

Module No.: physics610
 Credit Points (CP): 12
 Category: Elective
 Semester: 7.



Module: Specialization I

Module Elements:

Nr.	Course Title	Number	CP	Type	Workload	Sem.
Particle Physics						
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
Condensed Matter and Photonics						
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
Theoretical Physics						
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: universität  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:  **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"