University of Augsburg

Handbook of Modules

Master Program Materials Science

Faculty of Mathematics, Natural Sciences, and Materials Engineering

Examination regulations as of 20.11.2013

Valid Sommersemester 2018 - Printed 16.05.2018

Index by Groups of Modules

1) 1a Basics of Materials Science I

PHM-0144: Materials Physics (6 ECTS/LP, Wahlpflicht)..... 6

PHM-0110: Materials Chemistry (6 ECTS/LP, Wahlpflicht).....8

2) 1b Basics of Materials Science II

PHM-0117: Surfaces and Interfaces (6 ECTS/LP, Wahlpflicht)..... 10

PHM-0053: Chemical Physics I (6 ECTS/LP, Wahlpflicht).....12

3) 2 Methods in Materials Science

PHM-0224: Method Course: Theoretical Concepts and Simulation (8 ECTS/LP, Wahlpflicht) *..... 14

PHM-0171: Method Course: Coordination Materials (8 ECTS/LP, Wahlpflicht) *.....16

PHM-0147: Method Course: Electron Microscopy (8 ECTS/LP, Wahlpflicht).....18

PHM-0146: Method Course: Electronics for Physicists and Materials Scientists (8 ECTS/LP, Wahlpflicht) *.....20

PHM-0172: Method Course: Functional Silicate-analogous Materials (8 ECTS/LP, Wahlpflicht) *.....22

PHM-0148: Method Course: Optical Properties of Solids (8 ECTS/LP, Wahlpflicht) *..... 24

PHM-0149: Method Course: Methods in Biophysics (8 ECTS/LP, Wahlpflicht) *.....26

PHM-0151: Method Course: Porous Materials - Synthesis and Characterization (8 ECTS/LP, Wahlpflicht).....28

PHM-0221: Method Course: X-ray Diffraction Techniques (8 ECTS/LP, Wahlpflicht).....30

PHM-0235: Method Course: 2D Materials (8 ECTS/LP, Wahlpflicht) *..... 32

PHM-0153: Method Course: Magnetic and Superconducting Materials (8 ECTS/LP, Wahlpflicht) *..... 34

PHM-0154: Method Course: Modern Solid State NMR Spectroscopy (8 ECTS/LP, Wahlpflicht) *.....36

PHM-0206: Method Course: Infrared Microspectroscopy under Pressure (8 ECTS/LP, Wahlpflicht) *..... 38

PHM-0216: Method Course: Thermal Analysis (8 ECTS/LP, Wahlpflicht)..... 40

4) 3a Conducting and Presenting Scientific Work - Seminar

PHM-0158: Introduction to Materials (= Seminar) (4 ECTS/LP, Pflicht).....42

5) 3b Conducting and Presenting Scientific Work - Laboratory Project

PHM-0159: Laboratory Project (10 ECTS/LP, Pflicht)..... 43

6) 4 Materials Science - Major Topic

a) Physics of Materials

PHM-0051: Biophysics and Biomaterials (6 ECTS/LP, Wahlpflicht) *..... 44

PHM-0160: Dielectric and Optical Materials (6 ECTS/LP, Wahlpflicht) *..... 46

PHM-0059: Magnetism (6 ECTS/LP, Wahlpflicht) *..... 48

PHM-0048: Physics and Technology of Semiconductor Devices (6 ECTS/LP, Wahlpflicht) *..... 50

PHM-0049: Nanostructures / Nanophysics (6 ECTS/LP, Wahlpflicht)..... 52

b) Chemistry of Materials

PHM-0054: Chemical Physics II (6 ECTS/LP, Wahlpflicht) *..... 54

PHM-0161: Coordination Materials (6 ECTS/LP, Wahlpflicht) *..... 56

PHM-0113: Advanced Solid State Materials (6 ECTS/LP, Wahlpflicht)..... 58

PHM-0217: Advanced X-ray and Neutron Diffraction Techniques (6 ECTS/LP, Wahlpflicht) *..... 60

PHM-0114: Porous Functional Materials (6 ECTS/LP, Wahlpflicht)..... 62

PHM-0218: Novel Methods in Solid State NMR Spectroscopy (6 ECTS/LP, Wahlpflicht) *..... 64

c) Engineering of Materials

PHM-0164: Characterization of Composite Materials (6 ECTS/LP, Wahlpflicht) *..... 65

PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties (6 ECTS/LP, Wahlpflicht)..... 67

MRM-0052: Functional Polymers (6 ECTS/LP, Wahlpflicht) *..... 69

PHM-0122: Non-Destructive Testing (6 ECTS/LP, Wahlpflicht)..... 71

PHM-0168: Modern Metallic Materials (6 ECTS/LP, Wahlpflicht)..... 73

PHM-0196: Surfaces and Interfaces II: Joining processes (6 ECTS/LP, Wahlpflicht) *..... 75

7) 5 Materials Science Elective Topic (PO13)

PHM-0224: Method Course: Theoretical Concepts and Simulation (8 ECTS/LP, Wahlpflicht) *..... 77

PHM-0166: Carbon-based functional Materials (Carboterials) (6 ECTS/LP, Wahlpflicht)..... 79

PHM-0174: Theoretical Concepts and Simulation (6 ECTS/LP, Wahlpflicht)..... 81

PHM-0058: Organic Semiconductors (6 ECTS/LP, Wahlpflicht) *..... 83

PHM-0066: Superconductivity (6 ECTS/LP, Wahlpflicht)..... 85

PHM-0060: Low Temperature Physics (6 ECTS/LP, Wahlpflicht)..... 87

PHM-0114: Porous Functional Materials (6 ECTS/LP, Wahlpflicht)..... 89

PHM-0050: Electronics for Physicists and Materials Scientists (6 ECTS/LP, Wahlpflicht) *..... 91

PHM-0068: Spintronics (6 ECTS/LP, Wahlpflicht)..... 93

PHM-0057: Physics of Thin Films (6 ECTS/LP, Wahlpflicht)..... 95

PHM-0056: Ion-Solid Interaction (6 ECTS/LP, Wahlpflicht) *..... 97

PHM-0069: Applied Magnetic Materials and Methods (6 ECTS/LP, Wahlpflicht)..... 99

PHM-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons (6 ECTS/LP, Wahlpflicht) *..... 101

PHM-0051: Biophysics and Biomaterials (6 ECTS/LP, Wahlpflicht) *..... 103

PHM-0160: Dielectric and Optical Materials (6 ECTS/LP, Wahlpflicht) *..... 105

PHM-0059: Magnetism (6 ECTS/LP, Wahlpflicht) *..... 107

PHM-0048: Physics and Technology of Semiconductor Devices (6 ECTS/LP, Wahlpflicht) *..... 109

PHM-0049: Nanostructures / Nanophysics (6 ECTS/LP, Wahlpflicht)..... 111

PHM-0054: Chemical Physics II (6 ECTS/LP, Wahlpflicht) *..... 113

PHM-0161: Coordination Materials (6 ECTS/LP, Wahlpflicht) *..... 115

PHM-0113: Advanced Solid State Materials (6 ECTS/LP, Wahlpflicht)..... 117

PHM-0218: Novel Methods in Solid State NMR Spectroscopy (6 ECTS/LP, Wahlpflicht) *..... 119

PHM-0167: Oxidation and Corrosion (6 ECTS/LP, Wahlpflicht)..... 120

PHM-0164: Characterization of Composite Materials (6 ECTS/LP, Wahlpflicht) *..... 122

PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties (6 ECTS/LP, Wahlpflicht)..... 124

PHM-0165: Introduction to Mechanical Engineering (6 ECTS/LP, Wahlpflicht)..... 126

MRM-0052: Functional Polymers (6 ECTS/LP, Wahlpflicht) *..... 127

PHM-0168: Modern Metallic Materials (6 ECTS/LP, Wahlpflicht)..... 129

PHM-0196: Surfaces and Interfaces II: Joining processes (6 ECTS/LP, Wahlpflicht) *..... 131

PHM-0122: Non-Destructive Testing (6 ECTS/LP, Wahlpflicht)..... 133

PHM-0203: Physics of Cells (6 ECTS/LP, Wahlpflicht)..... 135

PHM-0217: Advanced X-ray and Neutron Diffraction Techniques (6 ECTS/LP, Wahlpflicht) *..... 137

PHM-0146: Method Course: Electronics for Physicists and Materials Scientists (8 ECTS/LP, Wahlpflicht) *..... 139

PHM-0147: Method Course: Electron Microscopy (8 ECTS/LP, Wahlpflicht)..... 141

PHM-0148: Method Course: Optical Properties of Solids (8 ECTS/LP, Wahlpflicht) * 143

PHM-0149: Method Course: Methods in Biophysics (8 ECTS/LP, Wahlpflicht) * 145

PHM-0151: Method Course: Porous Materials - Synthesis and Characterization (8 ECTS/LP, Wahlpflicht) 147

PHM-0153: Method Course: Magnetic and Superconducting Materials (8 ECTS/LP, Wahlpflicht) * 149

PHM-0154: Method Course: Modern Solid State NMR Spectroscopy (8 ECTS/LP, Wahlpflicht) * 151

PHM-0171: Method Course: Coordination Materials (8 ECTS/LP, Wahlpflicht) * 153

PHM-0172: Method Course: Functional Silicate-analogous Materials (8 ECTS/LP, Wahlpflicht) * 155

PHM-0206: Method Course: Infrared Microspectroscopy under Pressure (8 ECTS/LP, Wahlpflicht) * 157

PHM-0216: Method Course: Thermal Analysis (8 ECTS/LP, Wahlpflicht) 159

PHM-0221: Method Course: X-ray Diffraction Techniques (8 ECTS/LP, Wahlpflicht) 161

PHM-0234: 2D Materials (6 ECTS/LP, Wahlpflicht) * 163

PHM-0235: Method Course: 2D Materials (8 ECTS/LP, Wahlpflicht) * 165

8) 6 Finals

PHM-0169: Masterthesis (26 ECTS/LP, Pflicht) 167

PHM-0170: Colloquium (4 ECTS/LP, Pflicht) 168

Module PHM-0144: Materials Physics		6 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: • Electrons in solids • Phonons • Properties of metals, semiconductors and insulators • Application in optical, electronic, and optoelectronic devices • Dielectric solids, optical properties		
Learning Outcomes / Competences: • The students know the basic terms and concepts of solid state physics like the free electron gas, electronic band structure, charge carrier statistics, phonons, doping and optical properties, • are capable to apply derived approximations as the effective mass or the electron-hole concept to describe basic characteristics of semiconductor materials, • have the competence to apply these concepts for the description of electric, electro-optic and thermal properties of solids and to describe their functionalities, • understand size effects on material physical properties. • Integrated acquirement of soft skills: Working with specialist literature, literature search and interdisciplinary thinking.		
Remarks: compulsory module		
Workload: Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: basic knowledge of solid state physics		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Materials Physics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Electrons in solids: Free electron gas, band structure, effective mass
- Lattice dynamics: Phonons, phonon dispersion, acoustic and optical phonons
- Properties of metals: Electrical conductivity, Fermi surfaces, thermal properties
- Properties of semiconductors: Pure, intrinsic semiconductors, equilibrium conditions, doping
- Properties of dielectric materials: Propagation of electromagnetic waves, frequency dependent optical properties, polarization effects.
- Application in devices: Heterostructures, Schottky contact, pn-junction, solar cell, light emission and technological aspects

Literature:

- Hummel R. E. : Electronic Properties of Materials Springer 2001 (UP1000 H925)
- Burns G.: Solid State Physics Academic Press 1990 (UP1000 B967)
- Ashcroft N. W. , Mermin N.D. : Solid State Physics (UP1000 A 824)
- Kittel C. : Introduction to Solid State Physics (UP1000 K 62)

Part of the Module: Materials Physics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see module description

Examination

Materials Physics

written exam / length of examination: 90 minutes

Examination Prerequisites:

Materials Physics

Module PHM-0110: Materials Chemistry — 6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Henning Höppe

Contents:

- Revision of basic chemical concepts
- Solid state chemical aspects of selected materials, such as
  - Thermoelectrics
  - Battery electrode materials, ionic conductors
  - Hydrogen storage materials
  - Data storage materials
  - Phosphors and pigments
  - Ferroelectrics and Piezoelectrics
  - Heterogeneous catalysis
  - nanoscale materials

Learning Outcomes / Competences:
The students will

- be able to apply basic chemical concepts on materials science problems,
- broaden their ability to derive structure-property relations of materials combining their extended knowledge about symmetry-related properties, chemical bonding in solids and chemical properties of selected compound classes,
- be able to assess synthetic approaches towards relevant materials,
- acquire skills to perform literature research using online data bases.

Workload:
Total: 180 h
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:
The lecture course is based on the Bachelor in Materials Science courses Chemie I and Chemie III (solid state chemistry).

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Materials Chemistry

Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see description of module

Contents:
see description of module

Literature:

- A. R. West, Solid State Chemistry, John Wiley, Chichester.
- U. Müller, Inorganic Structural Chemistry, Wiley-VCH.
- R. Dronskowski, Computational Chemistry of Solid State Materials, Wiley VCH.
- Textbooks on Basics of Inorganic Chemistry such as J. E. Huheey, E. Keiter, R. Keiter, Anorganische Chemie, de Gruyter, or equivalents.
- Moreover, selected reviews and journal articles will be cited on the slides.

Part of the Module: Materials Chemistry (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

see associated lecture

Examination

Materials Chemistry

written exam / length of examination: 90 minutes

Examination Prerequisites:

Materials Chemistry

Module PHM-0117: Surfaces and Interfaces		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Siegfried Horn		
Contents: Introduction • The importance of surfaces and interfaces Some basic facts from solid state physics • Crystal lattice and reciprocal lattice • Electronic structure of solids • Lattice dynamics Physics at surfaces and interfaces • Structure of ideal and real surfaces • Relaxation and reconstruction • Transport (diffusion, electronic) on interfaces • Thermodynamics of interfaces • Electronic structure of surfaces • Chemical reactions on solid state surfaces (catalysis) • Interface dominated materials (nano scale materials) Methods to study chemical composition and electronic structure, application examples • Scanning electron microscopy • Scanning tunneling and scanning force microscopy • Auger – electron – spectroscopy • Photo electron spectroscopy		
Learning Outcomes / Competences: The students: • have knowledge of the structure, the electronical properties, the thermodynamics, and the chemical reactions on surfaces and interfaces, • acquire the skill to solve problems of fundamental research and applied sciences in the field of surface and interface physics, • have the competence to solve certain problems autonomously based on the thought physical basics. • Integrated acquirement of soft skills.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: The module "Physics IV - Solid State Physics" of the Bachelor of Physics / Materials Science program should be completed first.		
Frequency: each winter semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Surfaces and Interfaces
Mode of Instruction: lecture
Language: English
Frequency: annually
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:
- Ertl, Küppers: Low Energy Electrons and Surface Chemistry (VCH)
- Lüth: Surfaces and Interfaces of Solids (Springer)
- Zangwill: Physics at Surfaces (Cambridge)
- Feldmann, Mayer: Fundamentals of Surface and thin Film Analysis (North Holland)
- Henzler, Göpel: Oberflächenphysik des Festkörpers (Teubner)
- Briggs, Seah: Practical Surface Analysis I und II (Wiley)

Part of the Module: Surfaces and Interfaces (Tutorial)
Mode of Instruction: exercise course
Language: English
Frequency: annually
Contact Hours: 1

Examination
Surfaces and Interfaces
written exam / length of examination: 90 minutes
Examination Prerequisites:
Surfaces and Interfaces

Module PHM-0053: Chemical Physics I		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer		
Contents: • Basics of quantum chemical methods • Molecular symmetry and group theory • The electronical structure of transition metal complexes		
Learning Outcomes / Competences: The students: • know the basics of the extended-Hückel-method and the density functional theory, • know the basics of group theory, • are able to apply the knowledge gained through consideration of symmetry from vibration-, NMR-, and UV/VIS-spectroscopy, and • are able to interpret and predict the basical geometric, electronical and magnetical properties of transition metal complexes. • Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.		
Remarks: It is possible for students to do EHM calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.		
Workload: Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: It is recommended to complete the experiments FP11 (IR-spectroscopy) and FP17 (Raman-spectroscopy) of the module "Physikalisches Fortgeschrittenenpraktikum".		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Chemical Physics I **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Basics of quantum chemical methods
  - Extended Hueckel method (EHM)
  - Modern quantum chemical methods of chemical physics
  - Application: exemplary calculations and interpretation of simple electronical structures
- Molecular symmetry and group theory
  - Symmetry operations and matrix transformations
  - Point groups
  - Reducible and irreducible representations
  - Character tables
  - Application: infrared- and raman-spectroscopy, NMR-spectroscopy
- The electronical structure of transition metal complexes
  - Ligand field theory and angular-overlap model (AOM)
  - The physical basics of the spectrochemical series
  - Molecular orbital theory of transition metal complexes
  - Application: UV/VIS-spectroscopy, molecular magnetism

Literature:

- J. Reinhold, Quantentheorie der Moleküle (Teubner)
- H.-H. Schmidtke, Quantenchemie (VCH)
- D. C. Harris und M. D. Bertolucci, Symmetry and Spectroscopy (Dover Publications)
- D. M. Bishop, Group Theory and Chemistry (Dover Publications)
- J. K. Burdett, Chemical Bonds: A Dialog (Wiley)
- F. A. Kettle, Physical Inorganic Chemistry (Oxford University Press)
- A. Frisch, Exploring Chemistry with Electronic Structure Methods (Gaussian Inc. Pittsburg, PA)

Part of the Module: Chemical Physics I (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Chemical Physics I

written exam / length of examination: 90 minutes

Examination Prerequisites:

Chemical Physics I

Module PHM-0224: Method Course: Theoretical Concepts and Simulation *Method Course: Theoretical Concepts and Simulation*	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Liviu Chioncel

Contents:
This module covers Monte-Carlo methods (computational algorithms) for classical and quantum problems. Python as programing language will be employed. The following common applications will be discussed:

- Monte-Carlo integration, stochastic optimization, inverse problems
- Feynman path integrals: the connection between classical and quantum systems
- Oder and disorder in spin systems, fermions, and boson

Learning Outcomes / Competences:
- The students are capable of obtaining numerical solutions to problems too complicated to be solved analytically
- The students are able to present (graphically), discuss and analyze the results
- The students gain experience in formulatind and carrying out a collaborative project

Remarks:
The number of students will be limited to 8.

Workload:
Total: 240 h
90 h preparation of presentations (self-study)
60 h preparation of written term papers (self-study)
60 h studying of course content (self-study)
90 h (attendance)

Conditions:	**Credit Requirements:**
Knowledge of the programming language Phython is expected on the level taught in the modul PHM-0041. Requirements to understand basic concepts in physics: Classical Mechanics (Newton, Lagrange), Electrodynamics, Thermodynamics and Quantum Mechanics.	Bestehen der Modulprüfung

Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Theoretical Concepts and Simulation
Mode of Instruction: lecture
Language: English / German
Contact Hours: 2

Contents:
Concepts of classical and quantum statistical physics:

- the meaning of sampling, random variables, ergodicity
- equidistribution, pressure, temperature
- path integrals, quantum statistics, enumeration, cluster algorithms

Literature:
1. Werner Krauth, Algorithms and Computations (Oxford University Press, 2006)
2. R. H. Landau, A Survey of Computational Physics (Princeton Univ. Press, 2010)

Assigned Courses:

Method Course: Theoretical Concepts and Simulation (lecture)

Part of the Module: Method Course: Theoretical Concepts and Simulation (Practical Course)
Mode of Instruction: internship
Language: English / German
Contact Hours: 4

Contents:
see above

Literature:
see above

Assigned Courses:

Method Course: Theoretical Concepts and Simulation (Practical Course) (internship)

Examination
Method Course: Theoretical Concepts and Simulation
report / work period for assignment: 4 weeks
Description:
The requirement for the credit points is based on a programming project carried out in a team of 2-3 students. The final report contains the formulation and a theoretical introduction into the problem, the numerical implementation, and the presentation of the results.

Module PHM-0171: Method Course: Coordination Materials	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer
Dr. Hana Bunzen

Contents:

1. Synthesis of metal complexes:
2. Analytical characterization of metal complexes (thermal analysis, UV/vis spectroscopy, IR spectroscopy, X-ray diffraction)
3. Material composition and stability studies
4. Functional coordination materials (spin-crossover materials, oxygen-carrying materials)

Learning Outcomes / Competences:
The students will learn how to:

- prepare transition metal complexes employing modern preparation techniques (e.g. microwave synthesis), inert synthesis conditions (Schlenk technique),
- characterize coordination compounds by selected analytical techniques,
- develop functional coordination materials based on organic / inorganic hybrid compounds,
- employ X-ray diffraction methods for structural analysis.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
120 h lecture and exercise course (attendance)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)

Conditions:		**Credit Requirements:**
none		written report (protocols)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Coordination Materials (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Coordination Materials (Practical Course) (internship)

Part of the Module: Method Course: Coordination Materials (Seminar)
Mode of Instruction: seminar
Language: English
Contact Hours: 2

Literature:

- Chemical databases
- Primary literature

Assigned Courses:

Method Course: Coordination Materials (Seminar) (seminar)

Examination

Method Course: Coordination Materials (Seminar)

seminar

Examination Prerequisites:

Method Course: Coordination Materials (Seminar)

Module PHM-0147: Method Course: Electron Microscopy		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
Contents: 1. Scanning electron microscopy (SEM) 2. Transmission electron microscopy (TEM)		
Learning Outcomes / Competences: The students: • get introduced to the basics of scanning electron microscopy and transmission electron microscopy, using lectures to teach the theoretical basics, which are afterwards deepened using practical courses, • are able to characterize materials using different electron microscopy techniques and to decide, if the technique is feasible for a certain problem.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h 150 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
Conditions: Recommended: knowledge of solid-state physics, reciprocal lattice		**Credit Requirements:** regular participation, oral presentation (10 min), written report (one report per group)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Method Course: Electron Microscopy **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 2

Contents:

SEM:

1. Layout of Electron Microscopes and Electron Optical Components
2. Electron Solid Interactions
3. Contrast Formation in Scanning Electron Microscopy (SEM)
4. SE/BSE contrast
5. Electron Back Scattering Diffraction (EBSD)
6. Analytical techniques
7. Special Applications of SEM

TEM:

1. TEM specimen preparation techniques
2. Components of a TEM, principle lens design, lens aberrations
3. Electron diffraction: fundamentals
4. Contrast formation at bright field, dark field, weak beam dark field, and many beam conditions, „chemical“ imaging
5. Bright field, dark field, weak beam dark field imaging of dislocations
6. Kinematical theory of electron wave propagation in crystals
7. Howie Whelan equations, contrast of defects
8. High resolution TEM, lattice imaging of crystals
9. Advanced diffraction techniques: Kikuchi patterns, HOLZ lines and Convergent Beam Diffraction (CBED)
10. Image simulation
11. Analytical TEM: Electron energy loss spectroscopy & energy filtered TEM

Literature:

- D.B.Williams and C.B.Carter, Transmission Electron Microscopy,Plenum Press, New York/London, 1996
- M.A. Hirsch, A. Howie, R. Nicholson, D.W. Pashley, M.J. Whelan, Electron microscopy of thin crystals, Krieger Publishing Company, Malabar (Florida), 1977
- L. Reimer, Transmission electron microscopy, Springer Verlag, Berlin/Heidelberg/New York, 1984
- P.J. Goodhew, Thin foil preparation for electron microscopy,Elsevier, Amsterdam, 1985
- P.R. Buseck, J.M. Cowley, L. Eyring, High-resolution transmission electron microscopy, Oxford University Press, 1988
- E. Hornbogen, B. Skrotzki, Werkstoff-Mikroskopie, Springer Verlag, Berlin/Heidelberg/New York, 1995
- K. Wetzig, In situ scanning electron microscopy in materials research, Akad.-Verl., 1995
- J. I. goldstein, Scanning electron microscopy and x-ray microanalysis, Plenum Press, 1992
- L. Reimer, Scanning electron microscopy, Springer Verlag, 1985
- S. L. Flegler, J. W. Heckman, K. L. Klomparens, Elektronenmikroskopie, Spektrum, Akad. Verl., 1995

Part of the Module: Method Course: Electron Microscopy (Practical Course)

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Examination

Method Course: Electron Microscopy

report

Examination Prerequisites:

Method Course: Electron Microscopy

Module PHM-0146: Method Course: Electronics for Physicists and Materials Scientists *Method Course: Electronics for Physicists and Materials Scientists*	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Andreas Hörner

Contents:

1. Basics in electronic and electrical engineering [4]
2. Quadrupole theory [2]
3. Analog technique, transistor and opamp circuits [5]
4. Boolean algebra and logic [4]
5. Digital electronics and calculation circuits [6]
6. Microprocessors and Networks [4]
7. Basics in Electronic [8]
8. Implementation of transistors [8]
9. Operational amplifiers [8]
10. Digital electronics [8]
11. Practical circuit arrangement [8]

Learning Outcomes / Competences:
The students:

- know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the laboratory,
- have skills in easy circuit design, measuring and control technology, analog and digital electronics,
- have expertise in independent working on circuit problems. They can calculate and develop easy circuits.

Remarks:
ELECTIVE COMPULSORY MODULE

Attendance in the **Method Course: Electronics for Physicists and Materials Scientists (combined lab course AND lecture)** excludes credit points for the lecture **Electronics for Physicists and Materials Scientists.**

Workload:
Total: 240 h
140 h studying of course content using provided materials (self-study)
100 h lecture and exercise course (attendance)

Conditions: none		**Credit Requirements:** written report (one per group)
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 7	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Electronics for Physicists and Materials Scientists
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Literature:

- Paul Horowitz: The Art of Electronics (Cambridge University Press)
- National Instruments: MultiSim software package (available in lecture)

Assigned Courses:

Method Course: Electronics for Physicists and Materials Scientists (lecture)

Part of the Module: Method Course: Electronics for Physicists and Materials Scientists (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 3

Assigned Courses:

Method Course: Electronics for Physicists and Materials Scientists (Practical Course) (internship)

Examination
Method Course: Electronics for Physicists and Materials Scientists
oral exam / length of examination: 30 minutes
Examination Prerequisites:
Method Course: Electronics for Physicists and Materials Scientists

Module PHM-0172: Method Course: Functional Silicate-analogous Materials		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Henning Höppe		
Contents: Synthesis and characterization of functional materials according to the topics: 1. Silicate-analogous compounds 2. Luminescent materials / phosphors 3. Pigments 4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis		
Learning Outcomes / Competences: The students will know how to: • develop functional materials based on silicate-analogous materials, • apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules), • work under non-ambient atmospheres (e.g. reducing, inert conditions), • solve and refine crystal structures from single-crystal data, • describe and classify these structures properly.		
Remarks: **ELECTIVE COPULSORY MODULE**		
Workload: Total: 240 h 120 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: Recommended: attendance to the lecture "Advanced Solid State Materials"		**Credit Requirements:** written report (protocol)
Frequency: each semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course) **Mode of Instruction:** laboratory course **Language:** English **Contact Hours:** 6
Learning Outcome: The students will know how to: • develop functional materials based on silicate-analogous materials, • apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules), • work under non-ambient atmospheres (e.g. reducing, inert conditions), • solve and refine crystal structures from single-crystal data, • describe and classify these structures properly.

Contents:

Synthesis and characterization of functional materials according to the topics:

1. Silicate-analogous compounds
2. Luminescent materials / phosphors
3. Pigments
4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis

Assigned Courses:

Method Course: Functional Silicate-analogous Materials (Practical Course) (internship)

Examination

Method Course: Functional Silicate-analogous Materials

seminar

Examination Prerequisites:

Method Course: Functional Silicate-analogous Materials

Module PHM-0148: Method Course: Optical Properties of Solids *Method Course: Optical Properties of Solids*	8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer	

Contents:

Electrodynamics of solids

- Maxwell equations
- Electromagnetic waves
- Refraction and interference, Fresnel equations

FTIR spectroscopy

- Fourier transformation
- Michelson-Morley and Genzel interferometer
- Sources and detectors

Terahertz Time Domain spectroscopy

- Generation of pulsed THz radiation
- Gated detection, Austin switches

Elementary excitations in solid materials

- Rotational-vibrational bands
- Infrared-active phonons
- Interband excitations
- Crystal-field excitations

Learning Outcomes / Competences:

The students:

- get to know the basic principles of far-infrared spectroscop and terahertz time-domain-spectroscopy,
- learn about fundamental physical excitations in condensed matter that can be studied by these methods,
- learn to plan and carry out complex experiments,
- learn how to evaluate and analyze optical data.

Remarks:

Workload:

Total: 240 h
90 h lecture and exercise course (attendance)
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)

Conditions:	**Credit Requirements:**
Recommended: basic knowledge in solid-state physics, basic knowledge in electrodynamics and optics	written report

Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Optical Properties of Solids
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Literature:
Mark Fox, Optical Properties of Solids, Oxford Master Series

Assigned Courses:

Method Course: Optical Properties of Solids (lecture)

Part of the Module: Method Course: Optical Properties of Solids (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Optical Properties of Solids (Practical Course) (internship)

Examination
Method Course: Optical Properties of Solids
report
Examination Prerequisites:
Method Course: Optical Properties of Solids

Module PHM-0149: Method Course: Methods in Biophysics

8 ECTS/LP

Method Course: Methods in Biophysics

Version 1.0.0 (since SoSe15)
Person responsible for module: Dr. Stefan Thalhammer

Contents:

Unit radiation biophysics

- Concepts in radiation protection
- Low-dose irradiation biophysics
- DNA repair dynamics of living cells after ionizing radiation
- Confocal scanning laser microscopy

Unit microfluidic

- Microfluidic systems
- Accoustic driven microfluidics
- Calculation of microfluidic problems

Unit analysis

Learning Outcomes / Competences:

The students:

- know basic terms, concepts and phenomena in radiation biophysics,
- acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic analytical systems,
- learn skills in tissue culture and immun-histochemical staining procedures,
- learn skills in fluorescence and confocal scanning microscopy,
- learn skills to calculate fluidic problems on small length scales,
- learn skills to handle microfluidic channel systems.

Remarks:

ELECTIVE COMPULSORY MODULE

The course will partly take place at the Helmholtz Center Munich.

Workload:

Total: 240 h

Conditions:		**Credit Requirements:**
Attendance of the lecture "Biophysics and Biomaterials"		1 written lab report
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Methods in Biophysics

Mode of Instruction: lecture
Language: English
Contact Hours: 2

Assigned Courses:

Method Course: Methods in Biophysics (lecture)

Part of the Module: Method Course: Methods in Biophysics (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Literature:

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strah-lenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle und R. Zengerle, Microfluidic platforms for lab-on-a-chip applica-tions, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- Lecture notes

Assigned Courses:

Method Course: Methods in Biophysics (Practical Course) (internship)

Examination
Method Course: Methods in Biophysics
report
Examination Prerequisites:
Method Course: Methods in Biophysics

Module PHM-0151: Method Course: Porous Materials - Synthesis and Characterization	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:
Synthesis of porous functional materials (e.g. aerogels, mesoporous silica materials, zeolites, Metal-Organic Frameworks)

Characterization methods

- Structure and composition (XRD, UV/VIS, IR, ESEM, EDX)
- Thermal analysis (TGA)
- Adsorption and diffusion (BET, pore size distribution, pulse chemisorption)
- Catalytic properties (GC/MS, TPO, TPR)

Learning Outcomes / Competences:
The students will learn how to

- use modern solid state preparation techniques (e.g. hydrothermal, solvothermal, microwave synthesis),
- employ analytical methods dedicated to porous materials.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
120 h internship / practical course (attendance)
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions:	**Credit Requirements:**
Recommended: lecture Functional Porous Materials	written report (editing time 3 weeks) + written exam Please note that final grade of the Method Course consists of the maximum point score of of the exam and the grade of the report of the practical part which are weighted (40:60).

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Porous Materials Synthesis and Characterization (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Examination

Method Course: Porous Materials Synthesis and Characterization

written exam / length of examination: 45 minutes

Examination Prerequisites:

Method Course: Porous Materials Synthesis and Characterization

Module PHM-0221: Method Course: X-ray Diffraction Techniques	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Wolfgang Scherer
PD Dr. Georg Eickerling

Contents:
Subjects of the practical training and the accompanying lecture are the theoretical basics and the practical application of X-ray diffraction techniques:

Data collection and reduction techniques

Symmetry and space group determination

Structural refinements:
• The Rietveld method
• Difference Fourier synthesis

Structure determination:
• Patterson method
• Direct methods

Interpretation of structural refinement results

Errors and Pitfalls: twinning and disorder

Learning Outcomes / Competences:
The students:

- gain basic practical knowledge on structural characterization methods for single- and poly-crystalline samples employing X-ray diffraction techniques,
- have the skill to perform under guidance phase-analyses and X-ray structure determinations
- are competent to analyze hands-on the structure-property relationships of new materials

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
90 h lecture and exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)
30 h studying of course content using provided materials (self-study)

Conditions: none		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: X-ray Diffraction Techniques
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Part of the Module: Method Course: X-ray Diffraction Techniques (Practical Course)
Mode of Instruction: laboratory course
Language: German
Contact Hours: 4

Examination
Method Course: X-ray Diffraction Techniques
written exam / length of examination: 90 minutes

Module PHM-0235: Method Course: 2D Materials *Method Course: 2D Materials*	8 ECTS/LP
Version 1.0.1 (since SoSe18) Person responsible for module: Prof. Dr. Hubert J. Krenner	

Contents:

1. Fabrication of monolayers of 2D Materials on different substrates
2. Characterization of the structural, optical and vibrational properties of 2D Materials
3. Modelling of selected physical properties of these materials

Learning Outcomes / Competences:

- Knowledge and practical application of fabrication of selected monolayer 2D Materials
- Knowledge and practical application of basic characterization methods for these materials
- Practical application of simulation methods
- Planning and conducting experiments
- Data analysis

Workload:
Total: 240 h
90 h lecture and exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)
30 h studying of course content using provided materials (self-study)

Conditions: Basic knowledge of solid state physics, optics and quantum mechancis		**Credit Requirements:** written report, editing time 3 weeks, max. 30 pages
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: 2D Materials (Lecture)
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Assigned Courses:

Method Course: 2D Materials (lecture)

Part of the Module: Method Course: 2D Materials (Practical course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: 2D Materials (lecture)

Examination

Method Course: 2D Materials

report

Description:

written report

Module PHM-0153: Method Course: Magnetic and Superconducting Materials

8 ECTS/LP

Method Course: Magnetic and Superconducting Materials

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Philipp Gegenwart

Contents:
Methods of growth and characterization:

Sample preparation (bulk materials and thin films), e.g.,

- arcmelting
- flux-growth
- sputtering and evaporation

Sample characterization, e.g.,

- X-ray diffraction
- electron microscopy, scanning tunneling microscopy
- magnetic susceptibility, electrical resistivity
- specific heat

Learning Outcomes / Competences:
The students

- get to know the basic methods of materials growth and characterization, such as poly- and single crystal growth, thin-film growth, X-ray diffraction, magnetic susceptibility, dc-conductivity, and specific heat measurements
- are trained in planning and performing complex experiments
- learn to evaluate and analyze the collected data, are taught to work on problems in experimental solid state physics, including analysis of measurement results and their interpretation in the framework of models and theories

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
90 h lecture and exercise course (attendance)

Conditions:
Recommended: basic knowledge in solid state physics and quantum mechanics

Credit Requirements:
presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)

Frequency: each summer semester

Recommended Semester:
from 1.

Minimal Duration of the Module:
1 semester[s]

Contact Hours:
6

Repeat Exams Permitted:
according to the examination regulations of the study program

Parts of the Module

Part of the Module: Method Course: Magnetic and Superconducting Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Assigned Courses:

Method Course: Magnetic and Superconducting Materials (lecture)

Part of the Module: Method Course: Magnetic and Superconducting Materials (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Magnetic and Superconducting Materials (Practical Course) (internship)

Examination
Method Course: Magnetic and Superconducting Materials
report
Examination Prerequisites:
Method Course: Magnetic and Superconducting Materials

Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy	8 ECTS/LP

Version 2.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Leo van Wüllen

Contents:
Physical foundations of NMR spectroscopy

Internal interactions in NMR spectroscopy

- Chemical shift interaction
- Dipole interaction and
- Quadrupolar interaction

Magic Angle Spinning techniques

Modern applications of NMR in materials science

Experimental work at the Solid-State NMR spectrometers, computer-aided analysis and interpretation of acquired data

Learning Outcomes / Competences:
The students:

- gain basic knowledge of the physical foundations of modern Solid-State NMR spectroscopy,
- gain basic practical knowledge of operating a solid-state NMR spectrometer,
- can -- under guidance -- plan, perform, and analyze modern solid-state NMR experiments for the structural characterization of advanced materials.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using provided materials (self-study)
90 h lecture and exercise course (attendance)

Conditions:		**Credit Requirements:**
The attendance of the lecture "NOVEL METHODS IN SOLID STATE NMR SPECTROSCOPY" is highly recommended.		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Modern Solid State NMR Spectroscopy
Mode of Instruction: seminar
Language: English
Contact Hours: 2

Literature:

- M. H. Levitt, spin Dynamics, John Wiley and Sons, Ltd., 2008.
- H. Günther NMR spectroscopy, Wiley, 2001.
- M. Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
- D. Canet, NMR - concepts and methods, Springer, 1994.

Assigned Courses:

Method Course: Modern Solid State NMR Spectroscopy (seminar)

Part of the Module: Method Course: Modern Solid State NMR Spectroscopy (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Literature:

1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008.
2. H. Günther, NMR spectroscopy, Wiley 2001.
3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
4. D. Canet: NMR - concepts and methods, Springer, 1994.

Assigned Courses:

Method Course: Modern Solid State NMR Spectroscopy (Practical Course) (internship)

Examination
Method Course: Modern Solid State NMR Spectroscopy
report / work period for assignment: 2 weeks
Examination Prerequisites:
Method Course: Modern Solid State NMR Spectroscopy

Module PHM-0206: Method Course: Infrared Microspectroscopy under Pressure *Method Course: Infrared Microspectroscopy under Pressure*		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Christine Kuntscher		
Contents: Electrodynamics of solids Maxwell equations and electromagnetic waves in matter Optical variables Theories for dielectric function: i. Free carriers in metals and semiconductors (Drude) ii. Interband absorptions in semiconductors and insulators iii. Vibrational absorptions iv. Multilayer systems FTIR microspectroscopy Components of FTIR spectrometers i. Light sources ii. Interferometers iii. Detectors Microscope components High pressure experiments Equipments Pressure calibration Experimental techniques under high pressure i. IR spectroscopy ii. Raman scattering iii. Magnetic measurements iv. Transport measurements		
Learning Outcomes / Competences: The students Learn about the basics of the light interaction with various materials and the fundamentals of FTIR microspectroscopy, Are introduced to the high pressure equipments used in infrared spectroscopy, Learn to carry out infrared microspectroscopy experiments under pressure, Learn to analyze the measured optical spectra.		
Workload: Total: 240 h		
Conditions: none		**Credit Requirements:** Written report
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Infrared Microspectroscopy under Pressure
Mode of Instruction: lecture
Language: German
Contact Hours: 2

Assigned Courses:

Method Course: Infrared Microspectroscopy under Pressure (lecture)

Part of the Module: Method Course: Infrared Microspectroscopy under Pressure (Practical Course)
Mode of Instruction: laboratory course
Language: German
Contact Hours: 4

Assigned Courses:

Method Course: Infrared Microspectroscopy under Pressure (Practical Course) (internship)

Examination
Method Course: Infrared Microspectroscopy under Pressure
report

Module PHM-0216: Method Course: Thermal Analysis	8 ECTS/LP

Version 1.0.0 (since WS16/17)
Person responsible for module: Prof. Dr. Ferdinand Haider
Dr. Robert Horny

Contents:
Methods of thermal analysis:
- Differential Scanning Calorimetry: DSC, DTA
- Thermo-gravimetric Analysis: TG
- Dilatometry: DIL
- Dynamic-mechanical Analysis: DMA

Advanced Methods:
- Modulated Differential Scanning Calorimetry: MDSC
- Evolved Gas Analysis: EGA GCMS, FTIR

Learning Outcomes / Competences:
The students:

- get to know the basic principles of thermal analysis
- learn about fundamental thermal processes in condensed matter ,e.g. phase transitions and relaxation processes (metals, polymers, ceramics)
- learn to plan and carry out complex experiments and the usage of advanced measurement techniques
- learn how to evaluate and analyze thermal data

Remarks:

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h lecture and exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)

Conditions:		**Credit Requirements:**
Recommended: basic knowledge in solid-state physics		regular participation, oral presentation (10 min), written report
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Thermal Analysis
Mode of Instruction: lecture
Lecturers: Prof. Dr. Ferdinand Haider
Language: English
Contact Hours: 2

Part of the Module: Method Course: Thermal Analysis (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Examination

Method Course: Thermal Analysis

report

Module PHM-0158: Introduction to Materials (= Seminar)		4 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
Contents: Varying topics for each year, giving an overview into scope, application, requirements and preparation of all types of modern materials.		
Learning Outcomes / Competences: The students: • know the major principles, applications and processes of modern materials, • acquire the competence to compile knowledge for examples of material specific topics and to present this knowledge in given time to an audience.		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 120 h		
Conditions: Recommended: basic knowledge in materials science		**Credit Requirements:** regular participation, oral presentation with term paper (30 - 45 minutes)
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Introduction to Materials (Seminar) **Mode of Instruction:** seminar **Language:** English **Contact Hours:** 2
Literature: specific for each topic, to be gathered by the students

Examination
Introduction to Materials presentation **Examination Prerequisites:** Introduction to Materials

Module PHM-0159: Laboratory Project		10 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: Experimental or theoretical work in a laboratory / research group in the Institute of Physics. Has to be conducted within 3 months.		
Learning Outcomes / Competences: The students: • know the basic terms, skills and concepts to pursuit a real research project in the existing laboratories within the research groups, • experience the day to day life in a research group from within, • prepare themselves to conduct a research project during their Masters thesis.		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 300 h		
Conditions: Recommended: solid knowledge in (solid state) Physics, Chemistry and Materials Science, both experimentally and theoretically		**Credit Requirements:** 1 written report (editing time 2 weeks)
Frequency: each semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 0 semester[s]
Contact Hours: 8	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Laboratory Project
Mode of Instruction: internship
Language: English
Contact Hours: 8

Literature:
- Various

Examination
Laboratory Project
project work
Examination Prerequisites:
Laboratory Project

Module PHM-0051: Biophysics and Biomaterials *Biophysics and Biomaterials*	6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Stefan Thalhammer	
Contents: • Radiation Biophysics • Microfluidics • Membranes • Membranal transport	
Learning Outcomes / Competences: The students: • learn basic terms, concepts and phenomena of biological physics, • learn models of the (bio)polymer-theory, microfluidic, radiation biophysics, nanobiotechnology, membranes and neuronal networks, • adapt skills in the independent processing of problems and deal with current literature. They will be able to translate a biological oberservation into a physical question. • Integrated acquirement of soft skills: autonomous working with specialist literature in english, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.	
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study)	
Conditions: Mechanics, Thermodynamics, Statistical Physics, basic knowledge in Molecular Biology	

Frequency: each semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Biophysics and Biomaterials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Radiation Biophysics
  - Radiation sources
  - Interaction of radiation with biological matter
  - Radiation protection principles
  - Low dose radiation
  - LNT model in radiation biophysics
- Microfluidics
  - Life at Low Reynolds Numbers
  - The Navier-Stokes Equation
  - Low Reynolds Numbers – The Stokes Equation
  - Breaking the Symmetry
- Membranes
  - Thermodynamics and Fluctuations
  - Thermodynamics of Interfaces
  - Phase Transitions – 2 state model
  - Lipid membranes and biological membranes, membrane elasticity
- Membranal transport
  - Random walk, friction and diffusion
  - Transmembranal ionic transport and ion channels
  - Electrophysiology of cells
  - Neuronal Dynamics

Literature:

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle, R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- lecture notes

Assigned Courses:

Biophysics and Biomaterials (lecture)

Part of the Module: Biophysics and Biomaterials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Biophysics and Biomaterials (Tutorial) (exercise course)

Examination

Biophysics and Biomaterials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Biophysics and Biomaterials

Module PHM-0160: Dielectric and Optical Materials *Dielectric and Optical Materials*		6 ECTS/LP
Version 1.1.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
Contents: Optical materials: • Fundamentals of electromagnetic wave propagation in homogenous media (refraction, reflection, transmission, absorption) • Anisotropic media, linear optics • Optical properties semiconductors/insulators, molecular materials, metals • Absorption and Luminescence, excitons, luminescence centers • optoelectronics, detectors, light emitting devices • quantum confinement Dielectric materials: • Experimental techniques: quantities, broadband dielectric spectroscopy, nonlinear and polarization measurements • Dynamic processes in dielectric materials: relaxation processes, phenomenological models • Dielectric properties of disordered matter: liquids, glasses, plastic crystals • Charge transport: hopping conductivity, universal dielectric response, ionic conductors • Maxwell-Wagner relaxations: equivalent-circuits, applications (supercapacitors), colossal-dielectric-constant materials • Ferroelectricity: dielectric properties, polarization, relaxor ferroelectrics, applications • Multiferroic materials: mechanisms, materials, applications		
Learning Outcomes / Competences: Students know the fundamentals of electromagnetic wave propagation and have a sound background for a broad spectrum of dielectric and optical phenomena. They are able to analyze materials requirements and have the competence to select materials for different kinds of applications.		
Remarks: **Elective compulsory module**		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: Basic knowledge of solid state physics		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Dielectric and Optical Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Literature:
Mark Fox, Optical Properties of Solids, Oxford Master Series

Assigned Courses:

Dielectric and Optical Materials (lecture)

Examination
Dielectric and Optical Materials
written exam / length of examination: 90 minutes
Examination Prerequisites:
Dielectric and Optical Materials

Module PHM-0059: Magnetism	6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Hans-Albrecht Krug von Nidda	

Contents:

- History, basics
- Magnetic moments, classical and quantum phenomenology
- Exchange interaction and mean-field theory
- Magnetic anisotropy and magnetoelastic effects
- Thermodynamics of magnetic systems and applications
- Magnetic domains and domain walls
- Magnetization processes and micro magnetic treatment
- AC susceptibility and ESR
- Spintransport / spintronics
- Recent problems of magnetism

Learning Outcomes / Competences:

The students:

- know the basic properties and phenomena of magnetic materials and the most important methods and concepts for their description, like mean-field theory, exchange interactions and micro magnetic models,
- have the ability to classify different magnetic phenomena and to apply the corresponding models for their interpretation, and
- have the competence independently to treat fundamental and typical topics and problems of magnetism.
- Integrated acquirement of soft skills.

Workload:

Total: 180 h
60 h lecture and exercise course (attendance)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)

Conditions: basics of solid-state physics and quantum mechanics		
Frequency: annually	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Magnetism
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- D. H. Martin, Magnetism in Solids (London Iliffe Books Ltd.)
- J. B. Goodenough, Magnetism and the Chemical Bond (Wiley)
- P. A. Cox, Transition Metal Oxides (Oxford University Press)
- C. Kittel, Solid State Phyics (Wiley)
- D. C. Mattis, The Theory of Magnetism (Wiley)
- G. L. Squires, Thermal Neutron Scattering (Dover Publications Inc.)

Assigned Courses:

Magnetism (lecture)

Part of the Module: Magnetism (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Magnetism (Tutorial) (exercise course)

Examination

Magnetism

written exam / length of examination: 90 minutes

Examination Prerequisites:

Magnetism

Module PHM-0048: Physics and Technology of Semiconductor Devices *Physics and Technology of Semiconductor Devices*	6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Hubert J. Krenner

Contents:

1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport)
2. Semiconductor diodes and transistors
3. Semiconductor technology

Learning Outcomes / Competences:

- Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport.
- Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors.
- Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes and transistors
- Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication.
- Integrated acquisition of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:
recommended prerequisites: basic knowledge in solid state physics, statistical physics and quantum mechanics.

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Physics and Technology of Semiconductor Devices
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Yu und Cardona: Fundamentals of Semiconductors (Springer)
- Sze: Physics of Semiconductor Devices (Wiley)
- Sze: Semiconductor Devices (Wiley)
- Madelung: Halbleiterphysik (Springer)
- Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)

Assigned Courses:

Physics and Technology of Semiconductor Devices (lecture)

Part of the Module: Physics and Technology of Semiconductor Devices (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Contents:

see module description

Assigned Courses:

Physics and Technology of Semiconductor Devices (Tutorial) (exercise course)

Examination

Physics and Technology of Semiconductor Devices

written exam / length of examination: 90 minutes

Examination Prerequisites:

Physics and Technology of Semiconductor Devices

Module PHM-0049: Nanostructures / Nanophysics *Nanostructures / Nanophysics*	6 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Hubert J. Krenner	

Contents:

1. Semiconductor quantum wells, wires and dots, low dimensional electron systems
2. Magnetotransport in low-dimensional systems, Quanten-Hall-Effect, Quantized conductance
3. Optical properties of quantum wells and quantum dots and their application in modern optoelectonic devices
4. Nanofabrication techniques

Learning Outcomes / Competences:

- Basic knowledge of the fundamental concepts in modern nanoscale science
- Profound knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics
- Knowledge of different fabrication approaches using bottom-up and top-down techniques
- Application of these concepts to tackle present problems in nanophysics
- Integrated acquirement of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using literarture (self-study)
60 h lecture and exercise course (attendance)

Conditions: recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Nanostructures / Nanophysics
Mode of Instruction: lecture
Language: English
Frequency: each summer semester
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Yu und Cardona: Fundamentals of Semiconductors
- Singh:Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)
- Davies: The Physics of low-dimensional Semiconductors (Cambridge University Press)

Examination

Nanostructures / Nanophysics

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Nanostructures / Nanophysics

Module PHM-0054: Chemical Physics II		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
Contents: • Introduction to computational chemistry • Hartree-Fock Theory • DFT in a nutshell • Prediction of reaction mechanisms • calculation of physical and chemical properties		
Learning Outcomes / Competences: The students: • know the basic quantum chemical methods of chemical physics to interpret the electronic structures in molecules and solid-state compounds, • have therefore the competence to autonomously perform simple quantum chemical calculations using Hartree-Fock and Density Functional Theory (DFT) and to interpret the electronic structure of functional molecules and materials with regard to their chemical and physical properties • Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.		
Remarks: It is possible for students to do quantum chemical calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: It is highly recommended to complete the module Chemical Physics I first.		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Chemical Physics II **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Literature:

- I. N. Levine, Quantum Chemistry, Pearson, 7th ed **2013**.
- A. Szabo, N. S. Ostlund, Modern Quantum Chemistry, Dover, **1996** (EbookCentral ebook).
- E. G. Lewars, Computational Chemistry, Springer, **2011**.
- D. C. Young, Computational Chemistry: A practical guide for applying techniques to real world problems, Wiley ebook, **2002**.
- R. A. van Santen, Ph. Sautet, Computational Methods in Catalysis and Materials Science, Wiley ebook, **2009**.
- P. Popelier, Atoms in Molecules: An Introduction, Pearson Education Limited, **2000**.
- A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc. Pittsburg, PA.

Assigned Courses:

Chemical Physics II (lecture)

Part of the Module: Chemical Physics II (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see module description

Assigned Courses:

Chemical Physics II (Tutorial) (exercise course)

Examination

Chemical Physics II

written exam / length of examination: 90 minutes

Examination Prerequisites:

Chemical Physics II

Module PHM-0161: Coordination Materials	6 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer
Dr. Hana Bunzen

Contents:

A) Basics of coordination Chemistry

- Historical development of coordination chemistry [2]
- Structures and nomenclature rules [2]
- Chemical bonds in transition metal coordination compounds [3]
- Stability of transition metal coordination compounds [2]
- Characteristic reactions [3]

B) Selected classes of functional materials

- Bioinorganic chemistry [3]
- Coordination polymers / metal-organic frameworks [3]
- Coordination compounds in medical applications [3]
- Photochemistry of coordination compounds [3]

Learning Outcomes / Competences:

The students

- shall acquire knowledge about concepts of chemical bonding in coordination chemistry (main emphasis: d-block transition metal compounds),
- broaden their capabilities to interpret UV/vis absorption spectra and to predict stability and reactivity of coordination compounds,
- learn how to transfer concepts of coordination chemistry onto topics of materials sciences.
- Integrated acquirement of soft skills.

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:

Recommended: The lecture course is based on the courses "Chemistry I", "Chemistry II"

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Coordination Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Literature:

- Joan Ribas Gisbert, Coordination Chemistry, Wiley-VCH
- Lutz H. Gade, Koordinationschemie, Wiley-VCH
- As well as selected reviews and journals articles cited on the slides

Assigned Courses:

Coordination Materials (lecture)

Part of the Module: Coordination Materials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Coordination Materials (Tutorial) (exercise course)

Examination

Coordination Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Coordination Materials

Module PHM-0113: Advanced Solid State Materials	6 ECTS/LP

Version 1.0.0 (since WS10/11)
Person responsible for module: Prof. Dr. Henning Höppe

Contents:

- Repitition of concepts
- Novel silicate-analogous materials
- Luminescent materials
- Pigments
- Heterogeneous catalysis

Learning Outcomes / Competences:

- The students are aware of correlations between composition, structures and properties of functional materials,
- acquire skills to predict the properties of chemical compounds, based on their composition and structures,
- gain competence to evaluate the potential of functional materials for future technological developments, and
- will know how to measure the properties of these materials.
- Integrated acquirement of soft skills

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using literarture (self-study)
60 h lecture and exercise course (attendance)

Conditions: Contents of the modules Chemie I, and Chemie II or Festkörperchemie (Bachelor Physik, Bachelor Materialwissenschaften)		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Solid State Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:

- A. West, Solid State Chemistry and Its Applications
- L. Smart, E. Moore, Solid State Chemistry
- Scripts Solid State Chemistry and Chemistry I and II

Examination

Advanced Solid State Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Advanced Solid State Materials

Module PHM-0217: Advanced X-ray and Neutron Diffraction Techniques		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
Contents: Subjects of the lecture are advanced X-ray and neutron diffraction techniques: • The failure of the standard *I*ndependent *A*tom *M*odel (IAM) in X-ray diffraction • Beyond the standard model: The multipolar model • How to obtain and analyze experimental charge densities • How to derive chemical and physical properties from diffraction data • Applications of joined X-ray and neutron diffraction experiments		
Learning Outcomes / Competences: The students: • gain basic theoretical knowledge on the reconstruction of accurate electron density maps from X-ray and neutron diffraction data • know the basics of the *Quantum Theory of Atoms in Molecules* • are competent to analyze the topology of the electron density and correlate it with the physical and chemical properties of materials		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: It is recommended to complete the Module PHM-0053 Chemical Physics I.		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced X-ray and Neutron Diffraction Techniques

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

1. C. Giacovazzo et al., Fundamentals of Crystallography, Oxford Univ. Press, 2011.
2. P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.
3. P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.
4. P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.
5. P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.

Assigned Courses:

Advanced X-ray and Neutron Diffraction Techniques (lecture)

Part of the Module: Advanced X-ray and Neutron Diffraction Techniques (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Advanced X-ray and Neutron Diffraction Techniques (Tutorial) (exercise course)

Examination

Advanced X-ray and Neutron Diffraction Techniques

written exam / length of examination: 90 minutes

Examination Prerequisites:

Advanced X-ray and Neutron Diffraction Techniques

Module PHM-0114: Porous Functional Materials	6 ECTS/LP

Version 1.0.0 (since SS11)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:

- Overview and historical developments
- Structural families of porous frameworks
- Synthesis strategies
- Adsorption and diffusion
- Thermal analysis methods
- Catalytic properties
- Advanced applications and current trends

Learning Outcomes / Competences:

- The students shall acquire knowledge about design principles and synthesis of porous functional materials,
- broaden their capabilities to characterize porous solid state materials with special emphasis laid upon sorption and thermal analysis,
- become introduced into typical technical applications of porous solids.
- Integrated acquirement of soft skills

Remarks:
Subsequent to the lecture course, the students can take part in a hands-on method course ``Porous Materials Synthesis and Characterization'' to practice their knowledge.

Workload:
Total: 180 h
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:		**Credit Requirements:**
participation in the course Materials Chemistry		one written examination, 90 min
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Porous Functional Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Contents:
see module description

Literature:

- Paul A. Wright, Microporous Framework Solids (RSC Materials Monographs, 2008)
- selected reviews and journal articles cited on the slides

Examination

Porous Functional Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Porous Functional Materials

Module PHM-0218: Novel Methods in Solid State NMR Spectroscopy		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
Contents: The physical basis of nuclear magnetic resonance Pulsed NMR methods; Fourier Transform NMR Internal interactions Magic Angle Spinning Modern pulse sequences or how to obtain specific information about the structure and dynamics of solid materials Recent highlights of the application of modern solid state NMR in materials science		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each summer semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Novel Methods in Solid State NMR Spectroscopy
Mode of Instruction: lecture
Language: German
Contact Hours: 3

Assigned Courses:

Novel Methods in Solid State NMR Spectroscopy (lecture)

Part of the Module: Novel Methods in Solid State NMR Spectroscopy (Tutorial)
Mode of Instruction: exercise course
Language: German
Contact Hours: 1

Literature:

1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008.
2. H. Günther, NMR spectroscopy, Wiley 2001.
3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
4. D. Canet: NMR - concepts and methods, Springer, 1994.

Assigned Courses:

Novel Methods in Solid State NMR Spectroscopy (Tutorial) (exercise course)

Examination
Novel Methods in Solid State NMR Spectroscopy
written exam / length of examination: 90 minutes

Module PHM-0164: Characterization of Composite Materials

Characterization of Composite Materials

6 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Markus Sause

Contents:
The following topics are presented:

- Introduction to composite materials
- Applications of composite materials
- Mechanical testing
- Thermophysical testing
- Nondestructive testing

Learning Outcomes / Competences:
The students:

- acquire knowledge in the field of materials testing and evaluation of composite materials.
- are introduced to important concepts in measurement techniques, and material models applied to composites.
- are able to independently acquire further information of the scientific topic using various forms of information.

Workload:
Total: 180 h
60 h lecture and exercise course (attendance)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)

Conditions:
Recommended: basic knowledge in materials science, particularly in composite materials

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Characterization of Composite Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Literature:

- Morgan: Carbon fibers and their composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe
- Dowling: Mechanical behaviour of materials
- Issler: Festigkeitslehre - Grundlagen
- Landau, Lifschitz: Theoretische Physik Vol. 7

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

Assigned Courses:

Characterization of Composite Materials (lecture)

Part of the Module: Characterization of Composite Materials (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Literature:
see lecture

Assigned Courses:

Characterization of Composite Materials (Tutorial) (exercise course)

Examination
Characterization of Composite Materials
written exam / length of examination: 90 minutes
Examination Prerequisites:
Characterization of Composite Materials

Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Frau Dr. Judith Moosburger-Will		
Contents: The following topics are treated: • production of fibers (e.g. glass, carbon, or ceramic fibers) • Physical and chemical properties of fibers and their precursor materials • Physical and chemical properties of commonly used polymeric and ceramic matrix materials • Semi-finished products • Composite production technologies • Application of fiber reinforced materials		
Learning Outcomes / Competences: The students: • know the application areas of composite materials. • know the basics of production technologies of fibers, polymeric, and ceramic matrices and fiber reinforced materials. • are introduced to physical and chemical properties of fibers, matrices, and fiber reinforced materials. • are able to independently acquire further knowledge of the scientific topic using various forms of information.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study)		
Conditions: Recommended: basic knowledge in materials science, basic lectures in organic chemistry		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3

Literature:

- Morgan: Carbon fibers and their composites
- Ehrenstein: Polymeric materials
- Krenkel: Ceramic Matrix Composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunstoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe

Further litrature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Literature:

see lecture

Examination

Fiber Reinforced Composites: Processing and Materials Properties

written exam / length of examination: 90 minutes

Examination Prerequisites:

Fiber Reinforced Composites: Processing and Materials Properties

Module MRM-0052: Functional Polymers		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Klaus Ruhland		
Contents: • Introduction to polymer science • Elastomers and elastoplastic materials • Memory-shape polymers • Piezoelectric polymers • Electrically conducting polymers • Ion-conducting polymers • Magnetic polymers • Photoresponsive polymers • Polymers with second order non-linear optical properties • Polymeric catalysts • Self-healing polymers • Polymers in bio sciences>		
Learning Outcomes / Competences: The students learn how polymeric materials can be designed and applied to act in a smart manner on an external mechanical, magnetic, electric, optical, thermal or chemical impact.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: Recommended: Attendance to PHM-0035 (Chemie I), PHM-0036 (Chemie II) and MRM-0050 (Grundlagen der Polymerchemie und -physik)		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Functional Polymers **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Assigned Courses: **Functional Polymers** (lecture)
Part of the Module: Functional Polymers (Tutorial) **Mode of Instruction:** exercise course **Language:** English **Contact Hours:** 1
Assigned Courses:

Functional Polymers (Tutorial) (exercise course)

Examination

Functional Polymers

written exam / length of examination: 90 minutes

Examination Prerequisites:

Functional Polymers

Module PHM-0122: Non-Destructive Testing *Non-Destructive Testing*	6 ECTS/LP
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Markus Sause	

Contents:

- Introduction to nondestructive testing methods
- Visual inspection
- Ultrasonic testing
- Guided wave testing
- Acoustic emission analysis
- Thermography
- Radiography
- Eddy current testing
- Specialized nondestructive methods

Learning Outcomes / Competences:

The students

- acquire knowledge in the field of nondestructive evaluation of materials,
- are introduced to important concepts in nondestructive measurement techniques,
- are able to independently acquire further knowledge of the scientific topic using various forms of information.
- Integrated acquirement of soft skills

Workload:

Total: 180 h
60 h lecture and exercise course (attendance)
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions: Basic knowledge on materials science, in particular composite materials		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Non-Destructive Testing
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Raj: Practical Non-destructive Testing
- Shull: Nondestructive Evaluation - Theory and Applications
- Krautkrämer: Ultrasonic testing of materials
- Grosse: Acoustic Emission Testing
- Rose: Ultrasonic waves in solid media
- Maldague: Nondestructive Evaluation of Materials by Infrared Thermography
- Herman: Fundamentals of Computerized Tomography

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

Part of the Module: Non-Destructive Testing (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Non-Destructive Testing

written exam / length of examination: 90 minutes

Examination Prerequisites:

Non-Destructive Testing

Module PHM-0168: Modern Metallic Materials	6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider	

Contents:

Introduction

Review of physical metallurgy

Steels:

- principles
- common alloying elements
- martensitic transformations
- dual phase steels
- TRIP and TWIP steels
- maraging steel
- electrical steel
- production and processing

Aluminium alloys:

- 2xxx
- 6xxx
- 7xxx
- Processing – creep forming, hydroforming, spinforming

Titanium alloys

Magnesium cast alloys

Superalloys

Intermetallics, high entropy alloys

Copper, brass, bronzes

Metallic glasses

Alloy design

Learning Outcomes / Competences:

Students

- learn about all kinds of actual metallic alloys, their properties and how these properties can be derived from basic concepts

Workload:

Total: 180 h
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)
60 h lecture and exercise course (attendance)

Conditions: Recommended: Knowledge of physical metallurgy and physical chemistry		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Modern Metallic Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 4

Literature:

Cahn-Haasen-Kramer: Materials Science and Technology

Original literature

Examination

Modern Metallic Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Modern Metallic Materials

Module PHM-0196: Surfaces and Interfaces II: Joining processes	6 ECTS/LP

Version 1.1.0 (since WS15/16)
Person responsible for module: Prof. Dr. Siegfried Horn
Dozenten: Prof. Dr. Siegfried Horn, Dr. Judith Moosburger-Will

Learning Outcomes / Competences:
The students

- know the application areas of composite materials
- know the basics of cohesion and adhesion
- know the basics of joining techniques
- are introduced to physical and chemical properties metal-metal, metal-polymer and polymer-polymer interfaces
- Are able to independently acquire further knowledge of the scientific topic using various forms of information.

Workload:
Total: 180 h

Conditions:	**Credit Requirements:**
Basic knowledge on materials science, lecture “Surfaces and Interfaces I” Module Surfaces and Interfaces (PHM-0117) - recommended	Bestehen der Modulprüfung

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Surfaces and Interfaces II: Joining processes
Mode of Instruction: lecture
Lecturers: Prof. Dr. Siegfried Horn
Language: German
Contact Hours: 3

Contents:
The following topics are treated:

- Introduction to adhesion
- Role of surface and interface properties
- Introduction to interactions at surfaces and interfaces
- Adhesion theories
- Surface and interface energy
- Surface treatment techniques
- Joining techniques
- Physical and chemical properties of joints
- Applications

Literature:
Literature, including actual scientific papers and reviews, will be announced at the beginning of the lecture.

Assigned Courses:

Surfaces and Interfaces II: Joining processes (lecture)

Examination

Surfaces and Interfaces II: Joining processes

written exam / length of examination: 90 minutes

Examination Prerequisites:

Surfaces and Interfaces II: Joining processes

Parts of the Module

Part of the Module: Übung zu Surfaces and Interfaces II: Joining processes

Mode of Instruction: exercise course

Language: German

Contact Hours: 1

Assigned Courses:

Übung zu Surfaces and Interfaces II: Joining processes (exercise course)

Module PHM-0224: Method Course: Theoretical Concepts and Simulation

8 ECTS/LP

Method Course: Theoretical Concepts and Simulation

Version 1.0.0
Person responsible for module: Prof. Dr. Liviu Chioncel

Contents:
This module covers Monte-Carlo methods (computational algorithms) for classical and quantum problems. Python as programing language will be employed. The following common applications will be discussed:

- Monte-Carlo integration, stochastic optimization, inverse problems
- Feynman path integrals: the connection between classical and quantum systems
- Oder and disorder in spin systems, fermions, and boson

Learning Outcomes / Competences:
- The students are capable of obtaining numerical solutions to problems too complicated to be solved analytically
- The students are able to present (graphically), discuss and analyze the results
- The students gain experience in formulatind and carrying out a collaborative project

Remarks:
The number of students will be limited to 8.

Workload:
Total: 240 h
90 h preparation of presentations (self-study)
60 h preparation of written term papers (self-study)
60 h studying of course content (self-study)
90 h (attendance)

Conditions:	**Credit Requirements:**
Knowledge of the programming language Phython is expected on the level taught in the modul PHM-0041. Requirements to understand basic concepts in physics: Classical Mechanics (Newton, Lagrange), Electrodynamics, Thermodynamics and Quantum Mechanics.	Bestehen der Modulprüfung

Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Theoretical Concepts and Simulation
Mode of Instruction: lecture
Language: English / German
Contact Hours: 2

Contents:
Concepts of classical and quantum statistical physics:

- the meaning of sampling, random variables, ergodicity
- equidistribution, pressure, temperature
- path integrals, quantum statistics, enumeration, cluster algorithms

Literature:
1. Werner Krauth, Algorithms and Computations (Oxford University Press, 2006)
2. R. H. Landau, A Survey of Computational Physics (Princeton Univ. Press, 2010)

Assigned Courses:

Method Course: Theoretical Concepts and Simulation (lecture)

Part of the Module: Method Course: Theoretical Concepts and Simulation (Practical Course)
Mode of Instruction: internship
Language: English / German
Contact Hours: 4

Contents:
see above

Literature:
see above

Assigned Courses:

Method Course: Theoretical Concepts and Simulation (Practical Course) (internship)

Examination
Method Course: Theoretical Concepts and Simulation
report / work period for assignment: 4 weeks
Description:
The requirement for the credit points is based on a programming project carried out in a team of 2-3 students. The final report contains the formulation and a theoretical introduction into the problem, the numerical implementation, and the presentation of the results.

Module PHM-0166: Carbon-based functional Materials (Carboterials)		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: 1. Introduction to carbon allotropes and porous carbon materials [4] 2. Physical properties of fullerenes, carbon nanotubes and graphene [4] 3. Solid state NMR spectroscopy of carbon materials [4] 4. Metal carbides [4] 5. Carbon thin films and coatings [4] 6. Manufacturing and processing technology of carbon fibres [4] 7. Carbon-fibre reinforced polymer composites [4] 8. Carbon-fibre reinforced aluminium (Metal Matrix Composites, MMC) [4] 9. Energy storage in carbon materials [4] 10. Carbon-based materials for opto-electronics [4] 11. Quantum transport phenomena relating to carbon materials [4] 12. a) Manipulating heat flow with carbon-based electronic analogs: phononics in place of electronics [2] 12. b) Carbon-based spintronics [2] 13. Fabrication and processing of carbon-based nanostructures [4]		
Learning Outcomes / Competences: The students: • know the basics of the chemistry and physics of carbon materials and their applications, • acquire knowledge about the structural characterization, physical properties and engineering of functional materials and carbon based devices, • learn to work with specialist literature in english.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Carbon-based functional Materials (Carboterials)
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Literature:
will be announced by the lecturers

Examination
Carbon-based functional Materials (Carboterials)
written exam / length of examination: 120 minutes
Examination Prerequisites:
Carbon-based functional Materials (Carboterials)

Module PHM-0174: Theoretical Concepts and Simulation *Theoretical Concepts and Simulation*	6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Liviu Chioncel

Contents:

1. Introduction: operating systems, programming languages, data visualization tools
2. Basic numerical methods: interpolation, integration
3. Ordinary and Partial Differential Equations (e.g., diffusion equation, Schrödinger equation)
4. Molecular dynamics
5. Monte Carlo simulations

Learning Outcomes / Competences:
The students:

- know the principal concepts of thermodynamics and statistical physics as well as the numerical methods relevant in material science,
- are able to solve simple problems numerically. They are able to write the codes and to present the results,
- have the expertise to find the numerical method appropriate for the given problem and to judge the quality and validity of the numerical results,
- Integrated acquirement of soft skills: independent handling of hard- and software while using English documentations, ability to investigate abstract circumstances with the help of a computer and present the results in written and oral form, capacity for teamwork.

Remarks:
Links to software related to the course:

- http://www.bloodshed.net/
- http://www.cplusplus.com/doc/tutorial/
- http://www.cygwin.com/
- http://xmd.sourceforge.net/download.html
- http://www.rasmol.org/
- http://felt.sourceforge.net/

Workload:
Total: 180 h
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
60 h lecture and exercise course (attendance)

Conditions:	**Credit Requirements:**
Recommended: basic knowledge of quantum mechanics, thermodynamics, and numerical methods as well as of a programming language	project work in small groups, including a written summary of the results (ca. 10-20 pages) as well as an oral presentation

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Theoretical Concepts and Simulation

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

- Tao Pang, An Introduction to Computational Physics (Cambridge University Press)
- J. M. Thijssen, Computational Physics (Cambridge University Press)
- Koonin, Meredith, Computational Physics (Addison-Weseley)
- D. C. Rapaport, The Art of Molecular Dynamics Simulation, (Cambridge University Press)
- W. H. Press et al, Numerical Recipes (Cambridge University Press)

Part of the Module: Theoretical Concepts and Simulation (Project)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Theoretical Concepts and Simulation

seminar / length of examination: 30 minutes

Examination Prerequisites:

Theoretical Concepts and Simulation

Module PHM-0058: Organic Semiconductors *Organic Semiconductors*		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Brütting		
Contents: Basic concepts and applications of organic semiconductors Introduction • Materials and preparation • Structural properties • Electronic structure • Optical and electrical properties Devices and Applications • Organic metals • Light-emitting diodes • Field-effect transistors • Solar cells and laser		
Learning Outcomes / Competences: The students: • know the basic structural and electronic properties of organic semiconductors as well as the essential function of organic semiconductor devices, • have acquired skills for the classification of the materials taking into account their specific features in the functioning of components, • and have the competence to comprehend and attend to current problems in the field of organic electronics. • Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results		
Workload: Total: 180 h 40 h studying of course content using provided materials (self-study) 40 h studying of course content using literarture (self-study) 40 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: It is strongly recommended to complete the module solid-state physics first. In addition, knowledge of molecular physics is desired.		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Organic Semiconductors **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3

Learning Outcome:
see module description

Contents:
see module description

Literature:
- M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)
- W. Brütting (editor): Physics of Organic Semiconductors (Wiley-VCH)
- A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)

Assigned Courses:

Organic Semiconductors (lecture)

Part of the Module: Organic Semiconductors (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Assigned Courses:

Organic Semiconductors (Tutorial) (exercise course)

Examination
Organic Semiconductors
written exam / length of examination: 90 minutes
Examination Prerequisites:
Organic Semiconductors

Module PHM-0066: Superconductivity	6 ECTS/LP
Version 1.0.0 (since WS11/12) Person responsible for module: PD Dr. Reinhard Tidecks	

Contents:

- Introductory Remarks and Literature
- History and Main Properties of the Superconducting State, an Overview
- Phenomenological Thermodynamics and Electrodynamics of the SC
- Ginzburg-Landau Theory
- Microscopic Theories
- Fundamental Experiments on the Nature of the Superconducting State
- Josephson-Effects
- High Temperature Superconductors
- Application of Superconductivity

Learning Outcomes / Competences:

The students:

- will get an introduction to superconductivity,
- by a presentation of experimental results they will learn the fundamental properties of the superconducting state,
- are informed about the most important technical applications of superconductivity.
- Special attention will be drawn to the basic concepts of the main phenomeno-logical and microscopic theories of the superconducting state, to explain the experimental observations.
- For self-studies a comprehensive list of further reading will be supplied.

Workload:

Total: 180 h
60 h lecture and exercise course (attendance)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)

Conditions:

- Physik IV – Solid-state physics
- Theoretical physics I-III

Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Superconductivity
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:

- W. Buckel, Supraleitung, 5. Auflage (VCH, Weinheim, 1994)
- W. Buckel und R. Kleiner, Supraleitung, 6. Auflage (WILEY-VCH, Weinheim, 2004)
- M. Tinkham, Introduction to Superconductivity, 2nd Edition (McGraw-Hill, Inc., New York, 1996, Reprint by Dover Publications Inc. Miniola , 2004)
- Weitere Literatur wird in der Vorlesung angegeben

Examination

Superconductivity

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Superconductivity

Module PHM-0060: Low Temperature Physics		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: PD Dr. Reinhard Tidecks		
Contents: • Introduction • Thermodynamic fundamentals • Gas liquification • Properties of liquid helium • Cryogenic engineering		
Learning Outcomes / Competences: The students: • know the basic properties of matter at low temperatures and the corresponding experimental techniques, • have acquired the theoretical knowledge to perform low-temperature measurements, • and know how to experimentally investigate current problems in low-temperature physics.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: Physik IV - Solid-state physics		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Low Temperature Physics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Introduction
  - History, methods, realizations, and significance
- Thermodynamic fundamentals
  - Temperature, working cycles, real gases, Joul-Thomson-Effect
- Gas liquification
  - Air, hydrogen, helium
  - Separation of Oxygen and nitrogen
  - Storage and transfer of liquefied gases, superinsulation
- Properties of liquid helium
  - Production and thermodynamic properties of4He and3He
  - Phase diagrams (4He,3He)
  - Superfluidity of4He
    - Experiments, Two-Fluid-Model
    - Bose-Einstein-Condensation
    - Excitation spectrum, critical velocity
    - Rotating Helium
  - Normal and superfluid3He
  - -4He /3He-mixtures
- Cryogenic engineering
  - Bath-Cryostats (Helium-4, Helium-3),
  - -4He /3He-Dilution-Refrigerators
  - Pomeranchuck-Cooling
  - Adiabatic demagnetization
  - Primary and secondary thermometers

Literature:

- C. Enss, S. Hunklinger, Tieftemperaturphysik (Springer)
- F. Pobell, Matter and Methods at Low Temperatures (Springer)

Part of the Module: Low Temperature Physics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Low Temperature Physics

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Low Temperature Physics

Module PHM-0114: Porous Functional Materials	6 ECTS/LP

Version 1.0.0 (since SS11)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:

- Overview and historical developments
- Structural families of porous frameworks
- Synthesis strategies
- Adsorption and diffusion
- Thermal analysis methods
- Catalytic properties
- Advanced applications and current trends

Learning Outcomes / Competences:

- The students shall acquire knowledge about design principles and synthesis of porous functional materials,
- broaden their capabilities to characterize porous solid state materials with special emphasis laid upon sorption and thermal analysis,
- become introduced into typical technical applications of porous solids.
- Integrated acquirement of soft skills

Remarks:
Subsequent to the lecture course, the students can take part in a hands-on method course ``Porous Materials Synthesis and Characterization'' to practice their knowledge.

Workload:
Total: 180 h
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:		**Credit Requirements:**
participation in the course Materials Chemistry		one written examination, 90 min
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Porous Functional Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Contents:
see module description

Literature:

- Paul A. Wright, Microporous Framework Solids (RSC Materials Monographs, 2008)
- selected reviews and journal articles cited on the slides

Examination

Porous Functional Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Porous Functional Materials

Module PHM-0050: Electronics for Physicists and Materials Scientists *Electronics for Physicists and Materials Scientists*	6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: Andreas Hörner

Contents:

1. Basics in electronic and electrical engineering
2. Quadrupole theory
3. Analog technique, transistor and opamp circuits
4. Boolean algebra and logic
5. Digital electronics and calculation circuits
6. Microprocessors and Networks
7. Basics in Electronic
8. Implementation of transistors
9. Operational amplifiers
10. Digital electronics

Learning Outcomes / Competences:
The students:

- know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the Lab,
- have skills in easy circuit design, measuring and control technology, analog and digital electronics,
- have expertise in independent working on circuit problems. They can calculate and develop easy circuits.
- Integrated acquirement of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.

Workload:
Total: 180 h
60 h lecture and exercise course (attendance)
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions: none		
Frequency: each semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Electronics for Physicists and Materials Scientists
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Paul Horowitz: The Art of Electronics (Cambridge University Press)
- National Instruments: MultiSim software package (available in the lecture)

Assigned Courses:

Electronics for Physicists and Materials Scientists (lecture)

Examination

Electronics for Physicists and Materials Scientists

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Electronics for Physicists and Materials Scientists

Module PHM-0068: Spintronics	6 ECTS/LP

Version 1.0.0 (since SoSe14)
Person responsible for module: Dr. German Hammerl

Contents:

- Introduction into magnetism
- Basic spintronic effects and devices
- Novel materials for spintronic applications
- Spin-sensitive experimental methods
- Semiconductor based spintronics

Learning Outcomes / Competences:
The students:

- know the fundamental properties of magnetic materials, the basic spintronic effects, and the related device structures,
- have acquired skills in identifying materials with respect to their applicability for spintronic devices,
- and have the competence to deal with current problems in the field of semi-conductor and metal based spintronics largely autonomous.

Workload:
Total: 180 h
60 h lecture and exercise course (attendance)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)

Conditions: none		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Spintronics
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- N. W. Ashcroft, N. D. Mermin, Solid State Physics, Cengage Learning (2011), ISBN: 81-315-0052-7
- C. Felser, G. H. Hechter, Spintronics - From Materials to Devices, Springer (2013), ISBN: 978-90-481-3831-9
- S. Bandyopadhyay, M. Cahay, Introduction to Spintronics, CRC Press (2008), ISBN: 978-0-9493-3133-6

Part of the Module: Spintronics (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Examination
Spintronics
written exam / length of examination: 90 minutes
Examination Prerequisites:
Spintronics

Module PHM-0057: Physics of Thin Films		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. German Hammerl		
Contents: • Layer growth • Thin film technology • Analysis of thin films • Properties and applications of thin films		
Learning Outcomes / Competences: The students: • know methods of thin film technology and material properties and applications of thin films, • have acquired skills of grouping the various technologies for producing thin layers with respect to their properties and applications, and • have the competence to deal with current problems in the field of thin film technology largely autonomous. • Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results.		
Workload: Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: none		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Physics of Thin Films
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:
- H. Frey, G. Kienel, Dünnschichttechnologie (VDI Verlag, 1987)
- H. Lüth, Solid Surfaces, Interfaces and Thin Films (Springer Verlag, 2001)
- A. Wagendristel, Y. Wang, An Introduction to Physics and Technology of Thin Films (World Scientific Publishing, 1994)
- M. Ohring, The Materials Science of Thin Films (Academic Press, 1992)

Examination

Physics of Thin Films

written exam / length of examination: 90 minutes

Examination Prerequisites:

Physics of Thin Films

Module PHM-0056: Ion-Solid Interaction		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: • Introduction (areas of scientific and technological application, principles) • Fundamentals of atomic collision processes (scattering, cross-sections, energy loss models, potentials in binary collision models) • Ion-induced modification of solids (integrated circuit fabrication with emphasis on ion induced phenomena, ion implantation, radiation damage, ion milling and etching (RIE), sputtering, erosion, deposition) • Transport phenomena • Analysis with ion beams		
Learning Outcomes / Competences: The students: • know the physical principles and the basical mechanisms of the interaction between particles and solid state bodies in the energy range of eV to MeV, • are able to choose adequate physical models for specific technological and scientific applications, and • have the competence to work extensively autonomous on problems concerning the interaction between ions and solid state bodies. • Integrated acquirement of soft skills.		
Workload: Total: 180 h 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Basic Courses in Physics I–IV, Solid State Physics, Nuclear Physics		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Ion-Solid Interaction **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: see module description

Literature:

- R. Smith, Atomic and ion collisions in solids and at surfaces (Cambridge University Press, 1997)
- E. Rimini, Ion implantation: Basics to device fabrication (Kluwer, 1995)
- W. Eckstein: Computer Simulation of Ion-Solid Interactions (Springer, 1991)
- H. Ryssel, I. Ruge: Ionenimplantation (Teubner, 1978)
- Y. H. Ohtsuki: Charged Beam Interaction with Solids (Taylor & Francis, 1983)
- J. F. Ziegler (Hrsg.): The Stopping and Range of Ions in Solids (Pergamon)
- R. Behrisch (Hrsg.): Sputtering by Particle Bombardment (Springer)
- M. Nastasi, J. K. Hirvonen, J. W. Mayer: Ion-Solid Interactions: Fundamentals and Applications (Cambridge University Press, 1996)
- http://www.SRIM.org

Assigned Courses:

Ion-Solid Interaction (lecture)

Part of the Module: Ion-Solid Interaction (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Ion-Solid Interaction (Tutorial) (exercise course)

Examination

Ion-Solid Interaction

written exam / length of examination: 90 minutes

Examination Prerequisites:

Ion-Solid Interaction

Module PHM-0069: Applied Magnetic Materials and Methods *Applied Magnetic Materials and Methods*	6 ECTS/LP
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Manfred Albrecht	

Contents:

- Basics of magnetism
- Ferrimagnets, permanent magnets
- Magnetic nanoparticles
- Superparamagnetism
- Exchange bias effect
- Magnetoresistance, sensors
- Experimental methods (e.g. Mößbauer Spectroscopy, mu-SR)

Learning Outcomes / Competences:

- The students know the basic terms and concepts of magnetism,
- get a profound understanding of basic physical relations and their applications,
- acquire the ability to describe qualitative observations, interpret quantitative measurements, and develop mathematical descriptions of physical effects of chosen magnetic material systems.
- Integrated acquirement of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.

Workload:
Total: 180 h
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
60 h lecture and exercise course (attendance)

Conditions: Basics in solid state physics		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Applied Magnetic Materials and Methods
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:
to be announced at the beginning of the lecture

Part of the Module: Applied Magnetic Materials and Methods (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Examination
Applied Magnetic Materials and Methods
oral exam / length of examination: 30 minutes
Examination Prerequisites:
Applied Magnetic Materials and Methods

Module PHM-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons *Solid State Spectroscopy with Synchrotron Radiation and Neutrons*	6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Christine Kuntscher	

Contents:

1. Electromagnetic radiation: description, generation, detection [5]
2. Spectral analysis of electromagnetic radiation: monochromators, spectrometer, interferometer [2]
3. Excitations in the solid state: Dielectric function [2]
4. Infrared spectroscopy
5. Ellipsometry
6. Photoemission spectroscopy
7. X-ray absorption spectroscopy
8. Neutrons: Sources, detectors
9. Neutron scattering

Learning Outcomes / Competences:

The students:

- know the basics of spectroscopy and important instrumentation and methods,
- have acquired the skills of formulating a mathematical-physical ansatz in spectroscopy and can apply these in the field of solid state spectroscopy,
- have the competence to deal with current problems in solid state spectroscopy autonomously, and are able to judge proper measurement methods for application.
- Integrated acquirement of soft skills.

Workload:

Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions: basic knowledge in solid-state physics		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- H. Kuzmany, Solid State Spectroscopy (Springer)
- N. W. Ashcroft, N. D. Mermin, Solid State Physics (Holt, Rinehart and Winston)
- J. M. Hollas, Modern Spectroscopy

Assigned Courses:

Solid State Spectroscopy with Synchrotron Radiation and Neutrons (lecture)

Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Solid State Spectroscopy with Synchrotron Radiation and Neutrons (Tutorial) (exercise course)

Examination

Solid State Spectroscopy with Synchrotron Radiation and Neutrons

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Solid State Spectroscopy with Synchrotron Radiation and Neutrons

Module PHM-0051: Biophysics and Biomaterials *Biophysics and Biomaterials*	6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Stefan Thalhammer	
Contents: • Radiation Biophysics • Microfluidics • Membranes • Membranal transport	
Learning Outcomes / Competences: The students: • learn basic terms, concepts and phenomena of biological physics, • learn models of the (bio)polymer-theory, microfluidic, radiation biophysics, nanobiotechnology, membranes and neuronal networks, • adapt skills in the independent processing of problems and deal with current literature. They will be able to translate a biological oberservation into a physical question. • Integrated acquirement of soft skills: autonomous working with specialist literature in english, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.	
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study)	
Conditions: Mechanics, Thermodynamics, Statistical Physics, basic knowledge in Molecular Biology	

Frequency: each semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Biophysics and Biomaterials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Contents:

- Radiation Biophysics
  - Radiation sources
  - Interaction of radiation with biological matter
  - Radiation protection principles
  - Low dose radiation
  - LNT model in radiation biophysics
- Microfluidics
  - Life at Low Reynolds Numbers
  - The Navier-Stokes Equation
  - Low Reynolds Numbers – The Stokes Equation
  - Breaking the Symmetry
- Membranes
  - Thermodynamics and Fluctuations
  - Thermodynamics of Interfaces
  - Phase Transitions – 2 state model
  - Lipid membranes and biological membranes, membrane elasticity
- Membranal transport
  - Random walk, friction and diffusion
  - Transmembranal ionic transport and ion channels
  - Electrophysiology of cells
  - Neuronal Dynamics

Literature:

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle, R. Zengerle, Microfluidic platforms for lab-on-a-chip applications, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- lecture notes

Assigned Courses:

Biophysics and Biomaterials (lecture)

Part of the Module: Biophysics and Biomaterials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Biophysics and Biomaterials (Tutorial) (exercise course)

Examination

Biophysics and Biomaterials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Biophysics and Biomaterials

Module PHM-0160: Dielectric and Optical Materials *Dielectric and Optical Materials*	6 ECTS/LP
Version 1.1.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer	

Contents:

Optical materials:

- Fundamentals of electromagnetic wave propagation in homogenous media (refraction, reflection, transmission, absorption)
- Anisotropic media, linear optics
- Optical properties semiconductors/insulators, molecular materials, metals
- Absorption and Luminescence, excitons, luminescence centers
- optoelectronics, detectors, light emitting devices
- quantum confinement

Dielectric materials:

- Experimental techniques: quantities, broadband dielectric spectroscopy, nonlinear and polarization measurements
- Dynamic processes in dielectric materials: relaxation processes, phenomenological models
- Dielectric properties of disordered matter: liquids, glasses, plastic crystals
- Charge transport: hopping conductivity, universal dielectric response, ionic conductors
- Maxwell-Wagner relaxations: equivalent-circuits, applications (supercapacitors), colossal-dielectric-constant materials
- Ferroelectricity: dielectric properties, polarization, relaxor ferroelectrics, applications
- Multiferroic materials: mechanisms, materials, applications

Learning Outcomes / Competences:

Students know the fundamentals of electromagnetic wave propagation and have a sound background for a broad spectrum of dielectric and optical phenomena. They are able to analyze materials requirements and have the competence to select materials for different kinds of applications.

Remarks:

Elective compulsory module

Workload:

Total: 180 h
60 h lecture and exercise course (attendance)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)

Conditions: Basic knowledge of solid state physics		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Dielectric and Optical Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 4

Literature:

Mark Fox, Optical Properties of Solids, Oxford Master Series

Assigned Courses:

Dielectric and Optical Materials (lecture)

Examination

Dielectric and Optical Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Dielectric and Optical Materials

Module PHM-0059: Magnetism	6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Hans-Albrecht Krug von Nidda	

Contents:

- History, basics
- Magnetic moments, classical and quantum phenomenology
- Exchange interaction and mean-field theory
- Magnetic anisotropy and magnetoelastic effects
- Thermodynamics of magnetic systems and applications
- Magnetic domains and domain walls
- Magnetization processes and micro magnetic treatment
- AC susceptibility and ESR
- Spintransport / spintronics
- Recent problems of magnetism

Learning Outcomes / Competences:

The students:

- know the basic properties and phenomena of magnetic materials and the most important methods and concepts for their description, like mean-field theory, exchange interactions and micro magnetic models,
- have the ability to classify different magnetic phenomena and to apply the corresponding models for their interpretation, and
- have the competence independently to treat fundamental and typical topics and problems of magnetism.
- Integrated acquirement of soft skills.

Workload:

Total: 180 h
60 h lecture and exercise course (attendance)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)

Conditions: basics of solid-state physics and quantum mechanics		
Frequency: annually	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Magnetism
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- D. H. Martin, Magnetism in Solids (London Iliffe Books Ltd.)
- J. B. Goodenough, Magnetism and the Chemical Bond (Wiley)
- P. A. Cox, Transition Metal Oxides (Oxford University Press)
- C. Kittel, Solid State Phyics (Wiley)
- D. C. Mattis, The Theory of Magnetism (Wiley)
- G. L. Squires, Thermal Neutron Scattering (Dover Publications Inc.)

Assigned Courses:

Magnetism (lecture)

Part of the Module: Magnetism (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Magnetism (Tutorial) (exercise course)

Examination

Magnetism

written exam / length of examination: 90 minutes

Examination Prerequisites:

Magnetism

Module PHM-0048: Physics and Technology of Semiconductor Devices *Physics and Technology of Semiconductor Devices*	6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: Prof. Dr. Hubert J. Krenner

Contents:

1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport)
2. Semiconductor diodes and transistors
3. Semiconductor technology

Learning Outcomes / Competences:

- Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport.
- Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors.
- Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes and transistors
- Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication.
- Integrated acquisition of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:
recommended prerequisites: basic knowledge in solid state physics, statistical physics and quantum mechanics.

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Physics and Technology of Semiconductor Devices
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Yu und Cardona: Fundamentals of Semiconductors (Springer)
- Sze: Physics of Semiconductor Devices (Wiley)
- Sze: Semiconductor Devices (Wiley)
- Madelung: Halbleiterphysik (Springer)
- Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)

Assigned Courses:

Physics and Technology of Semiconductor Devices (lecture)

Part of the Module: Physics and Technology of Semiconductor Devices (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Contents:

see module description

Assigned Courses:

Physics and Technology of Semiconductor Devices (Tutorial) (exercise course)

Examination

Physics and Technology of Semiconductor Devices

written exam / length of examination: 90 minutes

Examination Prerequisites:

Physics and Technology of Semiconductor Devices

Module PHM-0049: Nanostructures / Nanophysics *Nanostructures / Nanophysics*	6 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Hubert J. Krenner	

Contents:

1. Semiconductor quantum wells, wires and dots, low dimensional electron systems
2. Magnetotransport in low-dimensional systems, Quanten-Hall-Effect, Quantized conductance
3. Optical properties of quantum wells and quantum dots and their application in modern optoelectonic devices
4. Nanofabrication techniques

Learning Outcomes / Competences:

- Basic knowledge of the fundamental concepts in modern nanoscale science
- Profound knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics
- Knowledge of different fabrication approaches using bottom-up and top-down techniques
- Application of these concepts to tackle present problems in nanophysics
- Integrated acquirement of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.

Workload:
Total: 180 h
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using literarture (self-study)
60 h lecture and exercise course (attendance)

Conditions: recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Nanostructures / Nanophysics
Mode of Instruction: lecture
Language: English
Frequency: each summer semester
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:

- Yu und Cardona: Fundamentals of Semiconductors
- Singh:Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)
- Davies: The Physics of low-dimensional Semiconductors (Cambridge University Press)

Examination

Nanostructures / Nanophysics

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Nanostructures / Nanophysics

Module PHM-0054: Chemical Physics II		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
Contents: • Introduction to computational chemistry • Hartree-Fock Theory • DFT in a nutshell • Prediction of reaction mechanisms • calculation of physical and chemical properties		
Learning Outcomes / Competences: The students: • know the basic quantum chemical methods of chemical physics to interpret the electronic structures in molecules and solid-state compounds, • have therefore the competence to autonomously perform simple quantum chemical calculations using Hartree-Fock and Density Functional Theory (DFT) and to interpret the electronic structure of functional molecules and materials with regard to their chemical and physical properties • Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.		
Remarks: It is possible for students to do quantum chemical calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: It is highly recommended to complete the module Chemical Physics I first.		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Chemical Physics II **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description

Literature:

- I. N. Levine, Quantum Chemistry, Pearson, 7th ed **2013**.
- A. Szabo, N. S. Ostlund, Modern Quantum Chemistry, Dover, **1996** (EbookCentral ebook).
- E. G. Lewars, Computational Chemistry, Springer, **2011**.
- D. C. Young, Computational Chemistry: A practical guide for applying techniques to real world problems, Wiley ebook, **2002**.
- R. A. van Santen, Ph. Sautet, Computational Methods in Catalysis and Materials Science, Wiley ebook, **2009**.
- P. Popelier, Atoms in Molecules: An Introduction, Pearson Education Limited, **2000**.
- A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc. Pittsburg, PA.

Assigned Courses:

Chemical Physics II (lecture)

Part of the Module: Chemical Physics II (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see module description

Assigned Courses:

Chemical Physics II (Tutorial) (exercise course)

Examination

Chemical Physics II

written exam / length of examination: 90 minutes

Examination Prerequisites:

Chemical Physics II

Module PHM-0161: Coordination Materials	6 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer
Dr. Hana Bunzen

Contents:

A) Basics of coordination Chemistry

- Historical development of coordination chemistry [2]
- Structures and nomenclature rules [2]
- Chemical bonds in transition metal coordination compounds [3]
- Stability of transition metal coordination compounds [2]
- Characteristic reactions [3]

B) Selected classes of functional materials

- Bioinorganic chemistry [3]
- Coordination polymers / metal-organic frameworks [3]
- Coordination compounds in medical applications [3]
- Photochemistry of coordination compounds [3]

Learning Outcomes / Competences:

The students

- shall acquire knowledge about concepts of chemical bonding in coordination chemistry (main emphasis: d-block transition metal compounds),
- broaden their capabilities to interpret UV/vis absorption spectra and to predict stability and reactivity of coordination compounds,
- learn how to transfer concepts of coordination chemistry onto topics of materials sciences.
- Integrated acquirement of soft skills.

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

Total: 180 h
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions:

Recommended: The lecture course is based on the courses "Chemistry I", "Chemistry II"

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Coordination Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Literature:

- Joan Ribas Gisbert, Coordination Chemistry, Wiley-VCH
- Lutz H. Gade, Koordinationschemie, Wiley-VCH
- As well as selected reviews and journals articles cited on the slides

Assigned Courses:

Coordination Materials (lecture)

Part of the Module: Coordination Materials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Coordination Materials (Tutorial) (exercise course)

Examination

Coordination Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Coordination Materials

Module PHM-0113: Advanced Solid State Materials		6 ECTS/LP
Version 1.0.0 (since WS10/11) Person responsible for module: Prof. Dr. Henning Höppe		
Contents: • Repitition of concepts • Novel silicate-analogous materials • Luminescent materials • Pigments • Heterogeneous catalysis		
Learning Outcomes / Competences: • The students are aware of correlations between composition, structures and properties of functional materials, • acquire skills to predict the properties of chemical compounds, based on their composition and structures, • gain competence to evaluate the potential of functional materials for future technological developments, and • will know how to measure the properties of these materials. • Integrated acquirement of soft skills		
Workload: Total: 180 h 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Contents of the modules Chemie I, and Chemie II or Festkörperchemie (Bachelor Physik, Bachelor Materialwissenschaften)		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Advanced Solid State Materials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: see module description
Contents: see module description
Literature: • A. West, Solid State Chemistry and Its Applications • L. Smart, E. Moore, Solid State Chemistry • Scripts Solid State Chemistry and Chemistry I and II

Examination

Advanced Solid State Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Advanced Solid State Materials

Module PHM-0218: Novel Methods in Solid State NMR Spectroscopy		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
Contents: The physical basis of nuclear magnetic resonance Pulsed NMR methods; Fourier Transform NMR Internal interactions Magic Angle Spinning Modern pulse sequences or how to obtain specific information about the structure and dynamics of solid materials Recent highlights of the application of modern solid state NMR in materials science		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each summer semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Novel Methods in Solid State NMR Spectroscopy
Mode of Instruction: lecture
Language: German
Contact Hours: 3

Assigned Courses:

Novel Methods in Solid State NMR Spectroscopy (lecture)

Part of the Module: Novel Methods in Solid State NMR Spectroscopy (Tutorial)
Mode of Instruction: exercise course
Language: German
Contact Hours: 1

Literature:

1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008.
2. H. Günther, NMR spectroscopy, Wiley 2001.
3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
4. D. Canet: NMR - concepts and methods, Springer, 1994.

Assigned Courses:

Novel Methods in Solid State NMR Spectroscopy (Tutorial) (exercise course)

Examination
Novel Methods in Solid State NMR Spectroscopy
written exam / length of examination: 90 minutes

Module PHM-0167: Oxidation and Corrosion	6 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Ferdinand Haider

Contents:

Introduction

Review of thermodynamics

Chemical equilibria

Electrochemistry

Electrode kinetics

High temperature oxidation

Localized corrosion

- Shallow pit corrosion
- Pitting corrosion
- Crevice corrosion
- Intercrystalline corrosion
- Stress corrosion cracking
- Fatigue corrosion
- Erosion corrosion
- Galvanic corrosion

Water and seawater corrosion

Corrosion monitoring

Corrosion properties of specific materials

Specific corrosion problems in certain branches

- Oil and Gas industry
- Automobile industry
- Food industry

Corrosion protection

- Passive layers
- Reaction layers (Diffusion layers …)
- Coatings (organic, inorganic)
- Cathodic, anodic protection
- Inhibitors

Learning Outcomes / Competences:

The students:

- know the the fundamental basics, mechanics, and types of corrosion processes,
- obtain specific knowledge of one type of corrosion.

Workload:

Total: 180 h
120 h studying of course content using provided materials (self-study)
60 h lecture and exercise course (attendance)

Conditions:	**Credit Requirements:**
Recommended: good knowledge in materials science, basic knowledge in physical chemistry	written exam (90 min)

Frequency: each winter semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Oxidation and Corrosion
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Literature:
- Schütze: Corrosion and Environmental Degradation

Part of the Module: Oxidation and Corrosion (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Examination
Oxidation and Corrosion
written exam / length of examination: 90 minutes
Examination Prerequisites:
Oxidation and Corrosion

Module PHM-0164: Characterization of Composite Materials *Characterization of Composite Materials*	6 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Markus Sause

Contents:
The following topics are presented:

- Introduction to composite materials
- Applications of composite materials
- Mechanical testing
- Thermophysical testing
- Nondestructive testing

Learning Outcomes / Competences:
The students:

- acquire knowledge in the field of materials testing and evaluation of composite materials.
- are introduced to important concepts in measurement techniques, and material models applied to composites.
- are able to independently acquire further information of the scientific topic using various forms of information.

Workload:
Total: 180 h
60 h lecture and exercise course (attendance)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)

Conditions: Recommended: basic knowledge in materials science, particularly in composite materials		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Characterization of Composite Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Literature:

- Morgan: Carbon fibers and their composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe
- Dowling: Mechanical behaviour of materials
- Issler: Festigkeitslehre - Grundlagen
- Landau, Lifschitz: Theoretische Physik Vol. 7

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

Assigned Courses:

Characterization of Composite Materials (lecture)

Part of the Module: Characterization of Composite Materials (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Literature:
see lecture

Assigned Courses:

Characterization of Composite Materials (Tutorial) (exercise course)

Examination
Characterization of Composite Materials
written exam / length of examination: 90 minutes
Examination Prerequisites:
Characterization of Composite Materials

Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Frau Dr. Judith Moosburger-Will		
Contents: The following topics are treated: • production of fibers (e.g. glass, carbon, or ceramic fibers) • Physical and chemical properties of fibers and their precursor materials • Physical and chemical properties of commonly used polymeric and ceramic matrix materials • Semi-finished products • Composite production technologies • Application of fiber reinforced materials		
Learning Outcomes / Competences: The students: • know the application areas of composite materials. • know the basics of production technologies of fibers, polymeric, and ceramic matrices and fiber reinforced materials. • are introduced to physical and chemical properties of fibers, matrices, and fiber reinforced materials. • are able to independently acquire further knowledge of the scientific topic using various forms of information.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study)		
Conditions: Recommended: basic knowledge in materials science, basic lectures in organic chemistry		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3

Literature:

- Morgan: Carbon fibers and their composites
- Ehrenstein: Polymeric materials
- Krenkel: Ceramic Matrix Composites
- Henning, Moeller: Handbuch Leichtbau
- Schürmann: Konstruieren mit Faser-Kunstoff-Verbunden
- Neitzel, Mitschang: Handbuch Verbundwerkstoffe

Further litrature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Literature:

see lecture

Examination

Fiber Reinforced Composites: Processing and Materials Properties

written exam / length of examination: 90 minutes

Examination Prerequisites:

Fiber Reinforced Composites: Processing and Materials Properties

Module PHM-0165: Introduction to Mechanical Engineering		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Dr. - Ing. Johannes Schilp		
Contents: The following topics are treated: • Statics and dynamics of objects • Transmissions and mechanisms • Tension, shear and bending moment • Hydrostatics • Hydrodynamics • Strength of materials and solid mechanics • Instrumentation and measurement • Mechanical design (including kinematics and dynamics)		
Learning Outcomes / Competences: The students understand and are able to apply basic concepts of physics and materials science to: • Engineering applications • Mechanical testing • Instrumentation • Mechanical design		
Workload: Total: 180 h		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mechanical Engineering
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Part of the Module: Mechanical Engineering (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Examination
Introduction to Mechanical Engineering
written exam / length of examination: 90 minutes
Examination Prerequisites:
Introduction to Mechanical Engineering

Module MRM-0052: Functional Polymers		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Klaus Ruhland		
Contents: • Introduction to polymer science • Elastomers and elastoplastic materials • Memory-shape polymers • Piezoelectric polymers • Electrically conducting polymers • Ion-conducting polymers • Magnetic polymers • Photoresponsive polymers • Polymers with second order non-linear optical properties • Polymeric catalysts • Self-healing polymers • Polymers in bio sciences>		
Learning Outcomes / Competences: The students learn how polymeric materials can be designed and applied to act in a smart manner on an external mechanical, magnetic, electric, optical, thermal or chemical impact.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: Recommended: Attendance to PHM-0035 (Chemie I), PHM-0036 (Chemie II) and MRM-0050 (Grundlagen der Polymerchemie und -physik)		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Functional Polymers **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Assigned Courses: **Functional Polymers** (lecture)
Part of the Module: Functional Polymers (Tutorial) **Mode of Instruction:** exercise course **Language:** English **Contact Hours:** 1
Assigned Courses:

Functional Polymers (Tutorial) (exercise course)

Examination

Functional Polymers

written exam / length of examination: 90 minutes

Examination Prerequisites:

Functional Polymers

Module PHM-0168: Modern Metallic Materials	6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider	

Contents:

Introduction

Review of physical metallurgy

Steels:

- principles
- common alloying elements
- martensitic transformations
- dual phase steels
- TRIP and TWIP steels
- maraging steel
- electrical steel
- production and processing

Aluminium alloys:

- 2xxx
- 6xxx
- 7xxx
- Processing – creep forming, hydroforming, spinforming

Titanium alloys

Magnesium cast alloys

Superalloys

Intermetallics, high entropy alloys

Copper, brass, bronzes

Metallic glasses

Alloy design

Learning Outcomes / Competences:

Students

- learn about all kinds of actual metallic alloys, their properties and how these properties can be derived from basic concepts

Workload:

Total: 180 h
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)
60 h lecture and exercise course (attendance)

Conditions: Recommended: Knowledge of physical metallurgy and physical chemistry		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Modern Metallic Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 4

Literature:

Cahn-Haasen-Kramer: Materials Science and Technology

Original literature

Examination

Modern Metallic Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Modern Metallic Materials

Module PHM-0196: Surfaces and Interfaces II: Joining processes	6 ECTS/LP

Version 1.1.0 (since WS15/16)
Person responsible for module: Prof. Dr. Siegfried Horn
Dozenten: Prof. Dr. Siegfried Horn, Dr. Judith Moosburger-Will

Learning Outcomes / Competences:
The students

- know the application areas of composite materials
- know the basics of cohesion and adhesion
- know the basics of joining techniques
- are introduced to physical and chemical properties metal-metal, metal-polymer and polymer-polymer interfaces
- Are able to independently acquire further knowledge of the scientific topic using various forms of information.

Workload:
Total: 180 h

Conditions:	**Credit Requirements:**
Basic knowledge on materials science, lecture “Surfaces and Interfaces I” Module Surfaces and Interfaces (PHM-0117) - recommended	Bestehen der Modulprüfung

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Surfaces and Interfaces II: Joining processes
Mode of Instruction: lecture
Lecturers: Prof. Dr. Siegfried Horn
Language: German
Contact Hours: 3

Contents:
The following topics are treated:

- Introduction to adhesion
- Role of surface and interface properties
- Introduction to interactions at surfaces and interfaces
- Adhesion theories
- Surface and interface energy
- Surface treatment techniques
- Joining techniques
- Physical and chemical properties of joints
- Applications

Literature:
Literature, including actual scientific papers and reviews, will be announced at the beginning of the lecture.

Assigned Courses:

Surfaces and Interfaces II: Joining processes (lecture)

Examination

Surfaces and Interfaces II: Joining processes

written exam / length of examination: 90 minutes

Examination Prerequisites:

Surfaces and Interfaces II: Joining processes

Parts of the Module

Part of the Module: Übung zu Surfaces and Interfaces II: Joining processes

Mode of Instruction: exercise course

Language: German

Contact Hours: 1

Assigned Courses:

Übung zu Surfaces and Interfaces II: Joining processes (exercise course)

Module PHM-0122: Non-Destructive Testing *Non-Destructive Testing*		6 ECTS/LP
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Markus Sause		
Contents: • Introduction to nondestructive testing methods • Visual inspection • Ultrasonic testing • Guided wave testing • Acoustic emission analysis • Thermography • Radiography • Eddy current testing • Specialized nondestructive methods		
Learning Outcomes / Competences: The students • acquire knowledge in the field of nondestructive evaluation of materials, • are introduced to important concepts in nondestructive measurement techniques, • are able to independently acquire further knowledge of the scientific topic using various forms of information. • Integrated acquirement of soft skills		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: Basic knowledge on materials science, in particular composite materials		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Non-Destructive Testing **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: see module description

Literature:

- Raj: Practical Non-destructive Testing
- Shull: Nondestructive Evaluation - Theory and Applications
- Krautkrämer: Ultrasonic testing of materials
- Grosse: Acoustic Emission Testing
- Rose: Ultrasonic waves in solid media
- Maldague: Nondestructive Evaluation of Materials by Infrared Thermography
- Herman: Fundamentals of Computerized Tomography

Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.

Part of the Module: Non-Destructive Testing (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Non-Destructive Testing

written exam / length of examination: 90 minutes

Examination Prerequisites:

Non-Destructive Testing

Module PHM-0203: Physics of Cells *Physics of Cells*	6 ECTS/LP

Version 1.0.0 (since WS16/17)
Person responsible for module: Prof. Dr. Achim Wixforth
Dr. Christoph Westerhausen

Contents:

- Physical principles in Biology
- Cell components: cell membrane, organelles, cytoskeleton
- Thermodynamics of proteins and biological membranes
- Physical methods and techniques for studying cells
- Cell adhesion – interplay of specific, universal and elastic forces
- Tensile strength and elasticity of tissue - macromolecules of the extra cellular matrix
- Micro mechanics of the cell
- Cell-cell-communication
- Cell migration
- Cell stimulation and cell-computer-communication

Learning Outcomes / Competences:
The students

- get to know a highly interdisciplinary field of physics.
- learn the basics on physical properties of human cells, as building blocks of living organisms.
- learn about the impact of forces on the behavior of living cells
- learn physical description of fundamental biological processes.
- are able to express biophysical questions and define model systems to answer these questions.

The students learn the following key qualifications:

- self-dependent working with English specialist literature.
- presentation techniques.
- documentation of experimental results.
- interdisciplinary thinking and working.

Workload:
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
60 h lecture and exercise course (attendance)

Conditions: Mechanics, Thermodynamics		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Physics of Cells
Mode of Instruction: lecture
Language: English / German
Contact Hours: 2

Learning Outcome:
see module description

Contents:
see module description

Literature:
- Sackmann, Erich, and Rudolf Merkel. *Lehrbuch der Biophysik*. Wiley-VCH, 2010.
- Nelson, Philip. *Biological physics*. New York: WH Freeman, 2004.
- Boal, D. *Mechanics of the Cell*. Cambridge University Press, 2012.
- Lecture notes

Part of the Module: Physics of Cells (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 2

Learning Outcome:
see module description

Contents:
see module description

Literature:
see module description

Examination
Physics of Cells
oral exam / length of examination: 30 minutes

Module PHM-0217: Advanced X-ray and Neutron Diffraction Techniques		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
Contents: Subjects of the lecture are advanced X-ray and neutron diffraction techniques: • The failure of the standard *I*ndependent *A*tom *M*odel (IAM) in X-ray diffraction • Beyond the standard model: The multipolar model • How to obtain and analyze experimental charge densities • How to derive chemical and physical properties from diffraction data • Applications of joined X-ray and neutron diffraction experiments		
Learning Outcomes / Competences: The students: • gain basic theoretical knowledge on the reconstruction of accurate electron density maps from X-ray and neutron diffraction data • know the basics of the *Quantum Theory of Atoms in Molecules* • are competent to analyze the topology of the electron density and correlate it with the physical and chemical properties of materials		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: It is recommended to complete the Module PHM-0053 Chemical Physics I.		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced X-ray and Neutron Diffraction Techniques
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Literature:

1. C. Giacovazzo et al., Fundamentals of Crystallography, Oxford Univ. Press, 2011.
2. P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.
3. P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.
4. P. Coppens, X-ray Charge Densities and Chemical Bonding, Oxford Univ. Press, 1997.
5. P. Popelier, Atoms in Molecules: An Introduction, Longman, 1999.

Assigned Courses:

Advanced X-ray and Neutron Diffraction Techniques (lecture)

Part of the Module: Advanced X-ray and Neutron Diffraction Techniques (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

Advanced X-ray and Neutron Diffraction Techniques (Tutorial) (exercise course)

Examination

Advanced X-ray and Neutron Diffraction Techniques

written exam / length of examination: 90 minutes

Examination Prerequisites:

Advanced X-ray and Neutron Diffraction Techniques

Module PHM-0146: Method Course: Electronics for Physicists and Materials Scientists *Method Course: Electronics for Physicists and Materials Scientists*	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Andreas Hörner

Contents:

1. Basics in electronic and electrical engineering [4]
2. Quadrupole theory [2]
3. Analog technique, transistor and opamp circuits [5]
4. Boolean algebra and logic [4]
5. Digital electronics and calculation circuits [6]
6. Microprocessors and Networks [4]
7. Basics in Electronic [8]
8. Implementation of transistors [8]
9. Operational amplifiers [8]
10. Digital electronics [8]
11. Practical circuit arrangement [8]

Learning Outcomes / Competences:
The students:

- know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the laboratory,
- have skills in easy circuit design, measuring and control technology, analog and digital electronics,
- have expertise in independent working on circuit problems. They can calculate and develop easy circuits.

Remarks:
ELECTIVE COMPULSORY MODULE

Attendance in the **Method Course: Electronics for Physicists and Materials Scientists (combined lab course AND lecture)** excludes credit points for the lecture **Electronics for Physicists and Materials Scientists.**

Workload:
Total: 240 h
140 h studying of course content using provided materials (self-study)
100 h lecture and exercise course (attendance)

Conditions: none		**Credit Requirements:** written report (one per group)
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 7	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Electronics for Physicists and Materials Scientists
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Literature:

- Paul Horowitz: The Art of Electronics (Cambridge University Press)
- National Instruments: MultiSim software package (available in lecture)

Assigned Courses:

Method Course: Electronics for Physicists and Materials Scientists (lecture)

Part of the Module: Method Course: Electronics for Physicists and Materials Scientists (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 3

Assigned Courses:

Method Course: Electronics for Physicists and Materials Scientists (Practical Course) (internship)

Examination
Method Course: Electronics for Physicists and Materials Scientists
oral exam / length of examination: 30 minutes
Examination Prerequisites:
Method Course: Electronics for Physicists and Materials Scientists

Module PHM-0147: Method Course: Electron Microscopy		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
Contents: 1. Scanning electron microscopy (SEM) 2. Transmission electron microscopy (TEM)		
Learning Outcomes / Competences: The students: • get introduced to the basics of scanning electron microscopy and transmission electron microscopy, using lectures to teach the theoretical basics, which are afterwards deepened using practical courses, • are able to characterize materials using different electron microscopy techniques and to decide, if the technique is feasible for a certain problem.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h 150 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
Conditions: Recommended: knowledge of solid-state physics, reciprocal lattice		**Credit Requirements:** regular participation, oral presentation (10 min), written report (one report per group)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Method Course: Electron Microscopy **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 2

Contents:

SEM:

1. Layout of Electron Microscopes and Electron Optical Components
2. Electron Solid Interactions
3. Contrast Formation in Scanning Electron Microscopy (SEM)
4. SE/BSE contrast
5. Electron Back Scattering Diffraction (EBSD)
6. Analytical techniques
7. Special Applications of SEM

TEM:

1. TEM specimen preparation techniques
2. Components of a TEM, principle lens design, lens aberrations
3. Electron diffraction: fundamentals
4. Contrast formation at bright field, dark field, weak beam dark field, and many beam conditions, „chemical“ imaging
5. Bright field, dark field, weak beam dark field imaging of dislocations
6. Kinematical theory of electron wave propagation in crystals
7. Howie Whelan equations, contrast of defects
8. High resolution TEM, lattice imaging of crystals
9. Advanced diffraction techniques: Kikuchi patterns, HOLZ lines and Convergent Beam Diffraction (CBED)
10. Image simulation
11. Analytical TEM: Electron energy loss spectroscopy & energy filtered TEM

Literature:

- D.B.Williams and C.B.Carter, Transmission Electron Microscopy,Plenum Press, New York/London, 1996
- M.A. Hirsch, A. Howie, R. Nicholson, D.W. Pashley, M.J. Whelan, Electron microscopy of thin crystals, Krieger Publishing Company, Malabar (Florida), 1977
- L. Reimer, Transmission electron microscopy, Springer Verlag, Berlin/Heidelberg/New York, 1984
- P.J. Goodhew, Thin foil preparation for electron microscopy,Elsevier, Amsterdam, 1985
- P.R. Buseck, J.M. Cowley, L. Eyring, High-resolution transmission electron microscopy, Oxford University Press, 1988
- E. Hornbogen, B. Skrotzki, Werkstoff-Mikroskopie, Springer Verlag, Berlin/Heidelberg/New York, 1995
- K. Wetzig, In situ scanning electron microscopy in materials research, Akad.-Verl., 1995
- J. I. goldstein, Scanning electron microscopy and x-ray microanalysis, Plenum Press, 1992
- L. Reimer, Scanning electron microscopy, Springer Verlag, 1985
- S. L. Flegler, J. W. Heckman, K. L. Klomparens, Elektronenmikroskopie, Spektrum, Akad. Verl., 1995

Part of the Module: Method Course: Electron Microscopy (Practical Course)

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Examination

Method Course: Electron Microscopy

report

Examination Prerequisites:

Method Course: Electron Microscopy

Module PHM-0148: Method Course: Optical Properties of Solids *Method Course: Optical Properties of Solids*	8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer	

Contents:

Electrodynamics of solids

- Maxwell equations
- Electromagnetic waves
- Refraction and interference, Fresnel equations

FTIR spectroscopy

- Fourier transformation
- Michelson-Morley and Genzel interferometer
- Sources and detectors

Terahertz Time Domain spectroscopy

- Generation of pulsed THz radiation
- Gated detection, Austin switches

Elementary excitations in solid materials

- Rotational-vibrational bands
- Infrared-active phonons
- Interband excitations
- Crystal-field excitations

Learning Outcomes / Competences:

The students:

- get to know the basic principles of far-infrared spectroscop and terahertz time-domain-spectroscopy,
- learn about fundamental physical excitations in condensed matter that can be studied by these methods,
- learn to plan and carry out complex experiments,
- learn how to evaluate and analyze optical data.

Remarks:

Workload:

Total: 240 h
90 h lecture and exercise course (attendance)
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)

Conditions:	**Credit Requirements:**
Recommended: basic knowledge in solid-state physics, basic knowledge in electrodynamics and optics	written report

Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Optical Properties of Solids
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Literature:
Mark Fox, Optical Properties of Solids, Oxford Master Series

Assigned Courses:

Method Course: Optical Properties of Solids (lecture)

Part of the Module: Method Course: Optical Properties of Solids (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Optical Properties of Solids (Practical Course) (internship)

Examination
Method Course: Optical Properties of Solids
report
Examination Prerequisites:
Method Course: Optical Properties of Solids

Module PHM-0149: Method Course: Methods in Biophysics

8 ECTS/LP

Method Course: Methods in Biophysics

Version 1.0.0 (since SoSe15)
Person responsible for module: Dr. Stefan Thalhammer

Contents:

Unit radiation biophysics

- Concepts in radiation protection
- Low-dose irradiation biophysics
- DNA repair dynamics of living cells after ionizing radiation
- Confocal scanning laser microscopy

Unit microfluidic

- Microfluidic systems
- Accoustic driven microfluidics
- Calculation of microfluidic problems

Unit analysis

Learning Outcomes / Competences:

The students:

- know basic terms, concepts and phenomena in radiation biophysics,
- acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic analytical systems,
- learn skills in tissue culture and immun-histochemical staining procedures,
- learn skills in fluorescence and confocal scanning microscopy,
- learn skills to calculate fluidic problems on small length scales,
- learn skills to handle microfluidic channel systems.

Remarks:

ELECTIVE COMPULSORY MODULE

The course will partly take place at the Helmholtz Center Munich.

Workload:

Total: 240 h

Conditions:		**Credit Requirements:**
Attendance of the lecture "Biophysics and Biomaterials"		1 written lab report
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Methods in Biophysics

Mode of Instruction: lecture
Language: English
Contact Hours: 2

Assigned Courses:

Method Course: Methods in Biophysics (lecture)

Part of the Module: Method Course: Methods in Biophysics (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Literature:

- T. Herrmann, Klinische Strahlenbiologie – kurz und bündig, Elsevier Verlag, ISBN-13: 978-3-437-23960-1
- J. Freyschmidt, Handbuch diagnostische Radiologie – Strahlenphysik, Strah-lenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle und R. Zengerle, Microfluidic platforms for lab-on-a-chip applica-tions, Lab-on-a-chip, 2007, 7, 1094-1110
- J. Berthier, Microdrops and digital microfluidics, William Andrew Verlag, ISBN:978-0-8155-1544-9
- Lecture notes

Assigned Courses:

Method Course: Methods in Biophysics (Practical Course) (internship)

Examination

Method Course: Methods in Biophysics

report

Examination Prerequisites:

Method Course: Methods in Biophysics

Module PHM-0151: Method Course: Porous Materials - Synthesis and Characterization	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:
Synthesis of porous functional materials (e.g. aerogels, mesoporous silica materials, zeolites, Metal-Organic Frameworks)

Characterization methods

- Structure and composition (XRD, UV/VIS, IR, ESEM, EDX)
- Thermal analysis (TGA)
- Adsorption and diffusion (BET, pore size distribution, pulse chemisorption)
- Catalytic properties (GC/MS, TPO, TPR)

Learning Outcomes / Competences:
The students will learn how to

- use modern solid state preparation techniques (e.g. hydrothermal, solvothermal, microwave synthesis),
- employ analytical methods dedicated to porous materials.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
120 h internship / practical course (attendance)
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions:	**Credit Requirements:**
Recommended: lecture Functional Porous Materials	written report (editing time 3 weeks) + written exam Please note that final grade of the Method Course consists of the maximum point score of of the exam and the grade of the report of the practical part which are weighted (40:60).

Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Porous Materials Synthesis and Characterization (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Examination

Method Course: Porous Materials Synthesis and Characterization

written exam / length of examination: 45 minutes

Examination Prerequisites:

Method Course: Porous Materials Synthesis and Characterization

Module PHM-0153: Method Course: Magnetic and Superconducting Materials *Method Course: Magnetic and Superconducting Materials*	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Philipp Gegenwart

Contents:
Methods of growth and characterization:

Sample preparation (bulk materials and thin films), e.g.,

- arcmelting
- flux-growth
- sputtering and evaporation

Sample characterization, e.g.,

- X-ray diffraction
- electron microscopy, scanning tunneling microscopy
- magnetic susceptibility, electrical resistivity
- specific heat

Learning Outcomes / Competences:
The students

- get to know the basic methods of materials growth and characterization, such as poly- and single crystal growth, thin-film growth, X-ray diffraction, magnetic susceptibility, dc-conductivity, and specific heat measurements
- are trained in planning and performing complex experiments
- learn to evaluate and analyze the collected data, are taught to work on problems in experimental solid state physics, including analysis of measurement results and their interpretation in the framework of models and theories

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
90 h lecture and exercise course (attendance)

Conditions: Recommended: basic knowledge in solid state physics and quantum mechanics		**Credit Requirements:** presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Magnetic and Superconducting Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Assigned Courses:

Method Course: Magnetic and Superconducting Materials (lecture)

Part of the Module: Method Course: Magnetic and Superconducting Materials (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Magnetic and Superconducting Materials (Practical Course) (internship)

Examination
Method Course: Magnetic and Superconducting Materials
report
Examination Prerequisites:
Method Course: Magnetic and Superconducting Materials

Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy	8 ECTS/LP

Version 2.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Leo van Wüllen

Contents:
Physical foundations of NMR spectroscopy

Internal interactions in NMR spectroscopy

- Chemical shift interaction
- Dipole interaction and
- Quadrupolar interaction

Magic Angle Spinning techniques

Modern applications of NMR in materials science

Experimental work at the Solid-State NMR spectrometers, computer-aided analysis and interpretation of acquired data

Learning Outcomes / Competences:
The students:

- gain basic knowledge of the physical foundations of modern Solid-State NMR spectroscopy,
- gain basic practical knowledge of operating a solid-state NMR spectrometer,
- can -- under guidance -- plan, perform, and analyze modern solid-state NMR experiments for the structural characterization of advanced materials.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
30 h studying of course content using literarture (self-study)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using provided materials (self-study)
90 h lecture and exercise course (attendance)

Conditions:		**Credit Requirements:**
The attendance of the lecture "NOVEL METHODS IN SOLID STATE NMR SPECTROSCOPY" is highly recommended.		Bestehen der Modulprüfung
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Modern Solid State NMR Spectroscopy
Mode of Instruction: seminar
Language: English
Contact Hours: 2

Literature:

- M. H. Levitt, spin Dynamics, John Wiley and Sons, Ltd., 2008.
- H. Günther NMR spectroscopy, Wiley, 2001.
- M. Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
- D. Canet, NMR - concepts and methods, Springer, 1994.

Assigned Courses:

Method Course: Modern Solid State NMR Spectroscopy (seminar)

Part of the Module: Method Course: Modern Solid State NMR Spectroscopy (Practical Course)

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Literature:

1. M. H. Levitt, Spin Dynamics, John Wiley and Sons, Ltd., 2008.
2. H. Günther, NMR spectroscopy, Wiley 2001.
3. M.Duer, Introduction to Solid-State NMR spectroscopy, Blackwell Publishing Ltd., 2004.
4. D. Canet: NMR - concepts and methods, Springer, 1994.

Assigned Courses:

Method Course: Modern Solid State NMR Spectroscopy (Practical Course) (internship)

Examination

Method Course: Modern Solid State NMR Spectroscopy

report / work period for assignment: 2 weeks

Examination Prerequisites:

Method Course: Modern Solid State NMR Spectroscopy

Module PHM-0171: Method Course: Coordination Materials	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Dirk Volkmer
Dr. Hana Bunzen

Contents:

1. Synthesis of metal complexes:
2. Analytical characterization of metal complexes (thermal analysis, UV/vis spectroscopy, IR spectroscopy, X-ray diffraction)
3. Material composition and stability studies
4. Functional coordination materials (spin-crossover materials, oxygen-carrying materials)

Learning Outcomes / Competences:
The students will learn how to:

- prepare transition metal complexes employing modern preparation techniques (e.g. microwave synthesis), inert synthesis conditions (Schlenk technique),
- characterize coordination compounds by selected analytical techniques,
- develop functional coordination materials based on organic / inorganic hybrid compounds,
- employ X-ray diffraction methods for structural analysis.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
120 h lecture and exercise course (attendance)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
20 h studying of course content using provided materials (self-study)

Conditions:		**Credit Requirements:**
none		written report (protocols)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Coordination Materials (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Coordination Materials (Practical Course) (internship)

Part of the Module: Method Course: Coordination Materials (Seminar)
Mode of Instruction: seminar
Language: English
Contact Hours: 2

Literature:

- Chemical databases
- Primary literature

Assigned Courses:

Method Course: Coordination Materials (Seminar) (seminar)

Examination

Method Course: Coordination Materials (Seminar)

seminar

Examination Prerequisites:

Method Course: Coordination Materials (Seminar)

Module PHM-0172: Method Course: Functional Silicate-analogous Materials	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Henning Höppe

Contents:
Synthesis and characterization of functional materials according to the topics:

1. Silicate-analogous compounds
2. Luminescent materials / phosphors
3. Pigments
4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis

Learning Outcomes / Competences:
The students will know how to:

- develop functional materials based on silicate-analogous materials,
- apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),
- work under non-ambient atmospheres (e.g. reducing, inert conditions),
- solve and refine crystal structures from single-crystal data,
- describe and classify these structures properly.

Remarks:
ELECTIVE COPULSORY MODULE

Workload:
Total: 240 h
120 h lecture and exercise course (attendance)
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)

Conditions:		**Credit Requirements:**
Recommended: attendance to the lecture "Advanced Solid State Materials"		written report (protocol)
Frequency: each semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 6

Learning Outcome:
The students will know how to:

- develop functional materials based on silicate-analogous materials,
- apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),
- work under non-ambient atmospheres (e.g. reducing, inert conditions),
- solve and refine crystal structures from single-crystal data,
- describe and classify these structures properly.

Contents:

Synthesis and characterization of functional materials according to the topics:

1. Silicate-analogous compounds
2. Luminescent materials / phosphors
3. Pigments
4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis

Assigned Courses:

Method Course: Functional Silicate-analogous Materials (Practical Course) (internship)

Examination

Method Course: Functional Silicate-analogous Materials

seminar

Examination Prerequisites:

Method Course: Functional Silicate-analogous Materials

Module PHM-0206: Method Course: Infrared Microspectroscopy under Pressure *Method Course: Infrared Microspectroscopy under Pressure*	8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Christine Kuntscher	

Contents:

Electrodynamics of solids

Maxwell equations and electromagnetic waves in matter

Optical variables

Theories for dielectric function:

i. Free carriers in metals and semiconductors (Drude)

ii. Interband absorptions in semiconductors and insulators
iii. Vibrational absorptions
iv. Multilayer systems

FTIR microspectroscopy

Components of FTIR spectrometers
i. Light sources
ii. Interferometers
iii. Detectors

Microscope components
High pressure experiments Equipments

Pressure calibration

Experimental techniques under high pressure
i. IR spectroscopy
ii. Raman scattering
iii. Magnetic measurements
iv. Transport measurements

Learning Outcomes / Competences:

The students

Learn about the basics of the light interaction with various materials and the fundamentals of FTIR microspectroscopy,

Are introduced to the high pressure equipments used in infrared spectroscopy,

Learn to carry out infrared microspectroscopy experiments under pressure,

Learn to analyze the measured optical spectra.

Workload:

Total: 240 h

Conditions: none		**Credit Requirements:** Written report
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Infrared Microspectroscopy under Pressure
Mode of Instruction: lecture
Language: German
Contact Hours: 2

Assigned Courses:

Method Course: Infrared Microspectroscopy under Pressure (lecture)

Part of the Module: Method Course: Infrared Microspectroscopy under Pressure (Practical Course)
Mode of Instruction: laboratory course
Language: German
Contact Hours: 4

Assigned Courses:

Method Course: Infrared Microspectroscopy under Pressure (Practical Course) (internship)

Examination
Method Course: Infrared Microspectroscopy under Pressure
report

Module PHM-0216: Method Course: Thermal Analysis	8 ECTS/LP

Version 1.0.0 (since WS16/17)
Person responsible for module: Prof. Dr. Ferdinand Haider
Dr. Robert Horny

Contents:
Methods of thermal analysis:
- Differential Scanning Calorimetry: DSC, DTA
- Thermo-gravimetric Analysis: TG
- Dilatometry: DIL
- Dynamic-mechanical Analysis: DMA

Advanced Methods:
- Modulated Differential Scanning Calorimetry: MDSC
- Evolved Gas Analysis: EGA GCMS, FTIR

Learning Outcomes / Competences:
The students:

- get to know the basic principles of thermal analysis
- learn about fundamental thermal processes in condensed matter ,e.g. phase transitions and relaxation processes (metals, polymers, ceramics)
- learn to plan and carry out complex experiments and the usage of advanced measurement techniques
- learn how to evaluate and analyze thermal data

Remarks:

Workload:
Total: 240 h
30 h studying of course content using provided materials (self-study)
30 h studying of course content using literarture (self-study)
90 h lecture and exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)

Conditions:		**Credit Requirements:**
Recommended: basic knowledge in solid-state physics		regular participation, oral presentation (10 min), written report
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Thermal Analysis
Mode of Instruction: lecture
Lecturers: Prof. Dr. Ferdinand Haider
Language: English
Contact Hours: 2

Part of the Module: Method Course: Thermal Analysis (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Examination

Method Course: Thermal Analysis

report

Module PHM-0221: Method Course: X-ray Diffraction Techniques	8 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Wolfgang Scherer
PD Dr. Georg Eickerling

Contents:
Subjects of the practical training and the accompanying lecture are the theoretical basics and the practical application of X-ray diffraction techniques:

Data collection and reduction techniques

Symmetry and space group determination

Structural refinements:
• The Rietveld method
• Difference Fourier synthesis

Structure determination:
• Patterson method
• Direct methods

Interpretation of structural refinement results

Errors and Pitfalls: twinning and disorder

Learning Outcomes / Competences:
The students:

- gain basic practical knowledge on structural characterization methods for single- and poly-crystalline samples employing X-ray diffraction techniques,
- have the skill to perform under guidance phase-analyses and X-ray structure determinations
- are competent to analyze hands-on the structure-property relationships of new materials

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h
90 h lecture and exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)
30 h studying of course content using provided materials (self-study)

Conditions: none		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: X-ray Diffraction Techniques
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Part of the Module: Method Course: X-ray Diffraction Techniques (Practical Course)
Mode of Instruction: laboratory course
Language: German
Contact Hours: 4

Examination
Method Course: X-ray Diffraction Techniques
written exam / length of examination: 90 minutes

Module PHM-0234: 2D Materials *2D Materials*	6 ECTS/LP

Version 1.0.1 (since SoSe18)
Person responsible for module: Prof. Dr. Hubert J. Krenner

Contents:
Two-dimensional materials: graphene to emerging new materials, such as transition metal dichalcogenides

1. Fabrication
2. Optical, electronic and vibrational properties
3. Applications in advanced functional devices

Learning Outcomes / Competences:

1. Specify different classes of 2D solid state materials and their properties.
2. Describe and explain preparation and nanofabrication methods for 2D materials.
3. Understand and explain and differentiate between suitable optical and structural characterization methods for 2D materials.
4. Understand and explain phonon properties of 2D materials.
5. Understand and explain magneto quantum transport phenomena such as the quantum Hall effect in graphene
6. Understand and explain absorption, excitonic and spin properties of transition metal dichalcogenides..
7. Understand and explain and discuss applications of 2D materials and their heterostructures for electronic, optoelectronic, spintronics devices and solar energy converstion.

Workload:
Total: 180 h
20 h studying of course content using literarture (self-study)
20 h studying of course content using provided materials (self-study)
60 h lecture (attendance)
80 h studying of course content through exercises / case studies (self-study)

Conditions:
recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.

Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: 2D Materials
Mode of Instruction: lecture
Language: English
Contact Hours: 4
ECTS Credits: 6

Learning Outcome:
see module description

Contents:
see module description

Assigned Courses:

2D Materials (lecture)

Examination

2D Materials

oral exam / length of examination: 30 minutes

Examination Prerequisites:

2D Materials

Module PHM-0235: Method Course: 2D Materials *Method Course: 2D Materials*	8 ECTS/LP
Version 1.0.1 (since SoSe18) Person responsible for module: Prof. Dr. Hubert J. Krenner	

Contents:

1. Fabrication of monolayers of 2D Materials on different substrates
2. Characterization of the structural, optical and vibrational properties of 2D Materials
3. Modelling of selected physical properties of these materials

Learning Outcomes / Competences:

- Knowledge and practical application of fabrication of selected monolayer 2D Materials
- Knowledge and practical application of basic characterization methods for these materials
- Practical application of simulation methods
- Planning and conducting experiments
- Data analysis

Workload:
Total: 240 h
90 h lecture and exercise course (attendance)
90 h studying of course content through exercises / case studies (self-study)
30 h studying of course content using literarture (self-study)
30 h studying of course content using provided materials (self-study)

Conditions: Basic knowledge of solid state physics, optics and quantum mechancis		**Credit Requirements:** written report, editing time 3 weeks, max. 30 pages
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: 2D Materials (Lecture)
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Assigned Courses:

Method Course: 2D Materials (lecture)

Part of the Module: Method Course: 2D Materials (Practical course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: 2D Materials (lecture)

Examination

Method Course: 2D Materials

report

Description:

written report

Module PHM-0169: Masterthesis		26 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: According to chosen topic		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 780 h 260 h studying of course content using provided materials (self-study) 520 h lecture and exercise course (attendance)		
Conditions: To begin with the Masterthesis students must have acquired 72 CP from modules consisting of the modulgroups 1a - 5. Recommended: according to the respective advisor		**Credit Requirements:** written thesis
Frequency: each semester	**Recommended Semester:** from 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Masterthesis
Language: English

Learning Outcome:
see description of module

Contents:
see description of module

Examination
Masterthesis
Master's thesis
Examination Prerequisites:
Masterthesis

Module PHM-0170: Colloquium		4 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: According to the respective Masterthesis		
Remarks: **COMPULSORY MODULE**		
Workload: Total: 120 h 80 h lecture and exercise course (attendance) 40 h studying of course content using provided materials (self-study)		
Conditions: submission of the masterthesis		
Frequency: each semester	**Recommended Semester:** from 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 1	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Colloquium **Language:** English
Learning Outcome: see description of module
Contents: see description of module

Examination
Colloquium seminar / length of examination: 20 minutes **Examination Prerequisites:** Colloquium