

# 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.	Laser Physics and Nonlinear Optics	physics614	6	Lect. + ex.	180 hrs	WT
3.	Applied Photonics	physics619	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

## 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:**  universität**bonn****Laser Physics and Nonlinear Optics**

Course No.: physics614

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 laser physics and nonlinear optics and enable them to practically apply their knowledge in research and development.

Pivotal experiments will be shown during the lecture. The acquired knowledge will be dealt with in depth in the exercise groups. An additional offer: interested students may build and investigate a nitrogen laser device.

**Contents of the Course:**

Laser physics: advanced geometric optics and wave optics (ABCDmatrix, Gauss rays, wave guides). Light-matter interaction (spontaneous/ excited processes, inversion, light intensification). Principle of the laser; mode of operation and properties of lasers (standing wave-/ring laser, mode condition, hole burning). Continuous wave laser (gas, solid states), pulsed laser (Q-switching, mode coupling), optical properties of semiconductors, semiconductor laser; dynamic properties of laser light (Schawlow-Townes line width, chaotic laser radiation). Petawatt laser, white light laser, free electron laser, laser application in telecommunications, metrology and material processing;

Nonlinear Optics: Frequency doubling, sum-, difference frequency generation, parametric oscillators, phase matching (critical, non-critical, quasi), photorefraction, nonlinear Kerr effect, 4-wave mixing.

**Recommended Literature:**

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

F. K. Kneubühl; Laser (Teubner, Wiesbaden 6th edition 2005)

J. Eichler, H.J. Eichler; Laser (Springer, Heidelberg 5th edition 2003)

R. Boyd; Nonlinear Optics (Academic Press 2003)

R. Menzel; Photonics (Springer, Berlin 2001)

Y.-R. Shen; The principles of nonlinear optics (Wiley, New York (u.a.) 1984)

# 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: 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: 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)