding components. The principles of lasers are described on the basis of a general laser model, which will then be extended to special aspects of semiconductor lasers. Basic concepts such as threshold condition, characteristic curve and laser efficiency are derived from coupled rate equations for charge carriers and photons. Other topics of the lecture are optical processes in semiconductors, layer and ridge waveguides, laser resonators, mode selection, dynamic properties as well as technology for the generation of semiconductor lasers. The lecture closes with current topics of laser research such as quantum dot lasers, quantum cascade lasers, terahertz lasers or high-performance lasers.

### Intended learning outcomes

The students have advanced knowledge of the principles of semiconductor-laser physics. They can apply their knowledge to modern questions and know the applications in the current development of components.

### 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: 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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<td>Fundamentals of Semiconductor Physics</td>
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</table>

**Contents**

1. Symmetry properties
2. Crystal formation and electronic band structure
3. Optical excitations and their coupling effects
4. Electron-phonon coupling
5. Temperature-dependent transport properties
6. (Semi-)magnetic semiconductors

**Intended learning outcomes**

The students are familiar with the principles of Semiconductor Physics. They understand the structure of semiconductors and know their physical properties and effects. They know important applications.

**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: 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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### Module Catalogue for the Subject
Bachelor's with 1 major, 180 ECTS credits

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### Contents
Crystal growth, thin films, lithography.

### Intended learning outcomes
The students have knowledge of crystal growth and the techniques and methods to control crystal growth in the laboratory. They have methodological knowledge of the production and examination of thin layers and know techniques and applications of lithography.

### 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: 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)
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<td>Nanoanalytics</td>
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**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**
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**Contents**
- Principles of analytic procedures in the field of nanostructure physics, imaging techniques from a microscopic level up to an atomic level, examination of chemical composition, spectroscopy of electronic properties, usage of X-ray methods.
- Physics and material systems on the nanoscale.
- Secondary ions - mass spectrometry - X-ray methods: Synchrotron spectroscopy. Photoemission. X-ray absorption

**Intended learning outcomes**
The students have basic knowledge of modern research methods for different nanostructures up to an atomic level. They know microscoping procedures that are used in practice in labs and the industry as well as spectroscopic methods for the determination of electronic properties. They are able to evaluate the efficiency of different research methods.

**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: 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)
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Module title | Abbreviation
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Principles of Energy Technologies | 11-ENT-152-m01

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

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

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

Contents

Intended learning outcomes
The students know the principles of different methods of energy technology, especially energy conversion, transport and storage. They understand the structures of corresponding installations and are able to compare them.

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: 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)
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</tr>
</thead>
<tbody>
<tr>
<td>1 semester</td>
<td>undergraduate</td>
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</tbody>
</table>

**Contents**


**Intended learning outcomes**

The students have basic knowledge of the generation and interaction processes of different types of radiation (heat, X-ray, terahertz), particles (neutrons) or ultrasound waves with materials. They know the applied methods for the detection of radiation types, particles and ultrasound waves and are able to apply them to basic problems of material testing and characterisation.

**Courses**

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

V (2) + 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: 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)

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<table>
<thead>
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<tr>
<td>Laboratory and Measurement Technology in Biophysics</td>
<td>11-LMB-152-m01</td>
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<tr>
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<td>Faculty of Physics and Astronomy</td>
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</table>

**Contents**

The lecture covers relevant principles of molecular and cellular biology as well as the physical principles of biophysical procedures for the examination and manipulation of biological systems. The main topics are optical measuring techniques and sensors, methods of single-particle detection, special microscoping techniques and methods of structure elucidation of biomolecules.

**Intended learning outcomes**

The students know the principles of molecular and cellular biology as well as the physical principles of biophysical procedures for the examination and manipulation of biological systems. They have knowledge of optical measuring techniques and their applications and are able to apply techniques of structure elucidation to simple biomolecules.

**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: 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)

--
Module title
Mathematics 4 for Students of Physics and related Disciplines (Complex Analysis)
Abbreviation
11-M-F-152-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

Duration
1 semester

Only after succ. compl. of module(s)
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Module level
undergraduate

Contents
Fundamentals of functional analysis and function theory. Basic knowledge of functional analysis, which is needed in the course Quantum Mechanics I. The definition of Hilbert space explains quantum mechanical states as vectors. The non-visualised form of quantum mechanics, the depiction as wave function created through basic states and the Dirac bracket formalism make up an important part of the formal framework of quantum mechanics.

Part I: Functional analysis
1. Linear vector spaces
2. Metric, normed spaces
3. Linear operators
4. Function space, completion, Lebesgue integral, Hilbert space
5. Linear operators on the Hilbert space
6. Matrix representation of operators
7. Fourier transform
8. The Dirac delta function and its different presentations.

Part II: Complex function theory
1. Extension to complex numbers, the specificity of the point 'infinite', representation of the complex plane, stereographic projection on a sphere
2. Complex functions and ambiguity of branch points
3. Solving the n-fold ambiguity using Riemann surfaces and n additional indexes, n (Riemann) numbered sheets on which the function is definite. Branch cuts.
4. Singularities in the complex: Pole nth-order, branching points
5. Differentiation: Concept of analytic or holomorphic function, complex differentiability, Cauchy-Riemann differential equation
6. Complex integration and Cauchy integral theorem
7. Cauchy integral formula, implications
8. Laurent series versus Taylor series
9. Residue
10. Computing integrals and series
11. Analytical continuation
12. Meromorphic functions, all functions
13. Sets of Mittag-Leffler (Mittag-Leffler-development) and Weierstrass
14. Differential equations in the complex domain, general and simple solutions near singularities
15. Special functions: Gamma, beta and hypergeometric functions, their definitions, integral representation, differential equations, series expansion
16. The saddle-point method or 'method of steepest descent' with widespread applications in field theory, statistics, and complex integration, for example the Stirling formula

Intended learning outcomes
The students have basic mathematical knowledge and basic knowledge of the mathematics of Hilbert space and the theory of functions of a complex variable and have mastered the required calculation methods.

Courses (type, number of weekly contact hours, language — if other than German)
V (4) + Ü (2)
Module taught in: Ü: German or English
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<tr>
<td>Module title</td>
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<tr>
<td>Principles of two- and three-dimensional Röntgen imaging</td>
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<td>1 semester</td>
<td>graduate</td>
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</table>

### Contents

Physics of X-ray generation (X-ray tubes, synchrotron). Physics of the interaction between X-rays and matter (photon absorption, scattering), physics of X-ray detection. Mathematics of reconstruction algorithms (filtered rear projection, Fourier reconstruction, iterative methods). Image processing (image data pre-processing, feature extraction, visualisation, ...). Applications of X-ray imaging in the industrial sector (component testing, material characterisation, metrology, biology, ...). Radiation protection and biological radiation effect (dose, ...).

### Intended learning outcomes

The students know the principles of generating X-rays and of their interactions with matter. They know imaging techniques using X-rays and methods of image processing as well as application areas of these methods.

### 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: 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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<td>1 semester</td>
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</table>

**Contents**


**Intended learning outcomes**

The students know the principles of digital image and signal processing. They know the ways of functioning and applications of different image processing methods and are able to apply them in practice.

**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)

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: 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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Module title: Imaging Sensors in Infrared
Abbreviation: 11-ASI-152-m01

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

ECTS: 3
Method of grading: numerical grade
Duration: 1 semester
Module level: undergraduate

Contents:
Infrared cameras are important experimental and technical tools, e.g. for measuring temperatures. The spectral range of infrared ranges from the visible spectrum, where the Sun is dominating as the natural source of light, up to microwaves and radiowaves with artificial emitters. There is distinct and sometimes dominating emission from bodies with ambient temperature in the infrared spectrum. The lecture provides an introduction to the physical optics of this spectral range and discusses: Peculiarities of infrared cameras and thermal images, different types of sensors (bolometer, quantum well, superlattice) as well as the evaluation of such sensors on the basis of neurophysiological aspects.

Intended learning outcomes:
The students have specific and advanced knowledge in the field of infrared spectral imaging. They know various technologies and detector structures as well as their application areas.

Courses:
V (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).

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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)
Module title: Principles of Image Processing

Abbreviation: 11-EBV-152-m01

Module coordinator: Managing Director of the Institute of Applied Physics

Module offered by: Faculty of Physics and Astronomy

ECTS: 3

Method of grading: numerical grade

Duration: 1 semester

Module level: undergraduate

Other prerequisites: --

Contents:
Introduction to image processing. Pictures as two-dimensional signals; digitalisation. Two-dimensional Fourier transform. Histogram equalisation (e.g. image brightening) and pixel connectivity (e.g. noise reduction). Automatic image recognition: Segmentation, classification. Technological image generation. Applications (e.g. motion tracking). Three-dimensional images.

Intended learning outcomes:
The students have specific and advanced knowledge in the field of image processing. They know the principles and theory of signal processing for images and have corresponding knowledge of image generation. They are able to independently work with literature, they understand the characteristics of image processing with commercial software and are able to process images for the analysis of experiments with imaging measuring methods.

Courses:

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: 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
**Principles of Pattern Classification**

**Abbreviation**
11-KVM-152-m01

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

### Module offered by
Faculty of Physics and Astronomy

### ECTS
3

### Method of grading
numerical grade

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

### Duration
1 semester

### Module level
undergraduate

### Other prerequisites
--

## Contents
Signals such as images, but also acoustic records, spectra, electrical measurements often contain recurring patterns. These patterns are often classified and analysed by observers, e.g. by a doctor when analysing an ECG. More and more automatic procedures are adopted to take on these tasks and classify patterns. The lecture will discuss principles of different classifiers such as "minimum distance" and "maximum likelihood".

## Intended learning outcomes
The students have specific and advanced knowledge in the field of pattern recognition. They know methods of classifying patterns in measuring data as well as ways to automatise these processes. They are able to apply these methods to practical problems.

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

V (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: 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)
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### Module title
Introduction to Labview

### Abbreviation
11-LVW-152-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)

### Numerical grade
--

### Duration
1 semester

### Module level
graduate

### Other prerequisites
--

### Contents
The module comprises basic and advanced courses. The basic course "NI LabVIEW Basic 1" is the first level of each LabVIEW learning phase. LabVIEW Basic provides a systematic introduction to the functions and application fields of the development environment of LabVIEW. The students become acquainted with dataflow programming and with common LabVIEW architectures. They learn to develop LabVIEW applications for various application fields, from assessment and measurement applications up to data collection, device control, data recording and measurement analysis. In the advanced course "NI LabVIEW Core 2", the students learn to develop comprehensive standalone applications, including the graphical development environment LabVIEW. The course builds upon LabVIEW Basic 1 and provides an introduction to the most common development technologies, in order to enable the students to successfully implement and distribute LabVIEW applications for different application fields. Course topics include techniques and procedures for the optimisation of application performance, e.g. through an optimised reuse of existing codes, usage of file I/O functions, principles of data management, event computing and methods of error handling. After finishing the course, the students have the ability to apply LabVIEW functions according to individual requirements, which enables a fast and productive application development.

### Intended learning outcomes
The students have specific and advanced knowledge in the application field of LabVIEW. They know the principles of working with LabVIEW and are able to develop applications, e.g. for recording and analysing measuring data.

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

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: 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)
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<td>Selected Topics in Solid State Physics</td>
<td>11-CSF6-152-m01</td>
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<tr>
<td>chairperson of examination committee</td>
<td>Faculty of Physics and Astronomy</td>
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<td>undergraduate</td>
<td>Approval from examination committee required.</td>
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</table>

**Contents**

Selected topics of Solid-State Physics.

**Intended learning outcomes**

The students have basic knowledge of a specialist field of Solid-State Physics and understand the measuring and evaluation 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)

--
Module title: Fit for Industry

Abbreviation: 11-FFI-152-m01

Module coordinator: Managing Director of the Institute of Applied Physics

Module offered by: Faculty of Physics and Astronomy

ECTS: 3

Method of grading: numerical grade

Duration: 1 semester

Module level: undergraduate

Other prerequisites: --

Contents:
- Occupations for physicists. Occupations in the industrial sector and at universities.
- Orientation in the industrial environment. Product development.
- Income opportunities. Project management.
- Marketing, corporate strategy and management.
- Management tasks and soft skills.

Intended learning outcomes:
The students know about the requirements of jobs in the industry and are able to make decisions for their own future based on their knowledge.

Courses:
- V (1) + 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).
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Assessment offered: Once a year, summer semester
Language of assessment: German and/or English

Allocation of places: --

Additional information: --

Referred to in LPO I (examination regulations for teaching-degree programmes): --
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<td>Project Management in Practice</td>
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**Contents**

Technical project management in practice, contents: Definitions, terms, cardinal errors in project management, project schedule, kick-off and stakeholder, teams and resources, milestones and planning, visualisation and reporting, conflicts, success factors, technical and economic controlling, target agreement, balanced score cards, solving exemplary cases

**Intended learning outcomes**

The students have knowledge of technical project management. They are familiar with different methods and success factors and are able to define, plan and successfully conduct a project.

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

V (1) + 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**

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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: Laboratory Course Physics B (Classical Physics, Electricity, Circuits)

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<td>11-P-PB-152-m01</td>
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### Module Coordinator
Managing Director of the Institute of Applied Physics

### Module Offered by
Faculty of Physics and Astronomy

### ECTS
8 (not) successfully completed

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

### Duration
2 semester

### Module Level
Undergraduate

### Other Prerequisites
Students are highly recommended to complete modules 11-P-PA and 11-P-FR1 prior to completing module 11-P-PB.

### Contents
Physical laws of optics, vibrations and waves, science of electricity and circuits with electric components.

### Intended Learning Outcomes
The students know and have mastered physical measuring methods and experimenting techniques. They are able to independently plan and conduct experiments, to cooperate with others, and to document the results in a measuring protocol. They are able to evaluate the measuring results on the basis of error propagation and of the principles of statistics and to draw, present and discuss the conclusions.

### Courses
- P (2) + P (2)

### Method of Assessment
Preparation, performing and evaluating (record of readings or lab report) the experiments will be considered successfully completed if a Testat (exam) is passed. Exactly one experiment that was not successfully completed can be repeated once. After completion of all experiments, talk (with discussion; approx. 30 minutes) to test the candidate's understanding of the physics-related contents of the module. Talks that were not successfully completed can be repeated once. Both components of the assessment have to be successfully completed.

### 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 Catalogue for the Subject Physics

#### Bachelor's with 1 major, 180 ECTS credits

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<td>Advanced Laboratory Course Physics C (Modern Physics, Computer Aided Experiments)</td>
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<td>Students are highly recommended to complete module 11-P-PB prior to completing module 11-P-PC.</td>
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**Contents**

- Physical laws of wave optics, Molecular, Atomic and Nuclear Physics and modern measuring methods using special computerised devices with examples from optics and Solid-State Physics.

**Intended learning outcomes**

The students are able to build and almost independently operate advanced experimental setups. They are able to record measuring results in a structured manner, even in case of huge data traffic, and to analyse the results by using error propagation and statistics. They are able to evaluate results, to draw conclusions and to present and discuss them in a scientific paper and a presentation.

**Courses**

(P (2) + P (2))

**Method of assessment**

Preparing, performing and evaluating (record of readings or lab report) the experiments will be considered successfully completed if a Testat (exam) is passed. Exactly one experiment that was not successfully completed can be repeated once. After completion of all experiments, talk (with discussion; approx. 30 minutes) to test the candidate's understanding of the physics-related contents of the module. Talks that were not successfully completed can be repeated once. Both components of the assessment have to be successfully completed.

**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**

Astrophysical experiments in the fields of detectors, telescopes, methodology, analysis and astronomic observations.

**Intended learning outcomes**

The students have mastered experimental methods of Astrophysics and are able to analyse and interpret the measuring data and present the results. They are familiar with the working methods of observational Astronomy and with basic techniques of detecting electromagnetic radiation. They are able to plan and evaluate observations and measurements and to present the results.

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

P (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)

a) Preparing, performing and evaluating the experiments will be considered successfully completed if a Testat (exam) is passed. Experiments that were not successfully completed can be repeated once. Or b) discussion to test the candidate’s understanding of the physics-related contents and results of the experiment (approx. 20 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**

Principles of interaction between particles and matter. Particle detectors for space and time measurement, determination of momentum, energy and particle identification. Conception of particle detectors in examples.

**Intended learning outcomes**

The students know the physical principles and the basic structure of particle detectors. They know the functions and applications of different types of detectors, they can explain the measurement of physical values and have basic knowledge of the conception of detector systems.

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

V (2) + 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: 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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## Module Catalogue for the Subject Physics

Bachelor's with 1 major, 180 ECTS credits

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### Contents

Current topics of Experimental 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 Physics of the Bachelor's programme. They have knowledge of a current subdiscipline of Experimental Physics and understand the measuring and/or evaluation 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).

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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

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

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### Courses

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<tr>
<td>V (3) + R (1)</td>
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### 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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Current topics of Experimental 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 Physics of the Bachelor’s programme. They have knowledge of a current subdiscipline of Experimental Physics and understand the measuring and/or evaluation 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 (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)

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. 5 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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**Contents**

Current topics of 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 Theoretical Physics of the Bachelor’s programme. They have advanced specialist knowledge of a subdiscipline of Theoretical Physics and have mastered the required methods. They are able to apply the acquired methods to current problems of Theoretical Physics.

**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)

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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 of 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 Theoretical Physics of the Bachelor’s programme. They have advanced specialist knowledge of a subdiscipline of Theoretical Physics and have mastered the required methods. They are able to apply the acquired methods to current problems of Theoretical Physics.

**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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**Contents**

Current topics of 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 Theoretical Physics of the Bachelor’s programme. They have advanced specialist knowledge of a subdiscipline of Theoretical Physics and have mastered the required methods. They are able to apply the acquired methods to current problems of Theoretical Physics.

**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)

- 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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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**

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**Contents**

Selected topics of Astrophysics.

**Intended learning outcomes**

The students have basic knowledge of a current field of Astrophysics and understand the measuring and evaluation 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)

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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<table>
<thead>
<tr>
<th>Module title</th>
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<tr>
<td>Selected Topics in Particle Physics</td>
<td>11-CST6-152-m01</td>
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<tr>
<th>Module coordinator</th>
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<tbody>
<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>undergraduate</td>
<td>Approval from examination committee required.</td>
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</table>

**Contents**

Selected topics of Particle Physics.

**Intended learning outcomes**

The students have basic knowledge of a special field of Elementary Particle Physics and of the experimental or theoretical 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)

- 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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- 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
Selected Topics in Theoretical Physics

### Abbreviation
11-CSTh6-152-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
Undergraduate

### Other Prerequisites
Approval from examination committee required.

### Contents
Selected topics of Theoretical Physics.

### Intended Learning Outcomes
The students have basic knowledge of a special field of Theoretical Physics and have mastered the necessary mathematical methods. They are able to apply the acquired methods to current problems of Theoretical Physics.

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

### Method of Assessment
- Written examination (approx. 90 to 120 minutes) or oral examination of one candidate each (approx. 30 minutes)
- 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.

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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## General Competences for Physicists

**Abbreviation**: 11-BASQ5-152-m01

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</table>

### Contents

General competencies for physicists.

### Intended learning outcomes

The students have general competencies corresponding to the requirements of a module of Physics of the Bachelor's programme. They have knowledge of a current subdiscipline of Physics and of the required understanding of this topic. 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).

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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

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<td></td>
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**Contents**

Mostly independent processing of an experimental or theoretical task of Physics according to known procedures and scientific aspects.

**Intended learning outcomes**

The students are able to independently work on an experimental or theoretical task from Physics, especially according to known methods and scientific aspects and to write the Bachelor's 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)

Bachelor's thesis (approx. 25 pages)
Language of assessment: German 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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<tbody>
<tr>
<td>holder of the Chair of Computer Science II</td>
<td>Institute of Computer Science</td>
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**Contents**

Data types, control structures, foundations of procedural programming, selected topics of C, introduction to object orientation in Java, selected topics of C++, further Java concepts, digression: scripting languages.

**Intended learning outcomes**

The students possess a fundamental knowledge about programming languages (in particular Java, C and C++) and are able to independently develop average to high level Java programs.

**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).

**Allocation of places**

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**Additional information**

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**Contents**

No information on contents available.

**Intended learning outcomes**

No information on intended learning outcomes available.

**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 (programming exercises, approx. 120 hours) and written examination (approx. 30 to 60 minutes)

**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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