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# Handbook of Modules

## Master Advanced Functional Materials (FAME)

### Faculty of Mathematics, Natural Sciences, and Materials Engineering

Prüfungsordnung vom 26.02.2014

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You can see the other use cases of the modules in Digicampus.

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**Important additional information due to the corona pandemic:**

**Please notice that due to the developments of the corona pandemic the information on the respective examination formats in the module handbooks are maybe not up to date. Which examination formats finally for which modules will be possible will be clarified and determined during the semester.**

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\* = At least one course for this module is offered in the current semester

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\* = At least one course for this module is offered in the current semester

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\* = At least one course for this module is offered in the current semester

<b>Module PHM-0144: Materials Physics</b> <i>Materials Physics</i>		6 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Electrons in solids</li> <li>• Phonons</li> <li>• Properties of metals, semiconductors and insulators</li> <li>• Application in optical, electronic, and optoelectronic devices</li> <li>• Dielectric solids, optical properties</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• 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,</li> <li>• are capable to apply derived approximations as the effective mass or the electron-hole concept to describe basic characteristics of semiconductor materials,</li> <li>• have the competence to apply these concepts for the description of electric, electro-optic and thermal properties of solids and to describe their functionalities,</li> <li>• understand size effects on material physical properties.</li> <li>• Integrated acquirement of soft skills: Working with specialist literature, literature search and interdisciplinary thinking.</li> </ul>		
<b>Remarks:</b> compulsory module		
<b>Workload:</b> Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> basic knowledge of solid state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Materials Physics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> 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)

**Assigned Courses:**

**Materials Physics** (lecture)

**Part of the Module: Materials Physics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Learning Outcome:**

see module description

**Assigned Courses:**

**Materials Physics (Tutorial)** (exercise course)

**Examination**

**Materials Physics**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Materials Physics

<b>Module PHM-0110: Materials Chemistry</b> <i>Materials Chemistry</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Revision of basic chemical concepts</li> <li>• Solid state chemical aspects of selected materials, such as <ul style="list-style-type: none"> <li>◦ Thermoelectrics</li> <li>◦ Battery electrode materials, ionic conductors</li> <li>◦ Hydrogen storage materials</li> <li>◦ Data storage materials</li> <li>◦ Phosphors and pigments</li> <li>◦ Heterogeneous catalysis</li> <li>◦ nanoscale materials</li> </ul> </li> </ul>		
<b>Learning Outcomes / Competences:</b> The students will <ul style="list-style-type: none"> <li>• be able to apply basic chemical concepts on materials science problems,</li> <li>• 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,</li> <li>• be able to assess synthetic approaches towards relevant materials,</li> <li>• acquire skills to perform literature research using online data bases.</li> </ul>		
<b>Workload:</b> 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 literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> The lecture course is based on the Bachelor in Materials Science courses Chemie I and Chemie III (solid state chemistry).		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Materials Chemistry</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see description of module		
<b>Contents:</b> 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

**Assigned Courses:**

**Materials Chemistry (Tutorial)** (exercise course)

**Examination**

**Materials Chemistry**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Materials Chemistry



<b>Module PHM-0117: Surfaces and Interfaces</b> <i>Surfaces and Interfaces</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Manfred Albrecht		
<p><b>Contents:</b></p> <p>Introduction</p> <ul style="list-style-type: none"> <li>The importance of surfaces and interfaces</li> </ul> <p>Some basic facts from solid state physics</p> <ul style="list-style-type: none"> <li>Crystal lattice and reciprocal lattice</li> <li>Electronic structure of solids</li> <li>Lattice dynamics</li> </ul> <p>Physics at surfaces and interfaces</p> <ul style="list-style-type: none"> <li>Structure of ideal and real surfaces</li> <li>Relaxation and reconstruction</li> <li>Transport (diffusion, electronic) on interfaces</li> <li>Thermodynamics of interfaces</li> <li>Electronic structure of surfaces</li> <li>Chemical reactions on solid state surfaces (catalysis)</li> <li>Interface dominated materials (nano scale materials)</li> </ul> <p>Methods to study chemical composition and electronic structure, application examples</p> <ul style="list-style-type: none"> <li>Scanning electron microscopy</li> <li>Scanning tunneling and scanning force microscopy</li> <li>Auger – electron – spectroscopy</li> <li>Photo electron spectroscopy</li> </ul>		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students:</p> <ul style="list-style-type: none"> <li>have knowledge of the structure, the electronical properties, the thermodynamics, and the chemical reactions on surfaces and interfaces,</li> <li>acquire the skill to solve problems of fundamental research and applied sciences in the field of surface and interface physics,</li> <li>have the competence to solve certain problems autonomously based on the thought physical basics.</li> <li>Integrated acquirement of soft skills.</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>20 h studying of course content using literature (self-study)</p> <p>20 h studying of course content using provided materials (self-study)</p> <p>80 h studying of course content through exercises / case studies (self-study)</p> <p>60 h lecture and exercise course (attendance)</p>		
<p><b>Conditions:</b></p> <p>The module "Physics IV - Solid State Physics" of the Bachelor of Physics / Materials Science program should be completed first.</p>		
<p><b>Frequency:</b> each winter semester</p>	<p><b>Recommended Semester:</b></p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 4</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	

<b>Parts of the Module</b>
<b>Part of the Module: Surfaces and Interfaces</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> annually <b>Contact Hours:</b> 3
<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Literature:</b> <ul style="list-style-type: none"><li>• Ertl, Küppers: Low Energy Electrons and Surface Chemistry (VCH)</li><li>• Lüth: Surfaces and Interfaces of Solids (Springer)</li><li>• Zangwill: Physics at Surfaces (Cambridge)</li><li>• Feldmann, Mayer: Fundamentals of Surface and thin Film Analysis (North Holland)</li><li>• Henzler, Göpel: Oberflächenphysik des Festkörpers (Teubner)</li><li>• Briggs, Seah: Practical Surface Analysis I und II (Wiley)</li></ul>
<b>Assigned Courses:</b> <b>Surfaces and Interfaces</b> (lecture)
<b>Part of the Module: Surfaces and Interfaces (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> annually <b>Contact Hours:</b> 1
<b>Assigned Courses:</b> <b>Surfaces and Interfaces (Tutorial)</b> (exercise course)
<b>Examination</b> <b>Surfaces and Interfaces</b> written exam / length of examination: 90 minutes <b>Examination Prerequisites:</b> Surfaces and Interfaces

<b>Module PHM-0053: Chemical Physics I</b> <i>Chemical Physics I</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Basics of quantum chemical methods</li> <li>• Molecular symmetry and group theory</li> <li>• The electronical structure of transition metal complexes</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basics of the extended-Hückel-method and the density functional theory,</li> <li>• know the basics of group theory,</li> <li>• are able to apply the knowledge gained through consideration of symmetry from vibration-, NMR-, and UV/VIS-spectroscopy, and</li> <li>• are able to interpret and predict the basical geometric, electronical and magnetical properties of transition metal complexes.</li> <li>• Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.</li> </ul>		
<b>Remarks:</b> 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.		
<b>Workload:</b> 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)		
<b>Conditions:</b> It is recommended to complete the experiments FP11 (IR-spectroscopy) and FP17 (Raman-spectroscopy) of the module "Physikalisches Fortgeschrittenenpraktikum".		
<b>Frequency:</b> each winter semester not in winter term 22/23	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Chemical Physics I</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> 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 electronic 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 electronic 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

<b>Module PHM-0287: Method Course: Spectroscopy of Organic Semiconductors</b> <i>Method Course: Spectroscopy of Organic Semiconductors</i>		8 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Wolfgang Brütting Dr. Alexander Hofmann		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Growth and characterisation of thin films (vapor deposition, spin coating, surface profiling, atomic force microscopy)</li> <li>• Optical spectroscopy and photophysics (ellipsometry, transmission, steady-state and time-resolved photoluminescence, orientation anisotropy)</li> <li>• Charge transport (space-charge limited current, field-effect mobility, doping)</li> <li>• Light-emitting diodes (different emitter types, device efficiency measurement and simulation)</li> <li>• Solar cells (different device architectures, power and quantum efficiency measurements)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• get familiar with the preparation of organic semiconductors as thin films and in devices and learn basic spectroscopic techniques to characterise them,</li> <li>• acquire skills to analyse properties of the materials taking into account their specific features,</li> <li>• and have the competence to comprehend and attend to current problems in the field of organic electronics.</li> <li>• Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to critically interpret experimental results.</li> </ul>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Basic knowledge of atomic and solid state physics, as well as elementary concepts of quantum physics.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Spectroscopy of Organic Semiconductors</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		
<b>Lehr-/Lernmethoden:</b> The basics for each topic will be taught in class, e.g. using black board and beamer presentation.		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)</li> <li>• A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)</li> <li>• S.R. Forrest: Organic Electronics (Oxford Univ. Press)</li> </ul>		
<b>Assigned Courses:</b> <b>Method Course: Spectroscopy of Organic Semiconductors</b> (internship)		

**Part of the Module: Method Course: Spectroscopy of Organic Semiconductors (Practical Course)**

**Mode of Instruction:** internship

**Language:** English / German

**Contact Hours:** 4

**Lehr-/Lernmethoden:**

After teaching in class, the students will go to the lab to get practical experience with each topic.

**Assigned Courses:**

**Method Course: Spectroscopy of Organic Semiconductors** (internship)

**Examination**

**Method Course: Spectroscopy of Organic Semiconductors**

report

<b>Module PHM-0297: Method Course: Methods in Bioanalytics</b> <i>Method Course: Methods in Bioanalytics</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. Janina Bahnemann		
<b>Contents:</b> <ul style="list-style-type: none"> <li>- Basic concepts of instrumental analytics, sensor technology, validation, quality assurance</li> <li>- Biological basics for sensor design and sample components</li> <li>- Biological markers, biomaterials and targets: bioreceptors: antibodies, enzymes, aptamers, cells, nanoparticles</li> <li>- Sensor principles / transducers: optical, thermal, electrochemical, electromechanical, colorimetric</li> <li>- Sensor materials (e.g., silicon, gold, plastics, polymers)</li> <li>- Immobilization of bioreceptors on sensor materials</li> <li>- Lateral flow assays, Point-of-Care diagnostics</li> <li>- Carbohydrate and lipid analysis: Chromatographic methods (HPLC, GC, DC, MS)</li> <li>- Amino acid analytics: HPLC, fluorescence spectroscopy</li> <li>- Nucleic acid analytics: PCR method, sequencing, electrophoresis, microarrays</li> <li>- Protein analytics: Chromatography, electrophoresis, spectroscopy, Bradford assay</li> <li>- Cell analytics: Flow cytometry and microscopy</li> <li>- Concepts and materials for sensor development and optimization: e.g., Microfluidics, additive manufacturing, nanoporous materials, nanoparticles, amplifiers</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Students will be able to use acquired analytical expertise to adequately describe and correlate basic principles of bioanalysis and their applications.</li> <li>• Students will be able to transfer acquired knowledge from the lecture to practical applications in the experimental practical course.</li> <li>• Students will demonstrate self-competence of work organization as well as social competence by working in small groups.</li> <li>• Students will learn to identify proteins using various analytical methods, to set up biosensors for measuring glucose concentrations, and to scientifically evaluate, comprehensibly record in writing, and present the practical results.</li> </ul>		
<b>Remarks:</b> ELECTIVE COMPULSORY MODULE Number of students will be limited to 9.		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> keine / none		<b>Credit Requirements:</b> Practical work and written report
<b>Frequency:</b> nach Bedarf WS und SoSe	<b>Recommended Semester:</b> 1. - 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> none	

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Methods in Bioanalytics</b> <b>Language:</b> German / English <b>Contact Hours:</b> 2
<b>Literature:</b> <ul style="list-style-type: none"><li>• Lottspeich and Engels: "Bioanalytik", Spektrum Akademischer Verlag, ISBN: 3-8274-2942-0</li><li>• Lottspeich and Engels: "Bioanalytics: Analytical Methods and Concepts in Biochemistry and Molecular Biology"</li><li>• Ozkan et al.: "Biosensors: Fundamentals, Emerging Technologies, and Application", CRC Press</li><li>• Yoon: "Introduction to Biosensors: From Electric Circuits to Immunosensors", Springer Verlag, ISBN: 978-3319801360</li><li>• Thieman: "Introduction to Biotechnology", Pearson, ISBN: 978-1292261775</li></ul>
<b>Assigned Courses:</b> <b>Method Course: Methods in Bioanalytics</b>
<b>Part of the Module: Method Course: Methods in Bioanalytics (Practical Course)</b> <b>Language:</b> German / English <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Method Course: Methods in Bioanalytics</b>
<b>Examination</b> <b>Method Course: Methods in Bioanalytics</b> report, Practical work and written report on practical work



<b>Module PHM-0298: Method course: From macroscopic to microscopic ferroic properties</b> <i>Method course: From macroscopic to microscopic ferroic properties</i>		8 ECTS/LP
Version 1.0.0 (since WS22/23) Person responsible for module: Prof. Dr. István Kézsmárki		
<p><b>Contents:</b></p> <p>Within this course, the students will learn the basic concepts of ferroic properties, e.g. ferroelectricity and ferromagnetism, which play a key role in materials science and engineering, at cryogenic temperatures. This method course will teach the students to understand and perform experiments on ferroic materials first, on a macroscopic scale and, after having a fundamental understanding, microscopic measurements. Therefore, the students will be taught in preparing single crystals, planning complex measurement procedures, and evaluating the measured data.</p> <p>Magnetic Properties will be investigated via:</p> <ul style="list-style-type: none"> <li>• Magnetization measurements</li> <li>• Susceptibility measurements</li> <li>• Magnetic force microscopy (MFM)</li> </ul> <p>Electric Properties will be investigated via:</p> <ul style="list-style-type: none"> <li>• Linear and non-linear dielectric spectroscopy</li> <li>• SEM / EDX</li> <li>• Polarization measurements</li> <li>• Conductive atomic force microscopy (cAFM) / piezo force microscopy (PFM)</li> </ul>		
<p><b>Learning Outcomes / Competences:</b></p> <ul style="list-style-type: none"> <li>• fundamental knowledge of properties in electric and magnetic materials</li> <li>• instruction in experimental methods for investigation of ferroic properties of condensed matter</li> <li>• perform experiments at cryogenic temperatures</li> <li>• trained in planning and performing complex experiments</li> <li>• learn to evaluate and analyze the collected data</li> <li>• combining knowledge of macroscopic measurements to understand microscopic data to fully understand electric and magnetic properties</li> </ul>		
<p><b>Remarks:</b> ELECTIVE COMPULSORY MODULES</p>		
<p><b>Workload:</b> Total: 240 h</p>		
<p><b>Conditions:</b> Recommended: basic knowledge in solid state physics and ferroic properties</p>		<p><b>Credit Requirements:</b> Participation in laboratory course and oral examination.</p>
<p><b>Frequency:</b> each semester</p>	<p><b>Recommended Semester:</b></p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>
<p><b>Contact Hours:</b> 6</p>	<p><b>Repeat Exams Permitted:</b> according to the examination regulations of the study program</p>	
<p><b>Parts of the Module</b></p>		
<p><b>Part of the Module: Method course: From macroscopic to microscopic ferroic properties</b> <b>Language:</b> English <b>Contact Hours:</b> 2</p>		

**Literature:**

- N.W. Ashcroft, N.D. Mermin, Festkörperphysik (Oldenbourg)
- Ch. Kittel, Einführung in die Festkörperphysik (Oldenbourg)
- V. K. Wadhawan, Introduction to ferroic materials (CRC Press)
- S. Kalinin, A. Gruverman, Scanning Probe Microscopy - Electrical and electromechanical phenomena at the nanoscale (Springer)
- A. K. Tagantsev, Domains in Ferroic Crystals and Thin films (Springer)

**Assigned Courses:**

**Method course: From macroscopic to microscopic ferroic properties** (lecture)

**Part of the Module: Method course: From macroscopic to microscopic ferroic properties (Practical Course)**

**Language:** English

**Contact Hours:** 4

**Assigned Courses:**

**Method course: From macroscopic to microscopic ferroic properties** (lecture)

**Examination**

**Method course: From macroscopic to microscopic ferroic properties**

oral exam / length of examination: 45 minutes

<b>Module PHM-0171: Method Course: Coordination Materials</b> <i>Method Course: Coordination Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer Dr. Hana Bunzen		
<b>Contents:</b> 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)		
<b>Learning Outcomes / Competences:</b> The students will learn how to: <ul style="list-style-type: none"> <li>• prepare transition metal complexes employing modern preparation techniques (e.g. microwave synthesis), inert synthesis conditions (Schlenk technique),</li> <li>• characterize coordination compounds by selected analytical techniques,</li> <li>• develop functional coordination materials based on organic / inorganic hybrid compounds,</li> <li>• employ X-ray diffraction methods for structural analysis.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 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 literature (self-study) 120 h lecture and exercise course (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> written report (protocols)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Coordination Materials (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Part of the Module: Method Course: Coordination Materials (Seminar)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Chemical databases</li> <li>• Primary literature</li> </ul>		

**Examination**

**Method Course: Coordination Materials (Seminar)**

seminar

**Examination Prerequisites:**

Method Course: Coordination Materials (Seminar)

<b>Module PHM-0147: Method Course: Electron Microscopy</b> <i>Method Course: Electron Microscopy</i>		8 ECTS/LP
Version 1.3.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Scanning electron microscopy (SEM) <ul style="list-style-type: none"> <li>• Electron optical components</li> <li>• Detectors</li> <li>• EDX, EBSD</li> </ul> Transmission electron microscopy (TEM) <ul style="list-style-type: none"> <li>• Diffraction</li> <li>• Contrast mechanisms</li> <li>• High resolution EM</li> <li>• Scanning TEM</li> <li>• Analytical TEM</li> <li>• Aberration correction</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• 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,</li> <li>• are able to operate SEM and TEM on a basic level</li> <li>• are able to characterize materials using different electron microscopy techniques</li> <li>• Acquire the competence to decide about a technique feasible for a certain problem.</li> <li>• acquire the competence to assess EM images, also regarding artefacts</li> <li>• learn to search for scientific literature and to formulate a scientific report</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 150 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: knowledge of solid-state physics, reciprocal lattice		<b>Credit Requirements:</b> regular participation, oral presentation (10 min), written report (one report per group)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Electron Microscopy</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 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

<b>Module PHM-0146: Method Course: Electronics for Physicists and Materials Scientists</b> <i>Method Course: Electronics for Physicists and Materials Scientists</i>		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering</li> <li>2. Quadrupole theory</li> <li>3. Analog technique, transistor and opamp circuits</li> <li>4. Boolean algebra and logic</li> <li>5. Digital electronics and calculation circuits</li> <li>6. Microprocessors and Networks</li> <li>7. Basics in Electronic</li> <li>8. Implementation of transistors</li> <li>9. Operational amplifiers</li> <li>10. Digital electronics</li> <li>11. Practical circuit arrangement</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the laboratory,</li> <li>• have skills in easy circuit design, measuring and control technology, analog and digital electronics,</li> <li>• have expertise in independent working on circuit problems. They can calculate and develop easy circuits.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b> Attendance in the <b>Method Course: Electronics for Physicists and Materials Scientists (combined lab course AND lecture)</b> excludes credit points for the lecture <b>Electronics for Physicists and Materials Scientists</b> .		
<b>Workload:</b> Total: 240 h 140 h studying of course content using provided materials (self-study) 60 h lecture (attendance) 10 h preparation of written term papers (self-study) 30 h internship / practical course (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> written report (one per group)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 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:** 2

**Assigned Courses:**

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

**Examination**

**Method Course: Electronics for Physicists and Materials Scientists**

written exam / length of examination: 90 minutes



<b>Module PHM-0172: Method Course: Functional Silicate-analogous Materials</b> <i>Method Course: Functional Silicate-analogous Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> Synthesis and characterization of functional materials according to the topics: <ol style="list-style-type: none"> <li>1. Silicate-analogous compounds</li> <li>2. Luminescent materials / phosphors</li> <li>3. Pigments</li> <li>4. Characterization methods: XRD, spectroscopy (luminescence, UV/vis, FT-IR), thermal analysis</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students will know how to: <ul style="list-style-type: none"> <li>• develop functional materials based on silicate-analogous materials,</li> <li>• apply classical and modern preparation techniques (e.g. solid state reaction, sol-gel reaction, precipitation, autoclave reactions, use of silica ampoules),</li> <li>• work under non-ambient atmospheres (e.g. reducing, inert conditions),</li> <li>• solve and refine crystal structures from single-crystal data,</li> <li>• describe and classify these structures properly.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> 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 literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: attendance to the lecture "Advanced Solid State Materials"		<b>Credit Requirements:</b> written report (protocol)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 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

**Examination**

**Method Course: Functional Silicate-analogous Materials**

seminar

**Examination Prerequisites:**

Method Course: Functional Silicate-analogous Materials

<b>Module PHM-0148: Method Course: Optical Properties of Solids</b> <i>Method Course: Optical Properties of Solids</i>		8 ECTS/LP
Version 1.4.0 (since SoSe15) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
<b>Contents:</b> Electrodynamics of solids <ul style="list-style-type: none"> <li>• Maxwell equations</li> <li>• Electromagnetic waves</li> <li>• Refraction and interference, Fresnel equations</li> </ul> FTIR spectroscopy <ul style="list-style-type: none"> <li>• Fourier transformation</li> <li>• Michelson-Morley and Genzel interferometer</li> <li>• Sources and detectors</li> </ul> Terahertz Time Domain spectroscopy <ul style="list-style-type: none"> <li>• Generation of pulsed THz radiation</li> <li>• Gated detection, Austin switches</li> </ul> Elementary excitations in solid materials <ul style="list-style-type: none"> <li>• Rotational-vibrational bands</li> <li>• Infrared-active phonons</li> <li>• Interband excitations</li> <li>• Crystal-field excitations</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic principles of far-infrared spectroscopy and terahertz time-domain-spectroscopy,</li> <li>• The students know about fundamental optical excitations in condensed matter materials that can be studied by these spectroscopic methods,</li> <li>• The students obtain the competence to plan and carry out complex experiments,</li> <li>• The students have the skills to evaluate and analyze optical data.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Remarks:</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study) 90 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge in solid-state physics, basic knowledge in electrodynamics and optics		<b>Credit Requirements:</b> written report
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> 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

Eugene Hecht, Optics, Walter de Gruyter

**Part of the Module: Method Course: Optical Properties of Solids (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Examination**

**Method Course: Optical Properties of Solids**

report

**Examination Prerequisites:**

Method Course: Optical Properties of Solids

<b>Module PHM-0149: Method Course: Methods in Biophysics</b> <i>Method Course: Methods in Biophysics</i>		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Dr. Christoph Westerhausen		
<b>Contents:</b> Unit Membrane biophysics <ul style="list-style-type: none"> <li>• Preparation of synthetic lipid membranes</li> <li>• Size, fluorescence and phase transition characterization of lipid membranes</li> <li>• Nanoparticle uptake synthetic membrane</li> </ul> Unit microfluidic <ul style="list-style-type: none"> <li>• Microfluidic systems</li> <li>• Fabrication of microfluidic systems</li> <li>• Calculation of microfluidic problems</li> </ul> Unit live cell experiments <ul style="list-style-type: none"> <li>• Cell culture</li> <li>• Cell coating and separation using microfluidics</li> </ul> Unit analysis		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know basic terms, concepts and phenomena in biophysics</li> <li>• acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic manipulation and analysis systems,</li> <li>• learn skills in tissue culture and immun-histochemical staining procedures,</li> <li>• learn skills in fluorescence microscopy,</li> <li>• learn skills to calculate fluidic problems on small length scales,</li> <li>• learn skills to handle microfluidic channel systems.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Attendance of the lecture "Biophysics and Biomaterials"		<b>Credit Requirements:</b> 1 written lab report
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Methods in Biophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		

**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, Strahlenbiologie, Strahlenschutz, Springer Verlag, ISBN: 3-540-41419-3
- S. Haeberle und 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

**Examination**

**Method Course: Methods in Biophysics**

report

**Examination Prerequisites:**

Method Course: Methods in Biophysics

<b>Module PHM-0151: Method Course: Porous Materials - Synthesis and Characterization</b> <i>Method Course: Porous Materials - Synthesis and Characterization</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15 to WS21/22) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> Synthesis of porous functional materials (e.g. aerogels, mesoporous silica materials, zeolites, Metal-Organic Frameworks) Characterization methods <ul style="list-style-type: none"> <li>• Structure and composition (XRD, UV/VIS, IR, ESEM, EDX)</li> <li>• Thermal analysis (TGA)</li> <li>• Adsorption and diffusion (BET, pore size distribution, pulse chemisorption)</li> <li>• Catalytic properties (GC/MS, TPO, TPR)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students will learn how to <ul style="list-style-type: none"> <li>• use modern solid state preparation techniques (e.g. hydrothermal, solvothermal, microwave synthesis),</li> <li>• employ analytical methods dedicated to porous materials.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 120 h internship / practical course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: lecture Functional Porous Materials		<b>Credit Requirements:</b> written report (editing time 3 weeks) + written exam  Please note that final grade of the Method Course consists of the maximum point score of the exam and the grade of the report of the practical part which are weighted (40:60).
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Porous Materials Synthesis and Characterization (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4		

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**Examination**

**Method Course: Porous Materials Synthesis and Characterization**

written exam / length of examination: 45 minutes

**Examination Prerequisites:**

Method Course: Porous Materials Synthesis and Characterization



<b>Module PHM-0221: Method Course: X-ray Diffraction Techniques</b> <i>Method Course: X-ray Diffraction Techniques</i>		8 ECTS/LP
Version 1.3.0 (since WS15/16) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<p><b>Contents:</b></p> <p>Subjects of the practical training and the accompanying lecture are the theoretical basics and the practical application of X-ray diffraction techniques:</p> <p>Data collection and reduction techniques</p> <p>Symmetry and space group determination</p> <p>Structural refinements:</p> <ul style="list-style-type: none"> <li>• The Rietveld method</li> <li>• Difference Fourier synthesis</li> </ul> <p>Structure determination:</p> <ul style="list-style-type: none"> <li>• Patterson method</li> <li>• Direct methods</li> </ul> <p>Interpretation of structural refinement results</p> <p>Errors and Pitfalls: twinning and disorder</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>The students:</p> <ul style="list-style-type: none"> <li>• gain basic practical knowledge on structural characterization methods for single- and poly-crystalline samples employing X-ray diffraction techniques,</li> <li>• have the skill to perform under guidance phase-analyses and X-ray structure determinations</li> <li>• are competent to analyze hands-on the structure-property relationships of new materials</li> </ul>		
<p><b>Remarks:</b></p> <p><b>ELECTIVE COMPULSORY MODULE</b></p>		
<p><b>Workload:</b></p> <p>Total: 240 h</p> <p>30 h studying of course content using provided materials (self-study)</p> <p>30 h studying of course content using literature (self-study)</p> <p>90 h studying of course content through exercises / case studies (self-study)</p> <p>90 h lecture and exercise course (attendance)</p>		
<b>Conditions:</b> none		
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> 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

**Literature:**

1. C. Giacovazzo et al., Fundamentals of Crystallography, Oxford Univ. Press, 2011.
2. W. Massa, Crystal structure determination, Berlin, Springer, 2016.

**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

<b>Module PHM-0153: Method Course: Magnetic and Superconducting Materials</b> <i>Method Course: Magnetic and Superconducting Materials</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> Methods of growth and characterization: Sample preparation (bulk materials and thin films), e.g., <ul style="list-style-type: none"> <li>• arc melting</li> <li>• flux-growth</li> <li>• sputtering and evaporation</li> </ul> Sample characterization, e.g., <ul style="list-style-type: none"> <li>• X-ray diffraction</li> <li>• electron microscopy, scanning tunneling microscopy</li> <li>• magnetic susceptibility, electrical resistivity</li> <li>• specific heat</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• 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</li> <li>• are trained in planning and performing complex experiments</li> <li>• 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</li> </ul>		
<b>Workload:</b> Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literature (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics and quantum mechanics		<b>Credit Requirements:</b> presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Magnetic and Superconducting Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Assigned Courses:</b>		

**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

<b>Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy</b> <i>Method Course: Modern Solid State NMR Spectroscopy</i>		8 ECTS/LP
Version 2.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
<b>Contents:</b> Physical foundations of NMR spectroscopy Internal interactions in NMR spectroscopy <ul style="list-style-type: none"> <li>• Chemical shift interaction</li> <li>• Dipole interaction and</li> <li>• Quadrupolar interaction</li> </ul> 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		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• gain basic knowledge of the physical foundations of modern Solid-State NMR spectroscopy,</li> <li>• gain basic practical knowledge of operating a solid-state NMR spectrometer,</li> <li>• can -- under guidance -- plan, perform, and analyze modern solid-state NMR experiments for the structural characterization of advanced materials.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using literature (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)		
<b>Conditions:</b> The attendance of the lecture "NOVEL METHODS IN SOLID STATE NMR SPECTROSCOPY" is highly recommended.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Modern Solid State NMR Spectroscopy</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 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.

**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.

**Examination**

**Method Course: Modern Solid State NMR Spectroscopy**

report / work period for assignment: 2 weeks

**Examination Prerequisites:**

Method Course: Modern Solid State NMR Spectroscopy

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

<b>Parts of the Module</b>
<b>Part of the Module: Method Course: Infrared Microspectroscopy under Pressure</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Assigned Courses:</b> <b>Method Course: Infrared Microspectroscopy under Pressure</b> (lecture)
<b>Part of the Module: Method Course: Infrared Microspectroscopy under Pressure (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Method Course: Infrared Microspectroscopy under Pressure (Practical Course)</b> (internship)
<b>Examination</b> <b>Method Course: Infrared Microspectroscopy under Pressure</b> report



<b>Module PHM-0216: Method Course: Thermal Analysis</b> <i>Method Course: Thermal Analysis</i>		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Ferdinand Haider Dr. Robert Horny		
<b>Contents:</b> Methods of thermal analysis: - Differential Scanning Calorimetry: DSC, DTA - Thermo-gravimetric Analysis: TGA - Dilatometry: DIL - Dynamic-mechanical Analysis: DMA -Rheology: RHEO  Advanced Methods: - Modulated Differential Scanning Calorimetry: MDSC - Evolved Gas Analysis: EGA (GCMS, FTIR)		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• get to know the basic principles of thermal analysis</li> <li>• learn about fundamental thermal processes in condensed matter ,e.g. phase transitions and relaxation processes (metals, polymers, ceramics)</li> <li>• learn to plan and carry out complex experiments and the usage of advanced measurement techniques</li> <li>• learn how to evaluate and analyze thermal data</li> <li>• are aware of common raw data artefacts leading to misinterpretation</li> </ul>		
<b>Remarks:</b>		
<b>Workload:</b> 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 literature (self-study) 30 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in solid-state physics		<b>Credit Requirements:</b> regular participation, oral presentation (10 min), written report
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Thermal Analysis</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Ferdinand Haider <b>Language:</b> English <b>Frequency:</b> each winter semester <b>Contact Hours:</b> 2		

**Literature:**

- Differential scanning calorimetry, Höhne, Hemminger, Flammersheim, H., Springer, 2003
- Practical Gas Chromatography, Dettmer-Wilde, Engewald, Springer, 2014
- Das Rheologie-Handbuch, Mezger, Vincentz, 2010

**Part of the Module: Method Course: Thermal Analysis (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Frequency:** each winter semester

**Contact Hours:** 4

**Examination**

**Method Course: Thermal Analysis**

report

<b>Module PHM-0224: Method Course: Theoretical Concepts and Simulation</b> <i>Method Course: Theoretical Concepts and Simulation</i>		8 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Liviu Chioncel		
<b>Contents:</b> This module covers Monte-Carlo methods (computational algorithms) for classical and quantum problems. Python as programming language will be employed. The following common applications will be discussed: <ul style="list-style-type: none"> <li>• Monte-Carlo integration, stochastic optimization, inverse problems</li> <li>• Feynman path integrals: the connection between classical and quantum systems</li> <li>• Order and disorder in spin systems, fermions, and boson</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are capable of obtaining numerical solutions to problems too complicated to be solved analytically</li> <li>• The students are able to present (graphically), discuss and analyze the results</li> <li>• The students gain experience in formulating and carrying out a collaborative project</li> </ul>		
<b>Remarks:</b> The number of students will be limited to 8.		
<b>Workload:</b> 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)		
<b>Conditions:</b> Knowledge of the programming language Python 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.		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Theoretical Concepts and Simulation</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		
<b>Contents:</b> Concepts of classical and quantum statistical physics: <ul style="list-style-type: none"> <li>• the meaning of sampling, random variables, ergodicity</li> <li>• equidistribution, pressure, temperature</li> <li>• path integrals, quantum statistics, enumeration, cluster algorithms</li> </ul>		
<b>Literature:</b> <ol style="list-style-type: none"> <li>1. Werner Krauth, Algorithms and Computations (Oxford University Press, 2006)</li> <li>2. R. H. Landau, A Survey of Computational Physics (Princeton Univ. Press, 2010)</li> </ol>		

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**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

**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.

<b>Module PHM-0223: Method Course: Tools for Scientific Computing</b> <i>Method Course: Tools for Scientific Computing</i>	8 ECTS/LP
Version 1.5.0 (since SoSe18) Person responsible for module: Prof. Dr. Gert-Ludwig Ingold	
<b>Contents:</b> Important tools for scientific computing are taught in this module and applied to specific scientific problems by the students. As far as tools depend on a particular programming language, Python will be employed. Tools to be discussed include: <ul style="list-style-type: none"> <li>• numerical libraries like NumPy and SciPy</li> <li>• visualisation of numerical results</li> <li>• use of a version control system like git and its application in collaborative work</li> <li>• testing of code</li> <li>• profiling</li> <li>• documentation of programs</li> </ul>	
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are capable of solving a physical problem of some complexity by means of numerical techniques. They are able to visualize the results and to adequately document their program code.</li> <li>• The students know examples of numerical libraries and are able to apply them to solve scientific problems.</li> <li>• The students know methods for quality assurance like the use of unit tests and can apply them to their code. They know techniques to identify run-time problems.</li> <li>• The students know a distributed version control system and are able to use it in a practical problem.</li> <li>• The students have gained practical experience in a collaborative project work. They are able to plan and carry out a programming project in a small group.</li> <li>• The students understand the relevance of the tools taught in the method course for good scientific practice.</li> </ul>	
<b>Remarks:</b> The number of students will be limited to 12.	
<b>Workload:</b> Total: 240 h 60 h studying of course content (self-study) 90 h (attendance) 30 h preparation of presentations (self-study) 60 h preparation of written term papers (self-study)	
<b>Conditions:</b> Knowledge of the programming language Python is expected on the level taught in the module PHM-0243 "Einführung in Prinzipien der Programmierung".	<b>Credit Requirements:</b> The module examination needs to be passed which is based on a scientific programming project carried out in a small team of 2-3 students. The work will be judged on the basis of a joint final report and the contributions of the individual students as documented in the team's Gitlab project. The final report should contain an explanation of the scientific problem and its numerical implementation as well as a presentation of results. The code should be appropriately documented and tested.

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

**Parts of the Module****Part of the Module: Method Course: Tools for Scientific Computing****Mode of Instruction:** lecture**Language:** English / German**Contact Hours:** 2**Learning Outcome:**

- The students know the numerical libraries NumPy and SciPy and selected tools for the visualization of numerical results.
- The students know fundamental techniques for the quality assurance of programs like the use of unit tests, profiling and the use of the version control system git. They are able to adequately document their code.
- The students understand the relevance of the tools taught in the method course for good scientific practice.

**Contents:**

- numerical libraries NumPy and SciPy
- graphics with matplotlib
- version control system Git and workflow for Gitlab/Github
- unit tests
- profiling
- documentation using docstrings and Sphinx

**Literature:**

- A. Scopatz, K. D. Huff, *Effective Computation in Physics* (O'Reilly, 2015)
- lecture notes are freely available at <https://gertingold.github.io/tools4scicomp>

**Part of the Module: Method Course: Tools for Scientific Computing (Practical Course)****Mode of Instruction:** internship**Language:** English / German**Contact Hours:** 4**Learning Outcome:**

- The students are capable of solving a physical problem of some complexity by means of numerical techniques and to visualize the results.
- They have gained some experience in the application of methods for quality assurance of their code and are able to appropriately document their programs.
- The students are able to work in a team and know how to make use of tools like Gitlab/Github.
- The students are able to present the status of their work, to critically assess it and to accept suggestions from others.

**Contents:**

The tools discussed in the lecture will be applied to specific scientific problems by small teams of 2-3 students under supervision. The teams regularly inform the other teams in oral presentations on their progress, the tools employed as well as encountered problems and their solution.

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**Examination**

**Method Course: Tools for Scientific Computing**

report / work period for assignment: 4 weeks

**Description:**

The requirement for credit points is based on a scientific programming project carried out in a small team of 2-3 students. The work will be judged on the basis of a joint final report and the contributions of the individual students as documented in the team's Gitlab project. The final report should contain an explanation of the scientific problem and its numerical implementation as well as a presentation of results. The code should be appropriately documented and tested.

<b>Module PHM-0258: Method course: Charge doping effects in semiconductors</b> <i>Method course: Charge doping effects in semiconductors</i>		8 ECTS/LP
Version 1.0.0 (since SoSe21) Person responsible for module: Prof. Dr. István Kézsmárki Dr. Lilian Prodan, Dr. Somnath Ghara		
<b>Contents:</b> The goal of the method course is to make students familiar with the concept of controlling the type and the concentration of charge carriers in semiconductors, which is widely used approach in electronics and various fields of materials science. For this purpose, the current method course will be dealing with the preparation of various electron-doped and / or hole-doped narrow-gap semiconductors and investigation of the influence of charge doping on transport and magnetic properties. The following techniques will be involved: <ul style="list-style-type: none"> <li>• Synthesis of electron and hole doped narrow-gap semiconductors, such as Zn- and Ge-doped GaV4S8, in polycrystalline forms using solid state reaction;</li> <li>• Refining the structure and checking phase purity by X-ray powder diffraction;</li> <li>• Resistivity and magneto-transport measurements;</li> <li>• Hall effect measurements to quantify carrier concentration;</li> <li>• Investigation of the doping-induced changes in the magnetic properties by magnetization measurements.</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students gain basic knowledge how to tailor the bulk properties of narrow-gap semiconductors via different doping techniques.</li> <li>• The students have detailed knowledge in performing XRD and magnetization experiments and know how to analyze the data.</li> <li>• The students acquire the competence to plan and perform Hall effect and magnetoresistance experiments and evaluate the obtained experimental results.</li> <li>• The students have the skill to distinguish between an n-type and p-type semiconductor.</li> <li>• The students know how to calculate the charge, mobility, and charge carrier density of a semiconductor using information obtained from the Hall effect experiments.</li> </ul>		
<b>Remarks:</b> ELECTIVE COMPULSORY MODULES		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics and semiconductors;		<b>Credit Requirements:</b> Written report on the experiments (editing time 2 weeks)
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method course: Charge doping effects in semiconductors (Practical Course)</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Contact Hours:</b> 4		



**Contents:**

The following techniques will be involved:

- Synthesis of electron and hole doped narrow-gap semiconductors, such as Zn- and Ge-doped GaV4S8, in poly-crystalline forms using solid state reaction;
- Refining the structure and checking phase purity by X-ray powder diffraction;
- Resistivity and magneto-transport measurements;
- Hall effect measurements to quantify carrier concentration;
- Investigation of the doping-induced changes in the magnetic properties by magnetization measurements.

**Part of the Module: Method course: Charge doping effects in semiconductors**

**Mode of Instruction:** lecture

**Language:** English

**Contact Hours:** 2

**Learning Outcome:**

The goal of the method course is to make students familiar with the concept of controlling the type and the concentration of charge carriers in semiconductors, which is widely used approach in electronics and various fields of materials science. For this purpose, the current method course will be dealing with the preparation of various electron-doped and / or hole-doped narrow-gap semiconductors and investigation of the influence of charge doping on transport and magnetic properties.

**Examination**

**Method course: Charge doping effects in semiconductors**

report

<b>Module PHM-0285: Method Course: Computational Biophysics</b> <i>Method Course: Computational Biophysics</i>		8 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Nadine Schwierz-Neumann		
<b>Contents:</b> Life relies on the interactions of proteins, nucleic acids, lipids and other biomolecules. This course introduces computational methods to study the structure, dynamics and mechanics of these biomolecules. In the first part of the course, the physics behind biomolecular simulations is explained and the basic principles of classical and statistical mechanics are reviewed. In the second part, different simulation techniques are introduced including molecular dynamics simulations and Monte Carlo simulations. Subsequently the methods are applied to biological systems consisting of proteins, nucleic acids and lipids		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Students develop an active understanding of the principles, the capacity and limitations of biomolecular simulations</li> <li>• Students learn to solve typical biophysical problems analytically and numerically</li> <li>• Students learn how to run and analyze computer simulations of biological matter</li> <li>• Students learn to visualize, document and present their simulation results</li> </ul>		
<b>Remarks:</b> Number of students will be limited to 15.		
<b>Workload:</b> Total: 240 h 90 h exam preparation (self-study) 60 h studying of course content (self-study) 90 h (attendance)		
<b>Conditions:</b> Knowledge of classical mechanics on the bachelor level is expected.		<b>Credit Requirements:</b> Passing of the module exam
<b>Frequency:</b> irregular	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 6	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Method Course: Computational Biophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		
<b>Learning Outcome:</b> <ul style="list-style-type: none"> <li>• Theoretical background of biomolecular simulations</li> <li>• Computational methods to describe the structure, dynamics and mechanics of biomolecules</li> </ul>		

**Contents:**

- Introduction to classical mechanics in phase space
- Probability and information theory
- Connection to statistical mechanics
- Molecular dynamics basics
- Monte Carlo Simulations
- Forces and force fields in biomolecular systems
- Simulations in different ensembles
- Calculating macroscopic thermodynamic properties from simulations

**Literature:**

- Daniel M. Zuckerman, *Statistical Physics of Biomolecules* (2010 by Taylor and Francis Inc.)
- Ken Dill and Sarina Bromberg, *Molecular Driving Forces* (2012 by Taylor and Francis Inc; 2nd edition)
- Daan Frenkel and Berend Smit, *Understanding Molecular Simulation* (2002 by Elsevier, 2nd edition)

**Part of the Module: Method Course: Computational Biophysics (Practical Course)**

**Mode of Instruction:** internship

**Language:** English / German

**Contact Hours:** 4

**Learning Outcome:**

- Students learn to solve typical biophysical problems analytically and numerically
- Students learn to run and analyze computer simulations of biological matter
- Students learn to visualization, documentation and presentation of results

**Contents:**

The methods and tools discussed in the lecture will be applied to typical biophysical problems and biological systems. The students work individually or in small teams under supervision. The students present their solutions, document their simulations and summarize their results in a final report.

**Examination**

**Method Course: Computational Biophysics**

written exam / length of examination: 2 hours

<b>Module PHM-0158: Introduction to Materials (= Seminar)</b> <i>Introduction to Materials</i>		4 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Varying topics for each year, giving an overview into scope, application, requirements and preparation of all types of modern materials.		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the major principles, applications and processes of modern materials,</li> <li>• acquire the competence to compile knowledge for examples of material specific topics and to present this knowledge in given time to an audience.</li> </ul>		
<b>Remarks:</b> <b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 120 h		
<b>Conditions:</b> Recommended: basic knowledge in materials science		<b>Credit Requirements:</b> regular participation, oral presentation with term paper (30 - 45 minutes)
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 2	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Introduction to Materials (Seminar)</b> <b>Mode of Instruction:</b> seminar <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Literature:</b> specific for each topic, to be gathered by the students		
<b>Assigned Courses:</b> <b>Introduction to Materials (Seminar)</b> (seminar)		
<b>Examination</b> <b>Introduction to Materials</b> presentation <b>Examination Prerequisites:</b> Introduction to Materials		

<b>Module PHM-0159: Laboratory Project</b> <i>Laboratory Project</i>		10 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> Experimental or theoretical work in a laboratory / research group in the Institute of Physics. Has to be conducted within 3 months.		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, skills and concepts to pursue a real research project in the existing laboratories within the research groups,</li> <li>• experience the day to day life in a research group from within,</li> <li>• prepare themselves to conduct a research project during their Masters thesis.</li> </ul>		
<b>Remarks:</b> The Laboratory Project will be offered in SoSe 2020 as soon as the current situation allows.		
<b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 300 h		
<b>Conditions:</b> Recommended: solid knowledge in (solid state) Physics, Chemistry and Materials Science, both experimentally and theoretically		<b>Credit Requirements:</b> 1 written report (editing time 2 weeks)
<b>Frequency:</b> each semester Siehe Bemerkungen	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 0 semester[s]
<b>Contact Hours:</b> 8	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Laboratory Project</b> <b>Mode of Instruction:</b> internship <b>Language:</b> English <b>Contact Hours:</b> 8		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Various</li> </ul>		
<b>Examination</b> <b>Laboratory Project</b> project work <b>Examination Prerequisites:</b> Laboratory Project		

<b>Module PHM-0051: Biophysics and Biomaterials</b> <i>Biophysics and Biomaterials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Dr. Stefan Thalhammer Westerhausen, Christoph, Dr.		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Transcription and translation</li> <li>• Membranes</li> <li>• DNA and proteins</li> <li>• Enabling technologies</li> <li>• Microfluidics</li> <li>• Radiation Biophysics</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students know: <ul style="list-style-type: none"> <li>• basic terms, concepts and phenomena of biological physics</li> <li>• models of the (bio)polymer-theory, microfluidics, radiation biophysics, nanobiotechnology, sequencing strategies, membranes and proteins</li> </ul> The students obtain skills <ul style="list-style-type: none"> <li>• for independent processing of problems and dealing with current literature.</li> <li>• to translate a biological observation into a physical question.</li> </ul> The students improve the key competences: <ul style="list-style-type: none"> <li>• self-dependent working with English specialist literature.</li> <li>• processing and interpretation of experimental data.</li> <li>• interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> 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 literature (self-study)		
<b>Conditions:</b> Mechanics, Thermodynamics, Statistical Physics		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Biophysics and Biomaterials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 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

**Part of the Module: Biophysics and Biomaterials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

See module description.

**Examination**

**Biophysics and Biomaterials**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Biophysics and Biomaterials

<b>Module PHM-0160: Dielectric and Optical Materials</b> <i>Dielectric and Optical Materials</i>		6 ECTS/LP
Version 1.1.0 (since SoSe15 to WS21/22) Person responsible for module: Prof. Dr. Joachim Deisenhofer		
<b>Contents:</b> Optical materials: <ul style="list-style-type: none"> <li>• Fundamentals of electromagnetic wave propagation in homogenous media (refraction, reflection, transmission, absorption)</li> <li>• Anisotropic media, linear optics</li> <li>• Optical properties semiconductors/insulators, molecular materials, metals</li> <li>• Absorption and Luminescence, excitons, luminescence centers</li> <li>• optoelectronics, detectors, light emitting devices</li> <li>• quantum confinement</li> </ul> Dielectric materials: <ul style="list-style-type: none"> <li>• Experimental techniques: quantities, broadband dielectric spectroscopy, nonlinear and polarization measurements</li> <li>• Dynamic processes in dielectric materials: relaxation processes, phenomenological models</li> <li>• Dielectric properties of disordered matter: liquids, glasses, plastic crystals</li> <li>• Charge transport: hopping conductivity, universal dielectric response, ionic conductors</li> <li>• Maxwell-Wagner relaxations: equivalent-circuits, applications (supercapacitors), colossal-dielectric-constant materials</li> <li>• Ferroelectricity: dielectric properties, polarization, relaxor ferroelectrics, applications</li> <li>• Multiferroic materials: mechanisms, materials, applications</li> </ul>		
<b>Learning Outcomes / Competences:</b> 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.		
<b>Remarks:</b> <b>Elective compulsory module</b>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literature (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)		
<b>Conditions:</b> Basic knowledge of solid state physics		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	



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**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

**Examination**

**Dielectric and Optical Materials**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Dielectric and Optical Materials

<b>Module PHM-0059: Magnetism</b> <i>Magnetism</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Hans-Albrecht Krug von Nidda		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• History, basics</li> <li>• Magnetic moments, classical and quantum phenomenology</li> <li>• Exchange interaction and mean-field theory</li> <li>• Magnetic anisotropy and magnetoelastic effects</li> <li>• Thermodynamics of magnetic systems and applications</li> <li>• Magnetic domains and domain walls</li> <li>• Magnetization processes and micro magnetic treatment</li> <li>• AC susceptibility and ESR</li> <li>• Spintransport / spintronics</li> <li>• Recent problems of magnetism</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• 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,</li> <li>• have the ability to classify different magnetic phenomena and to apply the corresponding models for their interpretation, and</li> <li>• have the competence independently to treat fundamental and typical topics and problems of magnetism.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> 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 literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> basics of solid-state physics and quantum mechanics		
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Magnetism</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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 Physics (Wiley)
- D. C. Mattis, The Theory of Magnetism (Wiley)
- G. L. Squires, Thermal Neutron Scattering (Dover Publications Inc.)

**Part of the Module: Magnetism (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Magnetism**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Magnetism

<b>Module PHM-0048: Physics and Technology of Semiconductor Devices</b> <i>Physics and Technology of Semiconductor Devices</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> 1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport) 2. Semiconductor diodes and transistors 3. Semiconductor technology		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport.</li> <li>• Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors.</li> <li>• Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes and transistors</li> <li>• Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication.</li> <li>• 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.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid state physics, statistical physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Physics and Technology of Semiconductor Devices</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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)

**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

**Examination**

**Physics and Technology of Semiconductor Devices**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Physics and Technology of Semiconductor Devices

<b>Module PHM-0049: Nanostructures / Nanophysics</b> <i>Nanostructures / Nanophysics</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. István Kézsmárki		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Semiconductor quantum wells, wires and dots, low dimensional electron systems</li> <li>2. Magnetotransport in low-dimensional systems, Quantum-Hall-Effect, Quantized conductance</li> <li>3. Optical properties of nanostructures and their application in modern optoelectronic devices, Nanophotonics</li> <li>4. Fabrication and detection techniques of nanostructures</li> <li>5. Ferroic properties of nanostructures (Ferroelectricity, Magnetism, Multiferroicity)</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students gain basic knowledge of the fundamental concepts in modern nanoscale science.</li> <li>• The students have detailed knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics</li> <li>• The students gain competence in selecting different fabrication and characterization approaches for specific nanostructures.</li> <li>• The students are able apply these concepts to tackle present problems in nanophysics.</li> <li>• The students acquire scientific skills to search for scientific literature and to evaluate scientific content.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Nanostructures / Nanophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Yu und Cardona: Fundamentals of Semiconductors</li> <li>• Singh: Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press)</li> <li>• Davies: The Physics of low-dimensional Semiconductors (Cambridge University Press)</li> </ul>		

**Examination**

**Nanostructures / Nanophysics**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Nanostructures / Nanophysics

<b>Module PHM-0174: Theoretical Concepts and Simulation</b> <i>Theoretical Concepts and Simulation</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Liviu Chioncel		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Introduction: operating systems, programming languages, data visualization tools</li> <li>2. Basic numerical methods: interpolation, integration</li> <li>3. Ordinary and Partial Differential Equations (e.g., diffusion equation, Schrödinger equation)</li> <li>4. Molecular dynamics</li> <li>5. Monte Carlo simulations</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the principal concepts of thermodynamics and statistical physics as well as the numerical methods relevant in material science,</li> <li>• are able to solve simple problems numerically. They are able to write the codes and to present the results,</li> <li>• have the expertise to find the numerical method appropriate for the given problem and to judge the quality and validity of the numerical results,</li> <li>• 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.</li> </ul>		
<b>Remarks:</b> Links to software related to the course: <ul style="list-style-type: none"> <li>• <a href="http://www.bloodshed.net/">http://www.bloodshed.net/</a></li> <li>• <a href="http://www.cplusplus.com/doc/tutorial/">http://www.cplusplus.com/doc/tutorial/</a></li> <li>• <a href="http://www.cygwin.com/">http://www.cygwin.com/</a></li> <li>• <a href="http://xmd.sourceforge.net/download.html">http://xmd.sourceforge.net/download.html</a></li> <li>• <a href="http://www.rasmol.org/">http://www.rasmol.org/</a></li> <li>• <a href="http://felt.sourceforge.net/">http://felt.sourceforge.net/</a></li> </ul>		
<b>Workload:</b> 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 literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: basic knowledge of quantum mechanics, thermodynamics, and numerical methods as well as of a programming language		<b>Credit Requirements:</b> project work in small groups, including a written summary of the results (ca. 10-20 pages) as well as an oral presentation
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	



<b>Parts of the Module</b>
<b>Part of the Module: Theoretical Concepts and Simulation</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3
<b>Literature:</b> <ul style="list-style-type: none"><li>• Tao Pang, An Introduction to Computational Physics (Cambridge University Press)</li><li>• J. M. Thijssen, Computational Physics (Cambridge University Press)</li><li>• Koonin, Meredith, Computational Physics (Addison-Weseley)</li><li>• D. C. Rapaport, The Art of Molecular Dynamics Simulation, (Cambridge University Press)</li><li>• W. H. Press et al, Numerical Recipes (Cambridge University Press)</li></ul>
<b>Part of the Module: Theoretical Concepts and Simulation (Project)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Contact Hours:</b> 1
<b>Examination</b> <b>Theoretical Concepts and Simulation</b> seminar / length of examination: 30 minutes <b>Examination Prerequisites:</b> Theoretical Concepts and Simulation

<b>Module PHM-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons</b> <i>Solid State Spectroscopy with Synchrotron Radiation and Neutrons</i>		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. Christine Kuntscher		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Electromagnetic radiation: description, generation, detection [5]</li> <li>2. Spectral analysis of electromagnetic radiation: monochromators, spectrometer, interferometer [2]</li> <li>3. Excitations in the solid state: Dielectric function [2]</li> <li>4. Infrared spectroscopy</li> <li>5. Ellipsometry</li> <li>6. Photoemission spectroscopy</li> <li>7. X-ray absorption spectroscopy</li> <li>8. Neutrons: Sources, detectors</li> <li>9. Neutron scattering</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basics of spectroscopy and important instrumentation and methods,</li> <li>• have acquired the skills of formulating a mathematical-physical ansatz in spectroscopy and can apply these in the field of solid state spectroscopy,</li> <li>• have the competence to deal with current problems in solid state spectroscopy autonomously, and are able to judge proper measurement methods for application.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> basic knowledge in solid-state physics		
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**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

<b>Module PHM-0056: Ion-Solid Interaction</b> <i>Ion-Solid Interaction</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction (areas of scientific and technological application, principles)</li> <li>• Fundamentals of atomic collision processes (scattering, cross-sections, energy loss models, potentials in binary collision models)</li> <li>• 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)</li> <li>• Transport phenomena</li> <li>• Analysis with ion beams</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the physical principles and the basic mechanisms of the interaction between particles and solid state bodies in the energy range of eV to MeV,</li> <li>• are able to choose adequate physical models for specific technological and scientific applications, and</li> <li>• have the competence to work extensively autonomous on problems concerning the interaction between ions and solid state bodies.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (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)		
<b>Conditions:</b> Basic Courses in Physics I–IV, Solid State Physics, Nuclear Physics		
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Ion-Solid Interaction</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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>

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Ion-Solid Interaction**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Ion-Solid Interaction

<b>Module PHM-0057: Physics of Thin Films</b> <i>Physics of Thin Films</i>		6 ECTS/LP
Version 1.6.0 (since WS09/10) Person responsible for module: PD Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Thin film growth: basics, thermodynamic considerations, surface kinetics, growth mechanisms</li> <li>Thin film growth techniques: vacuum technology, physical vapor deposition, chemical vapor deposition</li> <li>Analysis and characterization of thin films: in-sit methods, ex-situ methods, direct methods</li> <li>Properties and applications of thin films</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>know a broad spectrum of methods of thin film technology and material properties and applications of thin films,</li> <li>have the competence to deal with current problems in the field of thin film technology largely autonomous,</li> <li>are able to choose the right substrates and thin film materials for epitaxial thin film growth to achieve desired application conditions,</li> <li>acquire skills of combining the various technologies for growing thin layers with respect to their properties and applications, and</li> <li>acquire scientific soft skills to search for scientific literature, understand technical english, work with literature in the field of thin films, interpret experimental results.</li> </ul>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Physics of Thin Films</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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

<b>Module PHM-0058: Organic Semiconductors</b> <i>Organic Semiconductors</i>		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Brütting		
<b>Contents:</b> Basic concepts and applications of organic semiconductors Introduction <ul style="list-style-type: none"> <li>• Materials and preparation</li> <li>• Structural properties</li> <li>• Electronic structure</li> <li>• Optical and electrical properties</li> </ul> Devices and Applications <ul style="list-style-type: none"> <li>• Organic metals</li> <li>• Light-emitting diodes</li> <li>• Solar cells</li> <li>• Field-effect transistors</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic structural and electronic properties of organic semiconductors as well as the essential function of organic semiconductor devices,</li> <li>• have acquired skills for the classification of the materials taking into account their specific features in the functioning of components,</li> <li>• and have the competence to comprehend and attend to current problems in the field of organic electronics.</li> <li>• Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 40 h studying of course content through exercises / case studies (self-study) 40 h studying of course content using provided materials (self-study) 40 h studying of course content using literature (self-study)		
<b>Conditions:</b> It is strongly recommended to complete the module solid-state physics first. In addition, knowledge of molecular physics is desired.		
<b>Frequency:</b> annually	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Organic Semiconductors</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		



**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

- M. Schwoerer, H. Ch. Wolf: Organic Molecular Solids (Wiley-VCH)
- W. Brütting: Physics of Organic Semiconductors (Wiley-VCH)
- A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)
- S.R. Forrest: Organic Electronics (Oxford Univ. Press)

**Part of the Module: Organic Semiconductors (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Frequency:** every 3rd semester

**Contact Hours:** 1

**Examination****Organic Semiconductors**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Organic Semiconductors

<b>Module PHM-0060: Low Temperature Physics</b> <i>Low Temperature Physics</i>		6 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Properties of matter at low temperatures</li> <li>• Cryoliquids and superfluidity</li> <li>• Cryogenic engineering</li> <li>• Thermometry</li> <li>• Quantum transport, criticality and entanglement in matter</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic properties of matter at low temperatures and the corresponding experimental techniques,</li> <li>• have acquired the theoretical knowledge to perform low-temperature measurements,</li> <li>• and know how to experimentally investigate current problems in low-temperature physics.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Physik IV - Solid-state physics		
<b>Frequency:</b> every 3rd semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Low Temperature Physics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		

**Contents:**

- Introduction (temperature scale, history of low temperature physics)
- Properties of matter at low temperatures (specific heat, thermal expansion, electrical resistance, thermal conductivity)
- Cryoliquids and superfluidity (nitrogen, hydrogen, 4-He and 3-He: phase diagrams, superfluidity)
- Cryogenic engineering (liquefaction of gases, helium cryostats, dilution refrigerator, adiabatic demagnetization, further techniques)
- Thermometry (primary and secondary thermometers at different temperature regimes)
- Quantum Matter (quantum Transport, Quantum phase transitions, Quantum spin liquids)

**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

<b>Module PHM-0068: Spintronics</b> <i>Spintronics</i>		6 ECTS/LP
Version 1.6.0 (since SoSe14) Person responsible for module: PD Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Basic micromagnetic interactions (exchange, anisotropy, DMI, stray fields, external fields) and where they come from</li> <li>• Emergence of spin textures such as domain walls and bubbles/skyrmions</li> <li>• Torques acting on the local magnetization (magnetic field torque, current in-plane spin-transfer torque, spin-Hall effect and spin-orbit torques)</li> <li>• Switching</li> <li>• Motion of spin textures, 1D model and Thiele equation</li> <li>• Magneto-resistance and Hall effects and their utility in electrical readout</li> <li>• Ultrafast effects</li> <li>• Device applications</li> <li>• Experimental techniques in the field of spintronics</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: The students: <ul style="list-style-type: none"> <li>• know the fundamental interactions in magnetic materials, the basic spintronic effects, and the related device structures,</li> <li>• have the competence to deal with current problems in the field of spintronics largely autonomously,</li> <li>• are able to choose materials in order to achieve demanding properties in spintronic applications,</li> <li>• are able to design device components to achieve spin polarization,</li> <li>• acquire scientific skills in finding and understanding current literature dealing with spintronic devices and applications, identifying suitable materials and material combinations with respect to their applicability for spintronic devices.</li> </ul>		
<b>Workload:</b> 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 literature (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Spintronics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 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

<b>Module PHM-0066: Superconductivity</b> <i>Superconductivity</i>		6 ECTS/LP
Version 1.0.0 (since WS11/12) Person responsible for module: Prof. Dr. Philipp Gegenwart		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introductory Remarks and Literature</li> <li>• History and Main Properties of the Superconducting State, an Overview</li> <li>• Phenomenological Thermodynamics and Electrodynamics of the SC</li> <li>• Ginzburg-Landau Theory</li> <li>• Microscopic Theories</li> <li>• Fundamental Experiments on the Nature of the Superconducting State</li> <li>• Josephson-Effects</li> <li>• High Temperature Superconductors</li> <li>• Application of Superconductivity</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• will get an introduction to superconductivity,</li> <li>• by a presentation of experimental results they will learn the fundamental properties of the superconducting state,</li> <li>• are informed about the most important technical applications of superconductivity.</li> <li>• 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.</li> <li>• For self-studies a comprehensive list of further reading will be supplied.</li> </ul>		
<b>Workload:</b> 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 literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> <ul style="list-style-type: none"> <li>• Physik IV – Solid-state physics</li> <li>• Theoretical physics I-III</li> </ul>		
<b>Frequency:</b> every 3rd semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Superconductivity</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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

**Assigned Courses:**

**Superconductivity** (lecture)

**Examination**

**Superconductivity**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Superconductivity

<b>Module PHM-0069: Applied Magnetic Materials and Methods</b> <i>Applied Magnetic Materials and Methods</i>		6 ECTS/LP
Version 1.1.0 (since WS14/15) Person responsible for module: Prof. Dr. Manfred Albrecht		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Basics of magnetism</li> <li>• Ferrimagnets, permanent magnets</li> <li>• Magnetic nanoparticles</li> <li>• Superparamagnetism</li> <li>• Exchange bias effect</li> <li>• Magnetoresistance, sensors</li> <li>• Experimental methods (e.g. Mößbauer Spectroscopy, mu-SR)</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basic terms and concepts of magnetism,</li> <li>• get a profound understanding of basic physical relations and their applications,</li> <li>• acquire the ability to describe qualitative observations, interpret quantitative measurements, and develop mathematical descriptions of physical effects of chosen magnetic material systems.</li> <li>• 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.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literature (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Basics in solid state physics		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Applied Magnetic Materials and Methods</b>		
<b>Mode of Instruction:</b> lecture		
<b>Language:</b> English		
<b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> Stephan Bundell, Magnetism in Condensed Matter, Oxford University Press, ISBN: 0-19-850591-4 (Pbk) J.M.C. Coey, Magnetism and Magnetic Materials, Cambridge University Press, ISBN: 978-0-521-81614-4 (hardback)		



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**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

<b>Module PHM-0198: Special Topics in Materials Science (Foreign Institution)</b> <i>Special Topics in Materials Science (Foreign Institution)</i>		20 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Conditions:</b> studies at an international partner institution		<b>Credit Requirements:</b> written exam, oral exam, report, etc.
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> semester[s]
	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Special Topics in Materials Science (Foreign Institution)</b> <b>Language:</b> English		
<b>Examination</b> <b>Special Topics in Materials Science (Foreign Institution)</b> module exam, written exam, oral exam, report, etc. <b>Examination Prerequisites:</b> Special Topics in Materials Science (Foreign Institution)		

<b>Module PHM-0054: Chemical Physics II</b> <i>Chemical Physics II</i>		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to computational chemistry</li> <li>• Hartree-Fock Theory</li> <li>• DFT in a nutshell</li> <li>• Prediction of reaction mechanisms</li> <li>• calculation of physical and chemical properties</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic quantum chemical methods of chemical physics to interpret the electronic structures in molecules and solid-state compounds,</li> <li>• 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</li> <li>• Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.</li> </ul>		
<b>Remarks:</b> 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.		
<b>Workload:</b> 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 literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> It is highly recommended to complete the module Chemical Physics I first.		
<b>Frequency:</b> each summer semester not in summer term 23	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Chemical Physics II</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> 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.

**Part of the Module: Chemical Physics II (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Learning Outcome:**

see module description

**Examination**

**Chemical Physics II**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Chemical Physics II

<b>Module PHM-0161: Coordination Materials</b> <i>Coordination Materials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer Dr. Hana Bunzen		
<b>Contents:</b> A) Basics of coordination Chemistry <ul style="list-style-type: none"> <li>• Historical development of coordination chemistry [2]</li> <li>• Structures and nomenclature rules [2]</li> <li>• Chemical bonds in transition metal coordination compounds [3]</li> <li>• Stability of transition metal coordination compounds [2]</li> <li>• Characteristic reactions [3]</li> </ul> B) Selected classes of functional materials <ul style="list-style-type: none"> <li>• Bioinorganic chemistry [3]</li> <li>• Coordination polymers / metal-organic frameworks [3]</li> <li>• Coordination compounds in medical applications [3]</li> <li>• Photochemistry of coordination compounds [3]</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• shall acquire knowledge about concepts of chemical bonding in coordination chemistry (main emphasis: d-block transition metal compounds),</li> <li>• broaden their capabilities to interpret UV/vis absorption spectra and to predict stability and reactivity of coordination compounds,</li> <li>• learn how to transfer concepts of coordination chemistry onto topics of materials sciences.</li> <li>• Integrated acquirement of soft skills.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literature (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)		
<b>Conditions:</b> Recommended: The lecture course is based on the courses "Chemistry I", "Chemistry II"		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Coordination Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 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

**Part of the Module: Coordination Materials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Coordination Materials**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Coordination Materials

<b>Module PHM-0113: Advanced Solid State Materials</b> <i>Advanced Solid State Materials</i>		6 ECTS/LP
Version 1.0.0 (since WS10/11) Person responsible for module: Prof. Dr. Henning Höppe		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Repitition of concepts</li> <li>• Novel silicate-analogous materials</li> <li>• Luminescent materials</li> <li>• Pigments</li> <li>• Heterogeneous catalysis</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students are aware of correlations between composition, structures and properties of functional materials,</li> <li>• acquire skills to predict the properties of chemical compounds, based on their composition and structures,</li> <li>• gain competence to evaluate the potential of functional materials for future technological developments, and</li> <li>• will know how to measure the properties of these materials.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Workload:</b> 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)		
<b>Conditions:</b> Contents of the modules Chemie I, and Chemie II or Festkörperchemie (Bachelor Physik, Bachelor Materialwissenschaften)		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Advanced Solid State Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• A. West, Solid State Chemistry and Its Applications</li> <li>• L. Smart, E. Moore, Solid State Chemistry</li> <li>• Scripts Solid State Chemistry and Chemistry I and II</li> </ul>		

**Part of the Module: Advanced Solid State Materials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**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



<b>Module PHM-0217: Advanced X-ray and Neutron Diffraction Techniques</b> <i>Advanced X-ray and Neutron Diffraction Techniques</i>		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<b>Contents:</b> Subjects of the lecture are advanced X-ray and neutron diffraction techniques: <ul style="list-style-type: none"> <li>• The failure of the standard <i>Independent Atom Model</i> (IAM) in X-ray diffraction</li> <li>• Beyond the standard model: The multipolar model</li> <li>• How to obtain and analyze experimental charge densities</li> <li>• How to derive chemical and physical properties from diffraction data</li> <li>• Applications of joined X-ray and neutron diffraction experiments</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• gain basic theoretical knowledge on the reconstruction of accurate electron density maps from X-ray and neutron diffraction data</li> <li>• know the basics of the <i>Quantum Theory of Atoms in Molecules</i></li> <li>• are competent to analyze the topology of the electron density and correlate it with the physical and chemical properties of materials</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> 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 literature (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> It is recommended to complete the Module PHM-0053 Chemical Physics I.		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Advanced X-ray and Neutron Diffraction Techniques</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 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

<b>Module PHM-0114: Porous Functional Materials</b> <i>Porous Functional Materials</i>		6 ECTS/LP
Version 1.0.0 (since SS11 to WS22/23) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Overview and historical developments</li> <li>• Structural families of porous frameworks</li> <li>• Synthesis strategies</li> <li>• Adsorption and diffusion</li> <li>• Thermal analysis methods</li> <li>• Catalytic properties</li> <li>• Advanced applications and current trends</li> </ul>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students shall acquire knowledge about design principles and synthesis of porous functional materials,</li> <li>• broaden their capabilities to characterize porous solid state materials with special emphasis laid upon sorption and thermal analysis,</li> <li>• become introduced into typical technical applications of porous solids.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Remarks:</b> <b>This module and the exams for this module will be offered in WS 2022/23 for the last time !</b>		
<b>Workload:</b> 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 literature (self-study) 20 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> participation in the course Materials Chemistry		<b>Credit Requirements:</b> one written examination, 90 min
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Porous Functional Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Contents:</b> see module description		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Paul A. Wright, Microporous Framework Solids (RSC Materials Monographs, 2008)</li> <li>• selected reviews and journal articles cited on the slides</li> </ul>		
<b>Assigned Courses:</b> <b>Porous Functional Materials</b> (lecture)		

**Examination**

**Porous Functional Materials**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Porous Functional Materials

<b>Module PHM-0167: Oxidation and Corrosion</b> <i>Oxidation and Corrosion</i>	6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider	
<b>Contents:</b> Introduction Review of thermodynamics Chemical equilibria Electrochemistry Electrode kinetics High temperature oxidation Localized corrosion <ul style="list-style-type: none"> <li>• Shallow pit corrosion</li> <li>• Pitting corrosion</li> <li>• Crevice corrosion</li> <li>• Intercrystalline corrosion</li> <li>• Stress corrosion cracking</li> <li>• Fatigue corrosion</li> <li>• Erosion corrosion</li> <li>• Galvanic corrosion</li> </ul> Water and seawater corrosion Corrosion monitoring Corrosion properties of specific materials Specific corrosion problems in certain branches <ul style="list-style-type: none"> <li>• Oil and Gas industry</li> <li>• Automobile industry</li> <li>• Food industry</li> </ul> Corrosion protection <ul style="list-style-type: none"> <li>• Passive layers</li> <li>• Reaction layers (Diffusion layers ...)</li> <li>• Coatings (organic, inorganic)</li> <li>• Cathodic, anodic protection</li> <li>• Inhibitors</li> </ul>	
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the the fundamental basics, mechanics, types of corrosion processes and their electrochemical explanation</li> <li>• obtain the skill to understand typical electrochemical quantification of corrosion processes.</li> <li>• acquire the competence to assess corrosion phenomena from typical damage patterns</li> </ul>	
<b>Remarks:</b> Scheduled every second summer semester.	
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance)	

120 h studying of course content using provided materials (self-study)		
<b>Conditions:</b> Recommended: good knowledge in materials science, basic knowledge in physical chemistry		<b>Credit Requirements:</b> written exam (90 min)
<b>Frequency:</b> each summer semester alternating with PHM-0168	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> 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**Frequency:** each winter semester**Contact Hours:** 3**Literature:**

- Schütze: Corrosion and Environmental Degradation

**Part of the Module: Oxidation and Corrosion (Tutorial)****Mode of Instruction:** exercise course**Language:** English**Frequency:** each winter semester**Contact Hours:** 1**Examination****Oxidation and Corrosion**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Oxidation and Corrosion

<b>Module PHM-0198: Special Topics in Materials Science (Foreign Institution)</b> <i>Special Topics in Materials Science (Foreign Institution)</i>		20 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Conditions:</b> studies at an international partner institution		<b>Credit Requirements:</b> written exam, oral exam, report, etc.
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> semester[s]
	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Special Topics in Materials Science (Foreign Institution)</b> <b>Language:</b> English		
<b>Examination</b> <b>Special Topics in Materials Science (Foreign Institution)</b> module exam, written exam, oral exam, report, etc. <b>Examination Prerequisites:</b> Special Topics in Materials Science (Foreign Institution)		

<b>Module PHM-0218: Novel Methods in Solid State NMR Spectroscopy</b> <i>Novel Methods in Solid State NMR Spectroscopy</i>		6 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Leo van Wüllen		
<b>Contents:</b> 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		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> none		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Novel Methods in Solid State NMR Spectroscopy</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> German <b>Contact Hours:</b> 3		
<b>Assigned Courses:</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> (lecture)		
<b>Part of the Module: Novel Methods in Solid State NMR Spectroscopy (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> German <b>Contact Hours:</b> 1		
<b>Literature:</b> 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.		
<b>Assigned Courses:</b> <b>Novel Methods in Solid State NMR spectroscopy (tutorial)</b> (exercise course)		
<b>Examination</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> written exam / length of examination: 90 minutes		



<b>Module PHM-0164: Characterization of Composite Materials</b> <i>Characterization of Composite Materials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Markus Sause		
<b>Contents:</b> The following topics are presented: <ul style="list-style-type: none"> <li>• Introduction to composite materials</li> <li>• Applications of composite materials</li> <li>• Mechanical testing</li> <li>• Thermophysical testing</li> <li>• Nondestructive testing</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• acquire knowledge in the field of materials testing and evaluation of composite materials.</li> <li>• are introduced to important concepts in measurement techniques, and material models applied to composites.</li> <li>• are able to independently acquire further information of the scientific topic using various forms of information.</li> </ul>		
<b>Workload:</b> Total: 180 h 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: basic knowledge in materials science, particularly in composite materials		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

<b>Parts of the Module</b>
<b>Part of the Module: Characterization of Composite Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Morgan: Carbon fibers and their composites</li> <li>• Henning, Moeller: Handbuch Leichtbau</li> <li>• Schürmann: Konstruieren mit Faser-Kunststoff-Verbunden</li> <li>• Neitzel, Mitschang: Handbuch Verbundwerkstoffe</li> <li>• Dowling: Mechanical behaviour of materials</li> <li>• Issler: Festigkeitslehre - Grundlagen</li> <li>• Landau, Lifschitz: Theoretische Physik Vol. 7</li> </ul> <p>Further literature - actual scientific papers and reviews - will be announced at the beginning of the lecture.</p>

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**Part of the Module: Characterization of Composite Materials (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Literature:**

see lecture

**Examination**

**Characterization of Composite Materials**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Characterization of Composite Materials

<b>Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties</b> <i>Fiber Reinforced Composites: Processing and Materials Properties</i>		6 ECTS/LP
Version 1.2.0 (since SoSe15) Person responsible for module: Dr. Judith Moosburger-Will		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Production of fibers (e.g. glass, carbon, or ceramic fibers)</li> <li>• Physical and chemical properties of fibers and their precursor materials</li> <li>• Physical and chemical properties of commonly used polymeric and ceramic matrix materials</li> <li>• Semi-finished products</li> <li>• Composite production technologies</li> <li>• Application of fiber reinforced materials</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the physical and chemical properties of fibers, matrices, and fiber-reinforced materials.</li> <li>• know the basics of production technologies of fibers, polymeric, ceramic matrices, and fiber-reinforced materials.</li> <li>• know the application areas of composite materials.</li> <li>• have the competence to explain material properties of fibers, matrices, and composites.</li> <li>• have the competence to choose the right materials according to application relevant conditions.</li> <li>• are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> </ul>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literature (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: basic knowledge in materials science, basic lectures in organic chemistry		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Fiber Reinforced Composites: Processing and Materials Properties</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		

**Literature:**

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

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

**Assigned Courses:**

**Fiber Reinforced Composites: Processing and Materials Properties** (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

**Assigned Courses:**

**Fiber Reinforced Composites: Processing and Materials Properties (Tutorial)** (exercise course)

**Examination**

**Fiber Reinforced Composites: Processing and Materials Properties**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Fiber Reinforced Composites: Processing and Materials Properties

<b>Module PHM-0165: Introduction to Mechanical Engineering</b> <i>Introduction to Mechanical Engineering</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Dr. - Ing. Johannes Schilp		
<b>Contents:</b> The following topics are treated: <ul style="list-style-type: none"> <li>• Statics and dynamics of objects</li> <li>• Transmissions and mechanisms</li> <li>• Tension, shear and bending moment</li> <li>• Hydrostatics</li> <li>• Hydrodynamics</li> <li>• Strength of materials and solid mechanics</li> <li>• Instrumentation and measurement</li> <li>• Mechanical design (including kinematics and dynamics)</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students understand and are able to apply basic concepts of physics and materials science to: <ul style="list-style-type: none"> <li>• Engineering applications</li> <li>• Mechanical testing</li> <li>• Instrumentation</li> <li>• Mechanical design</li> </ul>		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> none		
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Mechanical Engineering</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Part of the Module: Mechanical Engineering (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Contact Hours:</b> 1		
<b>Examination</b> <b>Introduction to Mechanical Engineering</b> written exam / length of examination: 90 minutes <b>Examination Prerequisites:</b> Introduction to Mechanical Engineering		

<b>Module MRM-0052: Functional Polymers</b>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: PD Dr. Klaus Ruhland		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to polymer science</li> <li>• Elastomers and elastoplastic materials</li> <li>• Memory-shape polymers</li> <li>• Piezoelectric polymers</li> <li>• Electrically conducting polymers</li> <li>• Ion-conducting polymers</li> <li>• Magnetic polymers</li> <li>• Photoresponsive polymers</li> <li>• Polymers with second order non-linear optical properties</li> <li>• Polymeric catalysts</li> <li>• Self-healing polymers</li> <li>• Polymers in bio sciences&gt;</li> </ul>		
<b>Learning Outcomes / Competences:</b> 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.		
<b>Workload:</b> 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 literature (self-study) 60 h lecture and exercise course (attendance)		
<b>Conditions:</b> Recommended: Attendance to PHM-0035 (Chemie I), PHM-0036 (Chemie II) and MRM-0050 (Grundlagen der Polymerchemie und -physik)		
<b>Frequency:</b> irregular will not be offered in the next time	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Functional Polymers</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Part of the Module: Functional Polymers (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 1		

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**Examination**

**Functional Polymers**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Functional Polymers

<b>Module PHM-0122: Non-Destructive Testing</b> <i>Non-Destructive Testing</i>		6 ECTS/LP
Version 1.0.0 (since WS14/15) Person responsible for module: Prof. Dr. Markus Sause		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction to nondestructive testing methods</li> <li>• Visual inspection</li> <li>• Ultrasonic testing</li> <li>• Guided wave testing</li> <li>• Acoustic emission analysis</li> <li>• Thermography</li> <li>• Radiography</li> <li>• Eddy current testing</li> <li>• Specialized nondestructive methods</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>• acquire knowledge in the field of nondestructive evaluation of materials,</li> <li>• are introduced to important concepts in nondestructive measurement techniques,</li> <li>• are able to independently acquire further knowledge of the scientific topic using various forms of information.</li> <li>• Integrated acquirement of soft skills</li> </ul>		
<b>Workload:</b> Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literature (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)		
<b>Conditions:</b> Basic knowledge on materials science, in particular composite materials		
<b>Frequency:</b> each winter semester	<b>Recommended Semester:</b> from 1.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Non-Destructive Testing</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 3		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> 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.

**Assigned Courses:**

**Non-Destructive Testing** (lecture)

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Assigned Courses:**

**Non-Destructive Testing (Tutorial)** (exercise course)

**Examination**

**Non-Destructive Testing**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Non-Destructive Testing

<b>Module PHM-0168: Modern Metallic Materials</b> <i>Modern Metallic Materials</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> Introduction Review of physical metallurgy Steels: <ul style="list-style-type: none"> <li>• principles</li> <li>• common alloying elements</li> <li>• martensitic transformations</li> <li>• dual phase steels</li> <li>• TRIP and TWIP steels</li> <li>• maraging steel</li> <li>• electrical steel</li> <li>• production and processing</li> </ul> Aluminium alloys: <ul style="list-style-type: none"> <li>• 2xxx</li> <li>• 6xxx</li> <li>• 7xxx</li> <li>• Processing – creep forming, hydroforming, spinforming</li> </ul> Titanium alloys Magnesium alloys Superalloys Intermetallics, high entropy alloys		
<b>Learning Outcomes / Competences:</b> Students <ul style="list-style-type: none"> <li>• learn about relevant classes of actual metallic alloys and their properties</li> <li>• acquire the skill to derive alloy properties from physical metallurgy principles and concepts</li> <li>• have the competence to choose and to explain appropriate metallic materials for special applications</li> </ul>		
<b>Remarks:</b> Scheduled every second summer semester.		
<b>Workload:</b> 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 literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Recommended: Knowledge of physical metallurgy and physical chemistry		
<b>Frequency:</b> each summer semester alternating with PHM-0167	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	

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**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

<b>Module PHM-0184: Sustainable Resource Management</b> <i>Sustainable Resource Management</i>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Armin Reller		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• The students know the basics of geographic distribution and the technical relevancy of different resources like energy sources and metals.</li> <li>• Furthermore, the students know risk management methods, which are used to identify, measure and manage resource price risks. For this purpose, resource scarcity indicators, risk measures and instruments for risk protection are being presented, which enable the students to make economically well-grounded decisions in dealing with resources.</li> <li>• Moreover, the students know how resource-based strategies with the help of environmental management contribute to environmental risk management. All topics are being illustrated with examples (from practical projects).</li> </ul>		
<b>Remarks:</b> Elective Module		
<b>Workload:</b> Total: 180 h 140 h studying of course content using provided materials (self-study) 40 h seminar (attendance)		
<b>Conditions:</b> none		<b>Credit Requirements:</b> 1 written report on selected questions of sustainable resource management (number of pages: approx. 15 - 20; editing time 2 weeks), oral presentation (30 minutes), compulsory attendance (40 hours)
<b>Frequency:</b> irregular (usu. summer semester)	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Sustainable Resource Management</b> <b>Mode of Instruction:</b> seminar <b>Lecturers:</b> Prof. Dr. Armin Reller <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 2 <b>ECTS Credits:</b> 4.0		

<p><b>Contents:</b></p> <ol style="list-style-type: none"> <li>1. Introduction (global resource consumption)</li> <li>2. Overview of resource types</li> <li>3. Definition of mineral resources</li> <li>4. Introduction to resource management</li> <li>5. Identification of resource price risks</li> <li>6. Measurement of resource price risks</li> <li>7. Management of resource price risks</li> <li>8. Introduction in basics of environmental management</li> <li>9. Corporate environmental management</li> <li>10. Economical closed-loop systems</li> </ol>
<p><b>Lehr-/Lernmethoden:</b></p> <p>seminar</p> <p>media and methods: slides / blackboard with the help of other media</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• Holger Rogall: Nachhaltige Ökonomie, Metropolis, Marburg, 2009.</li> <li>• Hans-Dieter Haas, Dieter Matthew Schlesinger: Umweltökonomie und Res-sourcenmanagement, Wissenschaftliche Buchgesellschaft, Darmstadt, 2007.</li> <li>• Colin W. Clark: Mathematical Bioeconomics, Wiley, New York, 1976.</li> <li>• Werner Gocht: Handbuch der Metallmärkte, 2. Aufl., Springer, New York / Tokyo, 1985.</li> </ul>
<p><b>Part of the Module: Sustainable Resource Management (Tutorial)</b></p> <p><b>Mode of Instruction:</b> exercise course</p> <p><b>Lecturers:</b> Prof. Dr. Armin Reller</p> <p><b>Language:</b> English</p> <p><b>Frequency:</b> each summer semester</p> <p><b>Contact Hours:</b> 2</p> <p><b>ECTS Credits:</b> 2.0</p>
<p><b>Lehr-/Lernmethoden:</b></p> <p>tutorial</p> <p>media and methods: slides / blackboard with the help of other media</p>
<p><b>Examination</b></p> <p><b>Sustainable Resource Management</b></p> <p>seminar</p> <p><b>Examination Prerequisites:</b></p> <p>Sustainable Resource Management</p> <p><b>Description:</b></p> <p>1 written report (number of pages: approx. 15 - 20; editing time 2 weeks), oral presentation (30 minutes), compulsory attendance (40 hours)</p>

<b>Module PHM-0050: Electronics for Physicists and Materials Scientists</b> <i>Electronics for Physicists and Materials Scientists</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering</li> <li>2. Quadrupole theory</li> <li>3. Analog technique, transistor and opamp circuits</li> <li>4. Boolean algebra and logic</li> <li>5. Digital electronics and calculation circuits</li> <li>6. Microprocessors and Networks</li> <li>7. Basics in Electronic</li> <li>8. Implementation of transistors</li> <li>9. Operational amplifiers</li> <li>10. Digital electronics</li> </ol>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the Lab,</li> <li>• have skills in easy circuit design, measuring and control technology, analog and digital electronics,</li> <li>• have expertise in independent working on circuit problems. They can calculate and develop easy circuits.</li> <li>• 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.</li> </ul>		
<b>Workload:</b> 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 literature (self-study) 80 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> none		
<b>Frequency:</b> each semester	<b>Recommended Semester:</b> from 3.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

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

**Examination**

**Electronics for Physicists and Materials Scientists**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Electronics for Physicists and Materials Scientists

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



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**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)

<b>Module PHM-0198: Special Topics in Materials Science (Foreign Institution)</b> <i>Special Topics in Materials Science (Foreign Institution)</i>		20 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Conditions:</b> studies at an international partner institution		<b>Credit Requirements:</b> written exam, oral exam, report, etc.
<b>Frequency:</b> each semester	<b>Recommended Semester:</b>	<b>Minimal Duration of the Module:</b> semester[s]
	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Special Topics in Materials Science (Foreign Institution)</b> <b>Language:</b> English		
<b>Examination</b> <b>Special Topics in Materials Science (Foreign Institution)</b> module exam, written exam, oral exam, report, etc. <b>Examination Prerequisites:</b> Special Topics in Materials Science (Foreign Institution)		

<b>Module PHM-0196: Surfaces and Interfaces II: Joining processes</b> <i>Surfaces and Interfaces II: Joining processes</i>		6 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Dr. Judith Moosburger-Will		
<b>Learning Outcomes / Competences:</b> 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.		
<b>Workload:</b> Total: 180 h		
<b>Conditions:</b> Basic knowledge on materials science, lecture "Surfaces and Interfaces I" Module Surfaces and Interfaces (PHM-0117) - recommended		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<b>Frequency:</b> each summer semester	<b>Recommended Semester:</b> from 2.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> any	
<b>Parts of the Module</b>		
<b>Part of the Module: Surfaces and Interfaces II: Joining processes</b>		
<b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Siegfried Horn <b>Language:</b> German <b>Contact Hours:</b> 3		
<b>Contents:</b> 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		
<b>Lehr-/Lernmethoden:</b> Lecture: Beamer presentation and Blackboard Exercise: Exercises on recent topics, specialization of lecture contents		
<b>Literature:</b> Literature, including actual scientific papers and reviews, will be announced at the beginning of the 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

<b>Module PHM-0169: Masterthesis</b> <i>Masterthesis</i>		26 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> According to chosen topic		
<b>Remarks:</b> The master's thesis will be offered in SoSe 2020 as soon as the current situation allows.		
<b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 780 h 260 h studying of course content using provided materials (self-study) 520 h lecture and exercise course (attendance)		
<b>Conditions:</b> 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		<b>Credit Requirements:</b> written thesis
<b>Frequency:</b> each semester Siehe Bemerkungen	<b>Recommended Semester:</b> from 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1	<b>Repeat Exams Permitted:</b> 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

<b>Module PHM-0170: Colloquium</b> <i>Colloquium</i>		4 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
<b>Contents:</b> According to the respective Masterthesis		
<b>Remarks:</b> The Colloquium will be offered in SoSe 2020 as soon as the current situation allows.		
<b>COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 120 h 40 h studying of course content using provided materials (self-study) 80 h lecture and exercise course (attendance)		
<b>Conditions:</b> submission of the masterthesis		
<b>Frequency:</b> each semester Siehe Bemerkungen	<b>Recommended Semester:</b> from 4.	<b>Minimal Duration of the Module:</b> 1 semester[s]
<b>Contact Hours:</b> 1	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
<b>Parts of the Module</b>		
<b>Part of the Module: Colloquium</b>		
<b>Language:</b> English		
<b>Learning Outcome:</b> see description of module		
<b>Contents:</b> see description of module		
<b>Examination</b>		
<b>Colloquium</b> seminar / length of examination: 20 minutes		
<b>Examination Prerequisites:</b> Colloquium		