

Module No.:  
Credit Points (CP):  
Category:  
Semester:

physics610  
12  
Elective  
7.



# Module: Specialization I

## Module Elements:

| Nr.                                   | Course Title                                    | Number       | CP | Type        | Workload | Sem. |
|---------------------------------------|---|--------------|----|-------------|----------|------|
| <b>Particle Physics</b>               |   |              |    |             |          |      |
| 1.                                    | Particle Physics                                | physics611   | 6  | Lect. + ex. | 180 hrs  | WT   |
| 2.                                    | Accelerator Physics                             | physics612   | 6  | Lect. + ex. | 180 hrs  | WT   |
| 3.                                    | Physics of Particle Detectors                   | physics618   | 6  | Lect. + ex. | 180 hrs  | WT   |
| <b>Condensed Matter and Photonics</b> |   |              |    |             |          |      |
| 1.                                    | Condensed Matter Physics                        | physics613   | 6  | Lect. + ex. | 180 hrs  | WT   |
| 2.                                    | Condensed Matter Physics I                      | CondMatter I | 6  | Lect. + ex. | 180 hrs  | WT   |
| 3.                                    | Applied Photonics                               | physics619   | 6  | Lect. + ex. | 180 hrs  | WT   |
| 4.                                    | Advanced Atomic, Molecular, and Optical Physics | physics620   | 6  | Lect. + ex. | 180 hrs  | WT   |
| 5.                                    | Molecular Physics I                             | MolPhys I    | 6  | Lect. + ex. | 180 hrs  | WT   |
| <b>Theoretical Physics</b>            |   |              |    |             |          |      |
| 1.                                    | Theoretical Particle Physics                    | physics615   | 7  | Lect. + ex. | 210 hrs  | WT   |
| 2.                                    | Theoretical Hadron Physics                      | physics616   | 7  | Lect. + ex. | 210 hrs  | WT   |
| 3.                                    | Theoretical Condensed Matter Physics            | physics617   | 7  | Lect. + ex. | 210 hrs  | WT   |
| 4.                                    | Solid State Theory I                            | TheoSolidSt  | 6  | Lect. + ex. | 180 hrs  | WT   |

## Requirements:

### Preparation:

See with the description of the course

### Content:

Teaching of advanced fundamentals of physics from two research areas of physics in Bonn

### Aims/Skills:

The students will get acquainted with two research topics of today

### Form of Testing and Examination:

Requirements for the submodule examination (written or oral examination): successful work with exercises

**Length of Module:** 1 semester

**Maximum Number of Participants:** ca. 100

### Registration Procedure:

s. <https://basis.uni-bonn.de> u. <http://bamawww.physik.uni-bonn.de>

Note: The student must achieve 12 CP from two different specialization areas (Particle Physics; Condensed Matter and Photonics; Theoretical Physics)

# Module: Specialization I

Module No.: physics610

## Course: Particle Physics

Course No.: physics611

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

#### Preparation:

Introductory particle physics and quantum mechanics courses

#### Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

#### Length of Course:

1 semester

### Aims of the Course:

Understanding of the fundamentals of particle physics: properties of quarks and leptons and their interactions (electromagnetic, weak, strong), experiments that have led to this understanding, the Standard Model of particle physics and measurements that test this model, the structure of hadrons

### Contents of the Course:

Basics: leptons and quarks, antiparticles, hadrons, forces / interactions, Feynman graphs, relativistic kinematics, two-body decay, Mandelstam variables, cross-section, lifetime  
 Symmetries and Conservation Laws. Positronium, Quarkonium. Accelerators and Detectors  
 Electromagnetic interactions: (g-2) experiments, lepton-nucleon scattering  
 Strong interactions: colour, gauge principle, experimental tests of QCD. Electroweak interactions and the Standard Model of particle physics: spontaneous symmetry breaking, Higgs mechanism, experimental tests of the Standard Model. Neutrino physics, neutrino oscillations; CP violation

### Recommended Literature:

F Halzen, A. Martin; Quarks and Leptons (J. Wiley, Weinheim 1. Aufl. 1984)  
 C. Berger; Elementarteilchenphysik (Springer, Heidelberg 2. überarb. Aufl. 2006)  
 Perkins; Introduction to High Energy Physics (Cambridge University Press 4. Aufl. 2000)  
 D. Griffith; Introduction to Elementary Particle Physics (J. Wiley, Weinheim 1. Aufl. 1987)  
 A. Seiden; Particle Physics : A Comprehensive Introduction (2005)  
 Martin & Shaw; Particle Physics, Wiley (2nd edition, 1997)

# Module: Specialization I

Module No.: physics610

Course:  universität **bonn**

## Accelerator Physics

Course No.: physics612

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

### Preparation:

### Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

### Length of Course:

1 semester

### Aims of the Course:

Understanding of the functional principle of different types of particle accelerators  
 Layout and design of simple magneto-optic systems  
 Basic knowledge of radio frequency engineering and technology  
 Knowledge of linear beam dynamics in particle accelerators

### Contents of the Course:

Elementary overview of different types of particle accelerators: electrostatic and induction accelerators, RFQ, Alvarez, LINAC, Cyclotron, Synchrotron, Microtron  
 Subsystems of particle accelerators: particle sources, RF systems, magnets, vacuum systems  
 Linear beam optics: equations of motion, matrix formalism, particle beams and phase space  
 Circular accelerators: periodic focusing systems, transverse beam dynamics, longitudinal beam dynamics  
 Guided tours through the ELSA accelerator of the Physics Institute and excursions to other particle accelerators (COSY, MAMI, HERA, ...) complementing the lecture

### Recommended Literature:

F. Hinterberger; Physik der Teilchenbeschleuniger und Ionenoptik (Springer Heidelberg 1997)  
 H. Wiedemann; Particle Accelerator Physics (Springer, Heidelberg 2. Aufl. 1999)  
 K. Wille; Physik der Teilchenbeschleuniger und Synchrotronstrahlungsquellen (Teubner, Wiesbaden 2. Aufl. 1996)  
 D. A. Edwards, M.J. Syphers; An Introduction to the Physics of High Energy Accelerators, Wiley & Sons 1993)  
 Script of the Lecture "Particle Accelerators"  
<http://www-elsa.physik.uni-bonn.de/~hillert/Beschleunigerphysik/>

# Module: Specialization I

Module No.: physics610

## Course: Physics of Particle Detectors

Course No.: physics618

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

#### Preparation:

Useful: physik510

#### Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

#### Length of Course:

1 semester

### Aims of the Course:

Understanding the basics of the physics of particle detectors, their operation and readout

### Contents of the Course:

Physics of detectors and detection mechanisms, interactions of charged particles and photons with matter, ionization detectors, drift and diffusion, gas filled wire chambers, proportional and drift chambers, semiconductor detectors, microstrip detectors, pixel detectors, radiation damage, cerenkov detectors, transition radiation detectors, scintillation detectors (anorganic crystals and plastic scintillators), electromagnetic calorimeters, hadron calorimeters, readout techniques, VLSI readout and noise

### Recommended Literature:

Wermes: Skriptum and web-based Teaching Module

K. Kleinknecht; Detectors for Particle Radiation (Cambridge University Press 2nd edition 1998)

W.R. Leo; Techniques for Nuclear and Particle Detection (Springer, Heidelberg 2nd ed. 1994)

H. Spieler, Semiconductor detector system (Oxford University Press 2005)

L. Rossi, P. Fischer, T. Rohe, N. Wermes, Pixel Detectors: From Fundamentals to Applications (Springer 2006)

# Module: Specialization I

Module No.: physics610

Course:  universität**bonn**

## Condensed Matter Physics

Course No.: physics613

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

### Preparation:

### Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

### Length of Course:

1 semester

### Aims of the Course:

Understanding of the concepts of condensed matter physics

### Contents of the Course:

Crystallographic structures: Bravais lattices, Millers indices, crystallographic defects, structural analysis;  
Chemical bonds: van der Waals bond, covalent bond, hybridisation, ionic bond, metallic bond, Hydrogen bridge bond;

Lattice vibrations: acoustic and optical phonons, specific heat, phonon-phonon interaction;

Free electrons in the solid state: free electron gas, Drude model, Fermi distribution, specific heat of the electrons;

Band structure: metals, semiconductors, insulators, effective masses, mobility of charge carrier, pn-transition, basic principles of diodes, bipolar and unipolar transistors;

Superconductivity: basic phenomena, Cooper pairs, BSC-theory and its consequences;

Magnetic properties: diamagnetism, Langevin-theory of paramagnetism, Pauli-paramagnetism, spontaneous magnetic order, molecular field, Heisenberg-exchange;

Nuclear solid state physics: Hyperfine interaction, Mössbauer spectroscopy, perturbed angular correlation, positron annihilation, typical applications.

### Recommended Literature:

N. W. Ashcroft , N. D. Mermin , Solid State Physics ( Brooks Cole 1976) ISBN-13: 978-0030839931

N. W. Ashcroft , N. D. Mermin, Festkörperphysik (Oldenbourg 2001) ISBN-13: 978-3486248340

H. Ibach, H. Lüth, Solid-State Physics (Springer 2003) ISBN-13: 978-3540438700

H. Ibach, H. Lüth, Festkörperphysik (Springer 2002) ISBN-13: 978-3540427384

C. Kittel, Einführung in die Festkörperphysik (Oldenbourg 2006) ISBN-13: 978-3-486-57773-5

W. Demtröder, Experimentalphysik, Bd. 3. Atome, Moleküle und Festkörper (Springer 2005) ISBN-13: 978-3540214731

K. Kopitzki, P. Herzog Einführung in die Festkörperphysik (Vieweg+Teubner 2007) ISBN-13: 978-3835101449

L. Bergmann, C. Schaefer, R. Kassing, Lehrbuch der Experimentalphysik 6.: Festkörper (Gruyter 2005) ISBN-13: 978-3110174854

W. Buckel, R. Kleiner, Supraleitung (Wiley-VCH 2004) ISBN-13: 978-3527403486

# Module: Specialization I

Module No.: physics610

Course:



## Condensed Matter Physics I

Course No.:

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

#### Preparation:

Basic knowledge in condensed matter physics and quantum mechanics

#### Form of Testing and Examination:

Oral or written examination

#### Length of Course:

2 semesters

### Aims of the Course:

Comprehensive introduction to the basic principles of solid state physics and to some experimental methods. Examples of current research will be discussed.

### Contents of the Course:

The entire course (Condensed Matter I & II, given in 2 semesters) covers the following topics:

Crystal structure and binding

Reciprocal space

Lattice dynamics and thermal properties

Electronic structure (free-electron gas, Fermi surface, band structure)

Semiconductors and metals

Transport properties

Dielectric function and screening

Superconductivity

Magnetism

### Recommended Literature:

Skriptum (available during the course)

Ashcroft/Mermin: Solid State Physics

Kittel: Introduction to Solid State Physics

Ibach/Lüth: Festkörperphysik

# Module: Specialization I

Module No.: physics610

## Course: Applied Photonics

Course No.: physics619

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

### Preparation:

### Form of Testing and Examination:

Requirements for the examination (written or oral): successful work with the exercises

### Length of Course:

1 semester

### Aims of the Course:

To make the students understand physical and technological foundations of photonics and enable them to practically apply their knowledge in research and development.

### Contents of the Course:

Optics: Rays, Beams, Waves;

Waveguides, Fibers

Light sources; Detectors; Imaging devices

Optical amplification; Acoustooptics, electrooptics

Photonic circuits, optical communication

Optical Metrology (angle, distance, velocity, density...);

Material Processing (cutting, welding, lithography, lasers in medicine)

### Recommended Literature:

D. Meschede; Optik, Licht und Laser (Teubner, Wiesbaden 2. überarb. Aufl. 2005)

A. Yariv; Photonics: Optical Electronics in Modern Communications (Oxford Univ. Press 6th edition 2006)

B. Saleh, M. Teich; Fundamentals of Photonics (John Wiley & Sons, New York, 1991)

C. Yeh; Applied Photonics (Academic Press, 1994)

R. Menzel; Photonics (Springer, Berlin 2001)

# Module: Specialization I

Module No.: physics610

Course:  universität**bonn**

## Advanced Atomic, Molecular, and Optical Physics

Course No.: physics620

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

#### Preparation:

Fundamentals of Quantum Mechanics, Atomic Physics

#### Form of Testing and Examination:

Requirements for the examination (written or oral): successful work within the exercises

#### Length of Course:

1 semester

### Aims of the Course:

The aim of the course is to give the students a deeper insight to the field of atomic, molecular and optical (AMO) physics. Building on prior knowledge from the Bachelor courses it will cover advanced topics of atomic and molecular physics, as well as the interaction of light and matter.

### Contents of the Course:

Atomic physics: Atoms in external fields; QED corrections: Lamb-Shift; Interaction of light and matter: Lorentz oscillator, selection rules; magnetic resonance; Coherent control

Molecular physics: Hydrogen Molecule; Vibrations and rotations of molecules; Hybridization of molecular orbitals; Feshbach Resonances; Photoassociation; Cold Molecules

Bose Condensation; Matterwave Optics

### Recommended Literature:

C. J. Foot, Atomic Physics, Oxford University Press 2005

H. Haken, The physics of atoms and quanta, Springer 1996

S. Svanberg, Atomic and molecular spectroscopy basic aspects and practical applications, Springer 2001

W. Demtröder, Molecular Physics, Wiley VCH 2005

T. Buyana, Molecular physics, World Scientific 1997

W. Demtröder, Atoms, Molecules and Photons, Springer 2010

P. Meystre, Atom Optics, Springer 2010



# Module: Specialization I

Module No.: physics610

Course:



## Molecular Physics I

Course No.:

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

### Requirements:

#### Preparation:

Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics

#### Form of Testing and Examination:

Oral Examination

#### Length of Course:

1 semester

### Aims of the Course:

In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. Fundamental group theory is used to predict vibrational and rotational spectra of more complex molecules.

This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

### Contents of the Course:

- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

### Recommended Literature:

Bernath, "Spectra of Atoms and Molecules", Oxford University Press)  
 Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)  
 Gordy & Cook, "Microwave Spectra" (Wiley)  
 Engelke, "Aufbau der Moleküle" (Teubner)  
 P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition", ( NRC Research Press, Ottawa)

# Module: Specialization I

Module No.: physics610

## Course: Theoretical Particle Physics

Course No.: physics615

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+2            | 7  | WT       |

### Requirements:

#### Preparation:

Advanced quantum theory (physics606)

Quantum field theory (physics755)

Group theory (physics751)

#### Form of Testing and Examination:

Requirements for the examination (written): successful work with the exercises

#### Length of Course:

1 semester

### Aims of the Course:

Introduction to the standard model of elementary particle physics and its extensions (unified theories)

### Contents of the Course:

Classical field theory, gauge theories, Higgs mechanism;

Standard model of strong and electroweak interactions;

Supersymmetry and the supersymmetric extension of the standard model;

Grand unified theories (GUTs);

Neutrino physics;

Cosmological aspects of particle physics (dark matter, inflation)

### Recommended Literature:

T. P. Cheng, L.F. Li: Gauge theories of elementary particle physics (Clarendon Press, Oxford 1984)

M. E. Peskin, D.V. Schroeder; An introduction to quantum field theory (Addison Wesley, 1995)

J. Wess; J. Bagger; Supersymmetry and supergravity (Princeton University Press 1992)

# Module: Specialization I

Module No.: physics610

## Course: Theoretical Hadron Physics

Course No.: physics616

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+2            | 7  | WT       |

### Requirements:

#### Preparation:

Advanced quantum theory (physics606)

Quantum field theory (physics755)

Group theory (physics751)

#### Form of Testing and Examination:

Requirements for the examination (written): successful work with the exercises

#### Length of Course:

1 semester

### Aims of the Course:

Introduction to the theory of strong interaction, hadron structure and dynamics

### Contents of the Course:

Meson and Baryon Spectra: Group theoretical Classification, Simple Quark Models

Basics of Quantum Chromodynamics: Results in Perturbation Theory

Effective Field Theory

Bethe-Salpeter Equation

### Recommended Literature:

F. E. Close, An Introduction to Quarks and Partons (Academic Press 1980)

F. Donoghue, E. Golowich, B.R. Holstein; Dynamics of the Standard Model (Cambridge University Press 1994)

C. Itzykson, J.-B. Zuber; Quantum Field Theory (Dover Publications 2005)

S. Weinberg; The Quantum Theory of Fields (Cambridge University Press 1995)

**Module: Specialization I**

Module No.: physics610

**Course:**  universität**bonn****Theoretical Condensed Matter Physics**

Course No.: physics617

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+2            | 7  | WT       |

**Requirements:****Preparation:**

Advanced Quantum Theory (physics606)  
 Quantum Field Theory (physics755)  
 Group theory (physics751)

**Form of Testing and Examination:**

Requirements for the examination (written): successful work with the exercises

**Length of Course:**

1 semester

**Aims of the Course:**

Introduction to the theoretical standard methods and understanding important phenomena in the Physics of Condensed Matter

**Contents of the Course:**

Crystalline Solids: Lattice structure, point groups, reciprocal lattice  
 Elementary excitations of a crystal lattice: phonons  
 Electrons in a lattice; Bloch theorem, band structure  
 Fermi liquid theory  
 Magnetism  
 Symmetries and collective excitations in solids  
 Superconductivity  
 Integer and fractional quantum Hall effects

**Recommended Literature:**

N. W. Ashcroft, N.D. Mermin, Solid State Physics (Saunders College 1976)  
 P. M. Chaikin, T.C. Lubensky; Principles of Condensed Matter Physics (Cambridge University Press 1997)  
 W. Nolting; Grundkurs Theoretische Physik Band 7: Vielteilchentheorie (Springer, Heidelberg 2002)  
 Ch. Kittel; Quantentheorie der Festkörper (Oldenburg Verlag, München 3. Aufl. 1989)

**Module: Specialization I**

Module No.: physics610

**Course:****Solid State Theory I**

Course No.:

| Category | Type                   | Language | Teaching hours | CP | Semester |
|----------|------------------------|----------|----------------|----|----------|
| Elective | Lecture with exercises | English  | 3+1            | 6  | WT       |

**Requirements:****Preparation:**

training in theoretical physics at the B.Sc. level, experimental solid state physics

**Form of Testing and Examination:**

written or oral examination

**Length of Course:**

1 semester

**Aims of the Course:**

this course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

**Contents of the Course:**

The lecture investigates basic concepts to describe solids and their excitations. Various applications are discussed with emphasis on experimental and theoretical research directions of the physics department in Cologne.

**Recommended Literature:**

Ashcroft/ Mermin: "Solid State Physics"