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# **Handbook of Modules**

**Master Program Materials Science**

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

**Examination regulations as of 20.11.2013**

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\* = Im aktuellen Semester wird mindestens eine Lehrveranstaltung für dieses Modul angeboten

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<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>◦ Ferroelectrics and Piezoelectrics</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.

**Assigned Courses:**

**Materials Chemistry** (lecture)

**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. Siegfried Horn		
<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	<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)

**Assigned Courses:****Chemical Physics I** (lecture)**Part of the Module: Chemical Physics I (Tutorial)****Mode of Instruction:** exercise course**Language:** English**Contact Hours:** 1**Assigned Courses:****Chemical Physics I (Tutorial)** (exercise course)**Examination****Chemical Physics I**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Chemical Physics I

<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> <ol style="list-style-type: none"> <li>1. Synthesis of metal complexes:</li> <li>2. Analytical characterization of metal complexes (thermal analysis, UV/vis spectroscopy, IR spectroscopy, X-ray diffraction)</li> <li>3. Material composition and stability studies</li> <li>4. Functional coordination materials (spin-crossover materials, oxygen-carrying materials)</li> </ol>		
<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 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> 1. Scanning electron microscopy (SEM) 2. Transmission electron microscopy (TEM)		
<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 characterize materials using different electron microscopy techniques and to decide, if the technique is feasible for a certain problem.</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 1.0.0 (since SoSe15) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering [4]</li> <li>2. Quadrupole theory [2]</li> <li>3. Analog technique, transistor and opamp circuits [5]</li> <li>4. Boolean algebra and logic [4]</li> <li>5. Digital electronics and calculation circuits [6]</li> <li>6. Microprocessors and Networks [4]</li> <li>7. Basics in Electronic [8]</li> <li>8. Implementation of transistors [8]</li> <li>9. Operational amplifiers [8]</li> <li>10. Digital electronics [8]</li> <li>11. Practical circuit arrangement [8]</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 100 h lecture and exercise course (attendance) 140 h studying of course content using provided materials (self-study)		
<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> 7	<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		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Paul Horowitz: The Art of Electronics (Cambridge University Press)</li> <li>• National Instruments: MultiSim software package (available in lecture)</li> </ul>		

**Assigned Courses:**

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

**Part of the Module: Method Course: Electronics for Physicists and Materials Scientists (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 3

**Assigned Courses:**

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

**Examination**

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

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Method Course: Electronics for Physicists and Materials Scientists

<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 COPULSORY 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

**Assigned Courses:**

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

**Examination**

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

seminar

**Examination Prerequisites:**

Method Course: Functional Silicate-analogous Materials

<b>Module PHM-0148: Method Course: Optical Properties of Solids</b> <i>Method Course: Optical Properties of Solids</i>		8 ECTS/LP
Version 1.2.0 (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> The students: <ul style="list-style-type: none"> <li>• get to know the basic principles of far-infrared spectroscopy and terahertz time-domain-spectroscopy,</li> <li>• learn about fundamental physical excitations in condensed matter that can be studied by these methods,</li> <li>• learn to plan and carry out complex experiments,</li> <li>• learn how to evaluate and analyze optical data.</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 1.0.0 (since SoSe15) Person responsible for module: Dr. Stefan Thalhammer		
<b>Contents:</b> Unit radiation biophysics <ul style="list-style-type: none"> <li>• Concepts in radiation protection</li> <li>• Low-dose irradiation biophysics</li> <li>• DNA repair dynamics of living cells after ionizing radiation</li> <li>• Confocal scanning laser microscopy</li> </ul> Unit microfluidic <ul style="list-style-type: none"> <li>• Microfluidic systems</li> <li>• Acoustic driven microfluidics</li> <li>• Calculation of microfluidic problems</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 radiation biophysics,</li> <li>• acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic analytical systems,</li> <li>• learn skills in tissue culture and immun-histochemical staining procedures,</li> <li>• learn skills in fluorescence and confocal scanning 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> The course will partly take place at the Helmholtz Center Munich.		
<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) 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 1.0.0 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> 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: X-ray Diffraction Techniques</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Assigned Courses:</b> <b>Method Course: X-ray Diffraction Techniques</b> (lecture)
<b>Part of the Module: Method Course: X-ray Diffraction Techniques (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> German <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Method Course: X-ray Diffraction Techniques (Practical Course)</b> (internship)
<b>Examination</b> <b>Method Course: X-ray Diffraction Techniques</b> written exam / length of examination: 90 minutes

<b>Module PHM-0235: Method Course: 2D Materials</b> <i>Method Course: 2D Materials</i>		8 ECTS/LP
Version 1.0.1 (since SoSe18) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<b>Contents:</b> 1. Fabrication of monolayers of 2D Materials on different substrates 2. Characterization of the structural, optical and vibrational properties of 2D Materials 3. Modelling of selected physical properties of these materials		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Knowledge and practical application of fabrication of selected monolayer 2D Materials</li> <li>• Knowledge and practical application of basic characterization methods for these materials</li> <li>• Practical application of simulation methods</li> <li>• Planning and conducting experiments</li> <li>• Data analysis</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) 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Basic knowledge of solid state physics, optics and quantum mechanics		<b>Credit Requirements:</b> written report, 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: 2D Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Assigned Courses:</b> <b>Method Course: 2D Materials</b> (lecture)		
<b>Part of the Module: Method Course: 2D Materials (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: 2D Materials (Practical Course)</b> (internship)		

**Examination**

**Method Course: 2D Materials**

report

**Description:**

written report

<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> 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: 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.

**Assigned Courses:**

**Method Course: Modern Solid State NMR Spectroscopy** (seminar)

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

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Literature:**

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

**Assigned Courses:**

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

**Examination**

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

report / work period for assignment: 2 weeks

**Examination Prerequisites:**

Method Course: Modern Solid State NMR Spectroscopy

<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> German <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> German <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: TG - Dilatometry: DIL - Dynamic-mechanical Analysis: DMA 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> </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> 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: Thermal Analysis</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Ferdinand Haider <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Part of the Module: Method Course: Thermal Analysis (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 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 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

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**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 1.1.0 (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. 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> </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-0041 „Einführung in das Programmieren für Physiker und Materialwissenschaftler“.		<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: Tools for Scientific Computing</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 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.

**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)

**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.

**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-0150: Method Course: Spectroscopy on Condensed Matter</b> <i>Method Course: Spectroscopy on Condensed Matter</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Dr. Stephan Krohns		
<b>Contents:</b> Dielectric Spectroscopy [8] <ul style="list-style-type: none"> <li>• Methods</li> <li>• Cryo-techniques</li> <li>• Measurement quantities</li> <li>• Relaxation processes</li> <li>• Dielectric phenomena</li> </ul> Ferroelectric Materials [7] <ul style="list-style-type: none"> <li>• Mechanism of ferroelectric polarization</li> <li>• Hysteresis loop measurements</li> <li>• Dielectric spectroscopy</li> </ul> Glassy Matter [8] <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Glassy phenomena</li> <li>• Dielectric spectroscopy</li> </ul> Multiferroic Materials [7] <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Microscopic origins of multiferroicity</li> <li>• Pyrocurrent measurements</li> <li>• Dielectric spectroscopy</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• learn about the basic concepts of dielectric spectroscopy and the phenomena examined with it. Therefore they are instructed in experimental methods for the investigation of the dielectric properties of condensed matter,</li> <li>• are trained in planning and performing complex experiments. They learn to evaluate and analyze the collected data,</li> <li>• 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>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics, basic knowledge in physics of glasses and supercooled liquids		<b>Credit Requirements:</b> written report on the experiments (editing time 2 weeks)
<b>Frequency:</b> irregular (usu. 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	

<p><b>Parts of the Module</b></p>
<p><b>Part of the Module: Method Course: Spectroscopy on Condensed Matter</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 2</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• N.W. Ashcroft, N.D. Mermin, Festkörperphysik (Oldenbourg)</li> <li>• Ch. Kittel, Einführung in die Festkörperphysik (Oldenbourg)</li> <li>• C.J.F. Böttcher, P. Bordewijk, Theory of Electric Polarization (Elsevier)</li> <li>• J. R. Macdonald, Impedance Spectroscopy (Wiley)</li> <li>• H. Scholze, Glas (Springer)</li> <li>• S.R. Elliott, Physics of Amorphous Materials (Longman)</li> <li>• R. Zallen, The Physics of Amorphous Solids (Wiley)</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Method Course: Spectroscopy on Condensed Matter</b> (lecture)</p>
<p><b>Part of the Module: Method Course: Spectroscopy on Condensed Matter (Practical Course)</b></p> <p><b>Mode of Instruction:</b> laboratory course</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 4</p>
<p><b>Assigned Courses:</b></p> <p><b>Method Course: Spectroscopy on Condensed Matter (Practical Course)</b> (internship)</p>
<p><b>Examination</b></p> <p><b>Method Course: Spectroscopy on Condensed Matter</b> written exam / length of examination: 120 minutes</p> <p><b>Examination Prerequisites:</b> Method Course: Spectroscopy on Condensed Matter</p>

<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
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<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> <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	<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	

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

- Various

**Examination****Laboratory Project**

project work

**Examination Prerequisites:**

Laboratory Project

<b>Module PHM-0066: Superconductivity</b> <i>Superconductivity</i>		6 ECTS/LP
Version 1.0.0 (since WS11/12) Person responsible for module: PD Dr. Reinhard Tidecks		
<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-0051: Biophysics and Biomaterials</b> <i>Biophysics and Biomaterials</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Stefan Thalhammer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Radiation Biophysics</li> <li>• Microfluidics</li> <li>• Membranes</li> <li>• Membranal transport</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• learn basic terms, concepts and phenomena of biological physics,</li> <li>• learn models of the (bio)polymer-theory, microfluidic, radiation biophysics, nanobiotechnology, membranes and neuronal networks,</li> <li>• adapt skills in the independent processing of problems and deal with current literature. They will be able to translate a biological observation into a physical question.</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) 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, basic knowledge in Molecular Biology		
<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		
<b>Learning Outcome:</b> 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

**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) 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: Prof. Dr. Hubert J. Krenner		
<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 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: 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)

**Assigned Courses:**

**Physics and Technology of Semiconductor Devices** (lecture)

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

see module description

**Assigned Courses:**

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

**Examination**

**Physics and Technology of Semiconductor Devices**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Physics and Technology of Semiconductor Devices

<b>Module PHM-0049: Nanostructures / Nanophysics</b> <i>Nanostructures / Nanophysics</i>		6 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<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, Quanten-Hall-Effect, Quantized conductance</li> <li>3. Optical properties of quantum wells and quantum dots and their application in modern optoelectronic devices</li> <li>4. Nanofabrication techniques</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Basic knowledge of the fundamental concepts in modern nanoscale science</li> <li>• Profound 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>• Knowledge of different fabrication approaches using bottom-up and top-down techniques</li> <li>• Application of these concepts to tackle present problems in nanophysics</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 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 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: Nanostructures / Nanophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

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

**Examination**

**Nanostructures / Nanophysics**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Nanostructures / Nanophysics

<b>Module PHM-0203: Physics of Cells</b> <i>Physics of Cells</i>		6 ECTS/LP
Version 1.1.0 (since WS16/17) Person responsible for module: Prof. Dr. Achim Wixforth Dr. Christoph Westerhausen		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Physical principles in Biology</li> <li>Cell components and their material properties: cell membrane, organelles, cytoskeleton</li> <li>Thermodynamics of proteins and biological membranes</li> <li>Physical methods and techniques for studying cells</li> <li>Cell adhesion – interplay of specific, universal and elastic forces</li> <li>Tensile strength and elasticity of tissue - macromolecules of the extra cellular matrix</li> <li>Micro mechanics and properties of the cell as a biomaterial</li> <li>Cell-cell-communication</li> <li>Cell migration</li> <li>Cell stimulation and cell-computer-communication</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>get to know a highly interdisciplinary field of physics.</li> <li>learn the basics on physical properties of human cells, as building blocks of living organisms and their material properties.</li> <li>learn about the impact of forces on the behavior of living cells</li> <li>learn physical description of fundamental biological processes and properties of biomaterials.</li> <li>are able to express biophysical questions and define model systems to answer these questions.</li> </ul> The students learn the following key qualifications: <ul style="list-style-type: none"> <li>self-dependent working with English specialist literature.</li> <li>presentation techniques.</li> <li>documentation of experimental results.</li> <li>interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> 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> Mechanics, Thermodynamics		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<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: Physics of Cells</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

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

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 2

**Learning Outcome:**

see module description

**Contents:**

see module description

**Literature:**

see module description

**Examination**

**Physics of Cells**

oral exam / length of examination: 30 minutes

<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	<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> 4		
<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>		

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**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.

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**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) 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> Subsequent to the lecture course, the students can take part in a hands-on method course ``Porous Materials Synthesis and Characterization" to practice their knowledge.		
<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-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>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>Examination</b> <b>Novel Methods in Solid State NMR Spectroscopy</b> written exam / length of examination: 90 minutes		



<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	
<p><b>Contents:</b></p> 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>	
<p><b>Learning Outcomes / Competences:</b></p> The students: <ul style="list-style-type: none"> <li>• know the the fundamental basics, mechanics, and types of corrosion processes,</li> <li>• obtain specific knowledge of one type of corrosion.</li> </ul>	
<p><b>Workload:</b></p> Total: 180 h 60 h lecture and exercise course (attendance) 120 h studying of course content using provided materials (self-study)	
<p><b>Conditions:</b></p> Recommended: good knowledge in materials science, basic knowledge in physical chemistry	<p><b>Credit Requirements:</b></p> written exam (90 min)

<b>Frequency:</b> each winter 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	

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

- Schütze: Corrosion and Environmental Degradation

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

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Oxidation and Corrosion

<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	

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

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

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

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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 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Frau Dr. Judith Moosburger-Will		
<b>Contents:</b> The following topics are treated: <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 application areas of composite materials.</li> <li>• know the basics of production technologies of fibers, polymeric, and ceramic matrices and fiber reinforced materials.</li> <li>• are introduced to physical and chemical properties of fibers, matrices, and fiber reinforced materials.</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.

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Literature:**

see lecture

**Examination**

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

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Fiber Reinforced Composites: Processing and Materials Properties

<b>Module MRM-0052: Functional Polymers</b>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. 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> 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: 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>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		
<p><b>Contents:</b></p> <p>Introduction</p> <p>Review of physical metallurgy</p> <p>Steels:</p> <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> <p>Aluminium alloys:</p> <ul style="list-style-type: none"> <li>• 2xxx</li> <li>• 6xxx</li> <li>• 7xxx</li> <li>• Processing – creep forming, hydroforming, spinforming</li> </ul> <p>Titanium alloys</p> <p>Magnesium cast alloys</p> <p>Superalloys</p> <p>Intermetallics, high entropy alloys</p> <p>Copper, brass, bronzes</p> <p>Metallic glasses</p> <p>Alloy design</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students</p> <ul style="list-style-type: none"> <li>• learn about all kinds of actual metallic alloys, their properties and how these properties can be derived from basic concepts</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>60 h lecture and exercise course (attendance)</p> <p>20 h studying of course content using provided materials (self-study)</p> <p>20 h studying of course content using literature (self-study)</p> <p>80 h studying of course content through exercises / case studies (self-study)</p>		
<p><b>Conditions:</b></p> <p>Recommended: Knowledge of physical metallurgy and physical chemistry</p>		
<p><b>Frequency:</b> each summer semester</p>	<p><b>Recommended Semester:</b> from 2.</p>	<p><b>Minimal Duration of the Module:</b> 1 semester[s]</p>

<b>Contact Hours:</b> 4	<b>Repeat Exams Permitted:</b> according to the examination regulations of the study program	
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<b>Parts of the Module</b>
<p><b>Part of the Module: Modern Metallic Materials</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 4</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>Cahn-Haasen-Kramer: Materials Science and Technology</li> <li>Original literature</li> </ul>

<p><b>Examination</b></p> <p><b>Modern Metallic Materials</b></p> <p>written exam / length of examination: 90 minutes</p> <p><b>Examination Prerequisites:</b></p> <ul style="list-style-type: none"> <li>Modern Metallic Materials</li> </ul>
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<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: Prof. Dr. Siegfried Horn Dozenten: Prof. Dr. Siegfried Horn, 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>Literature:</b> Literature, including actual scientific papers and reviews, will be announced at the beginning of the lecture.		
<b>Examination</b> <b>Surfaces and Interfaces II: Joining processes</b> written exam / length of examination: 90 minutes <b>Examination Prerequisites:</b> Surfaces and Interfaces II: Joining processes		

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<b>Parts of the Module</b>
<b>Part of the Module:</b> Übung zu Surfaces and Interfaces II: Joining processes
<b>Mode of Instruction:</b> exercise course
<b>Language:</b> German
<b>Contact Hours:</b> 1

<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-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-0058: Organic Semiconductors</b> <i>Organic Semiconductors</i>		6 ECTS/LP
Version 1.0.0 (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>• Field-effect transistors</li> <li>• Solar cells and laser</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> 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: 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 (editor): Physics of Organic Semiconductors (Wiley-VCH)
- A. Köhler, H. Bässler: Electronic Processes in Organic Semiconductors (Wiley-VCH)

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination****Organic Semiconductors**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Organic Semiconductors

<b>Module PHM-0066: Superconductivity</b> <i>Superconductivity</i>		6 ECTS/LP
Version 1.0.0 (since WS11/12) Person responsible for module: PD Dr. Reinhard Tidecks		
<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-0060: Low Temperature Physics</b> <i>Low Temperature Physics</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: PD Dr. Reinhard Tidecks		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Thermodynamic fundamentals</li> <li>• Gas liquification</li> <li>• Properties of liquid helium</li> <li>• Cryogenic engineering</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
  - History, methods, realizations, and significance
- Thermodynamic fundamentals
  - Temperature, working cycles, real gases, Joule-Thomson-Effect
- Gas liquification
  - Air, hydrogen, helium
  - Separation of Oxygen and nitrogen
  - Storage and transfer of liquefied gases, superinsulation
- Properties of liquid helium
  - Production and thermodynamic properties of  $^4\text{He}$  and  $^3\text{He}$
  - Phase diagrams ( $^4\text{He}$ ,  $^3\text{He}$ )
  - Superfluidity of  $^4\text{He}$ 
    - Experiments, Two-Fluid-Model
    - Bose-Einstein-Condensation
    - Excitation spectrum, critical velocity
    - Rotating Helium
  - Normal and superfluid  $^3\text{He}$
  - $^4\text{He}$  /  $^3\text{He}$ -mixtures
- Cryogenic engineering
  - Bath-Cryostats (Helium-4, Helium-3),
  - $^4\text{He}$  /  $^3\text{He}$ -Dilution-Refrigerators
  - Pomeranchuk-Cooling
  - Adiabatic demagnetization
  - Primary and secondary thermometers

**Literature:**

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

**Part of the Module: Low Temperature Physics (Tutorial)**

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Examination**

**Low Temperature Physics**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Low Temperature Physics



<b>Module PHM-0114: Porous Functional Materials</b> <i>Porous Functional Materials</i>		6 ECTS/LP
Version 1.0.0 (since SS11) 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> Subsequent to the lecture course, the students can take part in a hands-on method course ``Porous Materials Synthesis and Characterization" to practice their knowledge.		
<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-0068: Spintronics</b> <i>Spintronics</i>		6 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Introduction into magnetism</li> <li>• Basic spintronic effects and devices</li> <li>• Novel materials for spintronic applications</li> <li>• Spin-sensitive experimental methods</li> <li>• Semiconductor based spintronics</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• know the fundamental properties of magnetic materials, the basic spintronic effects, and the related device structures,</li> <li>• have acquired skills in identifying materials with respect to their applicability for spintronic devices,</li> <li>• and have the competence to deal with current problems in the field of semi-conductor and metal based spintronics largely autonomously.</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		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• N. W. Ashcroft, N. D. Mermin, Solid State Physics, Cengage Learning (2011), ISBN: 81-315-0052-7</li> <li>• C. Felser, G. H. Hechler, Spintronics - From Materials to Devices, Springer (2013), ISBN: 978-90-481-3831-9</li> <li>• S. Bandyopadhyay, M. Cahay, Introduction to Spintronics, CRC Press (2008), ISBN: 978-0-9493-3133-6</li> </ul>		

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**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-0057: Physics of Thin Films</b> <i>Physics of Thin Films</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. German Hammerl		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Layer growth</li> <li>• Thin film technology</li> <li>• Analysis of thin films</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 methods of thin film technology and material properties and applications of thin films,</li> <li>• have acquired skills of grouping the various technologies for producing thin layers with respect to their properties and applications, and</li> <li>• have the competence to deal with current problems in the field of thin film technology largely autonomously.</li> <li>• Integrated acquisition of soft skills: practicing technical English, working with English specialist literature, ability to 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> 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: 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		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• H. Frey, G. Kienel, Dünnschichttechnologie (VDI Verlag, 1987)</li> <li>• H. Lüth, Solid Surfaces, Interfaces and Thin Films (Springer Verlag, 2001)</li> <li>• A. Wagendristel, Y. Wang, An Introduction to Physics and Technology of Thin Films (World Scientific Publishing, 1994)</li> <li>• M. Ohring, The Materials Science of Thin Films (Academic Press, 1992)</li> </ul>		

**Examination**

**Physics of Thin Films**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Physics of Thin Films

<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-0069: Applied Magnetic Materials and Methods</b> <i>Applied Magnetic Materials and Methods</i>		6 ECTS/LP
Version 1.0.0 (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> to be announced at the beginning of the lecture		

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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-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons</b> <i>Solid State Spectroscopy with Synchrotron Radiation and Neutrons</i>		6 ECTS/LP
Version 1.0.0 (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-0051: Biophysics and Biomaterials</b> <i>Biophysics and Biomaterials</i>		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Dr. Stefan Thalhammer		
<b>Contents:</b> <ul style="list-style-type: none"> <li>• Radiation Biophysics</li> <li>• Microfluidics</li> <li>• Membranes</li> <li>• Membranal transport</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• learn basic terms, concepts and phenomena of biological physics,</li> <li>• learn models of the (bio)polymer-theory, microfluidic, radiation biophysics, nanobiotechnology, membranes and neuronal networks,</li> <li>• adapt skills in the independent processing of problems and deal with current literature. They will be able to translate a biological observation into a physical question.</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) 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, basic knowledge in Molecular Biology		
<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		
<b>Learning Outcome:</b> 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

**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) 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: Prof. Dr. Hubert J. Krenner		
<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 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: 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)

**Assigned Courses:**

**Physics and Technology of Semiconductor Devices** (lecture)

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Contents:**

see module description

**Assigned Courses:**

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

**Examination**

**Physics and Technology of Semiconductor Devices**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Physics and Technology of Semiconductor Devices

<b>Module PHM-0049: Nanostructures / Nanophysics</b> <i>Nanostructures / Nanophysics</i>		6 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<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, Quanten-Hall-Effect, Quantized conductance</li> <li>3. Optical properties of quantum wells and quantum dots and their application in modern optoelectronic devices</li> <li>4. Nanofabrication techniques</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Basic knowledge of the fundamental concepts in modern nanoscale science</li> <li>• Profound 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>• Knowledge of different fabrication approaches using bottom-up and top-down techniques</li> <li>• Application of these concepts to tackle present problems in nanophysics</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 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 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: Nanostructures / Nanophysics</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Frequency:</b> each summer semester <b>Contact Hours:</b> 4		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

**Literature:**

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

**Examination**

**Nanostructures / Nanophysics**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Nanostructures / Nanophysics

<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 electronic 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	<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> 4		
<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>		

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**Examination**

**Advanced Solid State Materials**

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Advanced Solid State Materials

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

<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, and types of corrosion processes,</li> <li>• obtain specific knowledge of one type of corrosion.</li> </ul>	
<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 winter 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	

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

- Schütze: Corrosion and Environmental Degradation

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

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Oxidation and Corrosion

<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 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Siegfried Horn Frau Dr. Judith Moosburger-Will		
<b>Contents:</b> The following topics are treated: <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 application areas of composite materials.</li> <li>• know the basics of production technologies of fibers, polymeric, and ceramic matrices and fiber reinforced materials.</li> <li>• are introduced to physical and chemical properties of fibers, matrices, and fiber reinforced materials.</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.

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**Literature:**

see lecture

**Examination**

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

written exam / length of examination: 90 minutes

**Examination Prerequisites:**

Fiber Reinforced Composites: Processing and Materials Properties

<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
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<b>Module MRM-0052: Functional Polymers</b>		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. 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> 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: 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>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-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		
<p><b>Contents:</b></p> <p>Introduction</p> <p>Review of physical metallurgy</p> <p>Steels:</p> <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> <p>Aluminium alloys:</p> <ul style="list-style-type: none"> <li>• 2xxx</li> <li>• 6xxx</li> <li>• 7xxx</li> <li>• Processing – creep forming, hydroforming, spinforming</li> </ul> <p>Titanium alloys</p> <p>Magnesium cast alloys</p> <p>Superalloys</p> <p>Intermetallics, high entropy alloys</p> <p>Copper, brass, bronzes</p> <p>Metallic glasses</p> <p>Alloy design</p>		
<p><b>Learning Outcomes / Competences:</b></p> <p>Students</p> <ul style="list-style-type: none"> <li>• learn about all kinds of actual metallic alloys, their properties and how these properties can be derived from basic concepts</li> </ul>		
<p><b>Workload:</b></p> <p>Total: 180 h</p> <p>60 h lecture and exercise course (attendance)</p> <p>20 h studying of course content using provided materials (self-study)</p> <p>20 h studying of course content using literature (self-study)</p> <p>80 h studying of course content through exercises / case studies (self-study)</p>		
<b>Conditions:</b> Recommended: Knowledge of physical metallurgy and physical chemistry		
<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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<b>Parts of the Module</b>
<p><b>Part of the Module: Modern Metallic Materials</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 4</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>Cahn-Haasen-Kramer: Materials Science and Technology</li> <li>Original literature</li> </ul>

<p><b>Examination</b></p> <p><b>Modern Metallic Materials</b></p> <p>written exam / length of examination: 90 minutes</p> <p><b>Examination Prerequisites:</b></p> <ul style="list-style-type: none"> <li>Modern Metallic Materials</li> </ul>
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<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: Prof. Dr. Siegfried Horn Dozenten: Prof. Dr. Siegfried Horn, 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>Literature:</b> Literature, including actual scientific papers and reviews, will be announced at the beginning of the lecture.		
<b>Examination</b> <b>Surfaces and Interfaces II: Joining processes</b> written exam / length of examination: 90 minutes <b>Examination Prerequisites:</b> Surfaces and Interfaces II: Joining processes		

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<b>Parts of the Module</b>
<b>Part of the Module:</b> Übung zu Surfaces and Interfaces II: Joining processes
<b>Mode of Instruction:</b> exercise course
<b>Language:</b> German
<b>Contact Hours:</b> 1

<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-0203: Physics of Cells</b> <i>Physics of Cells</i>		6 ECTS/LP
Version 1.1.0 (since WS16/17) Person responsible for module: Prof. Dr. Achim Wixforth Dr. Christoph Westerhausen		
<b>Contents:</b> <ul style="list-style-type: none"> <li>Physical principles in Biology</li> <li>Cell components and their material properties: cell membrane, organelles, cytoskeleton</li> <li>Thermodynamics of proteins and biological membranes</li> <li>Physical methods and techniques for studying cells</li> <li>Cell adhesion – interplay of specific, universal and elastic forces</li> <li>Tensile strength and elasticity of tissue - macromolecules of the extra cellular matrix</li> <li>Micro mechanics and properties of the cell as a biomaterial</li> <li>Cell-cell-communication</li> <li>Cell migration</li> <li>Cell stimulation and cell-computer-communication</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students <ul style="list-style-type: none"> <li>get to know a highly interdisciplinary field of physics.</li> <li>learn the basics on physical properties of human cells, as building blocks of living organisms and their material properties.</li> <li>learn about the impact of forces on the behavior of living cells</li> <li>learn physical description of fundamental biological processes and properties of biomaterials.</li> <li>are able to express biophysical questions and define model systems to answer these questions.</li> </ul> The students learn the following key qualifications: <ul style="list-style-type: none"> <li>self-dependent working with English specialist literature.</li> <li>presentation techniques.</li> <li>documentation of experimental results.</li> <li>interdisciplinary thinking and working.</li> </ul>		
<b>Workload:</b> 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> Mechanics, Thermodynamics		<b>Credit Requirements:</b> Bestehen der Modulprüfung
<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: Physics of Cells</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 2		

<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Literature:</b> <ul style="list-style-type: none"><li>• Sackmann, Erich, and Rudolf Merkel. <i>Lehrbuch der Biophysik</i>. Wiley-VCH, 2010.</li><li>• Nelson, Philip. <i>Biological physics</i>. New York: WH Freeman, 2004.</li><li>• Boal, D. <i>Mechanics of the Cell</i>. Cambridge University Press, 2012.</li><li>• Lecture notes</li></ul>
<b>Part of the Module: Physics of Cells (Tutorial)</b> <b>Mode of Instruction:</b> exercise course <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Learning Outcome:</b> see module description
<b>Contents:</b> see module description
<b>Literature:</b> see module description
<b>Examination</b> <b>Physics of Cells</b> oral exam / length of examination: 30 minutes

<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.

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

**Mode of Instruction:** exercise course

**Language:** English

**Contact Hours:** 1

**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-0146: Method Course: Electronics for Physicists and Materials Scientists</b> <i>Method Course: Electronics for Physicists and Materials Scientists</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Basics in electronic and electrical engineering [4]</li> <li>2. Quadrupole theory [2]</li> <li>3. Analog technique, transistor and opamp circuits [5]</li> <li>4. Boolean algebra and logic [4]</li> <li>5. Digital electronics and calculation circuits [6]</li> <li>6. Microprocessors and Networks [4]</li> <li>7. Basics in Electronic [8]</li> <li>8. Implementation of transistors [8]</li> <li>9. Operational amplifiers [8]</li> <li>10. Digital electronics [8]</li> <li>11. Practical circuit arrangement [8]</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 100 h lecture and exercise course (attendance) 140 h studying of course content using provided materials (self-study)		
<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> 7	<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		
<b>Literature:</b> <ul style="list-style-type: none"> <li>• Paul Horowitz: The Art of Electronics (Cambridge University Press)</li> <li>• National Instruments: MultiSim software package (available in lecture)</li> </ul>		

**Assigned Courses:**

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

**Part of the Module: Method Course: Electronics for Physicists and Materials Scientists (Practical Course)**

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 3

**Assigned Courses:**

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

**Examination**

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

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Method Course: Electronics for Physicists and Materials Scientists

<b>Module PHM-0147: Method Course: Electron Microscopy</b> <i>Method Course: Electron Microscopy</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Ferdinand Haider		
<b>Contents:</b> 1. Scanning electron microscopy (SEM) 2. Transmission electron microscopy (TEM)		
<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 characterize materials using different electron microscopy techniques and to decide, if the technique is feasible for a certain problem.</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-0148: Method Course: Optical Properties of Solids</b> <i>Method Course: Optical Properties of Solids</i>		8 ECTS/LP
Version 1.2.0 (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> The students: <ul style="list-style-type: none"> <li>• get to know the basic principles of far-infrared spectroscopy and terahertz time-domain-spectroscopy,</li> <li>• learn about fundamental physical excitations in condensed matter that can be studied by these methods,</li> <li>• learn to plan and carry out complex experiments,</li> <li>• learn how to evaluate and analyze optical data.</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 1.0.0 (since SoSe15) Person responsible for module: Dr. Stefan Thalhammer		
<b>Contents:</b> Unit radiation biophysics <ul style="list-style-type: none"> <li>• Concepts in radiation protection</li> <li>• Low-dose irradiation biophysics</li> <li>• DNA repair dynamics of living cells after ionizing radiation</li> <li>• Confocal scanning laser microscopy</li> </ul> Unit microfluidic <ul style="list-style-type: none"> <li>• Microfluidic systems</li> <li>• Acoustic driven microfluidics</li> <li>• Calculation of microfluidic problems</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 radiation biophysics,</li> <li>• acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic analytical systems,</li> <li>• learn skills in tissue culture and immun-histochemical staining procedures,</li> <li>• learn skills in fluorescence and confocal scanning 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> The course will partly take place at the Helmholtz Center Munich.		
<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) 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-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> 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: 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.

**Assigned Courses:**

**Method Course: Modern Solid State NMR Spectroscopy** (seminar)

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

**Mode of Instruction:** laboratory course

**Language:** English

**Contact Hours:** 4

**Literature:**

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

**Assigned Courses:**

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

**Examination**

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

report / work period for assignment: 2 weeks

**Examination Prerequisites:**

Method Course: Modern Solid State NMR Spectroscopy

<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-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 COPULSORY 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

**Assigned Courses:**

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

**Examination**

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

seminar

**Examination Prerequisites:**

Method Course: Functional Silicate-analogous Materials

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

<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> German <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> German <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: TG - Dilatometry: DIL - Dynamic-mechanical Analysis: DMA 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> </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> 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: Thermal Analysis</b> <b>Mode of Instruction:</b> lecture <b>Lecturers:</b> Prof. Dr. Ferdinand Haider <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Part of the Module: Method Course: Thermal Analysis (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> English <b>Contact Hours:</b> 4		

**Examination**

**Method Course: Thermal Analysis**

report

<b>Module PHM-0221: Method Course: X-ray Diffraction Techniques</b> <i>Method Course: X-ray Diffraction Techniques</i>		8 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
<b>Contents:</b> Subjects of the practical training and the accompanying lecture are the theoretical basics and the practical application of X-ray diffraction techniques: Data collection and reduction techniques Symmetry and space group determination Structural refinements: <ul style="list-style-type: none"> <li>• The Rietveld method</li> <li>• Difference Fourier synthesis</li> </ul> Structure determination: <ul style="list-style-type: none"> <li>• Patterson method</li> <li>• Direct methods</li> </ul> Interpretation of structural refinement results Errors and Pitfalls: twinning and disorder		
<b>Learning Outcomes / Competences:</b> The students: <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>		
<b>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study) 90 h lecture and exercise course (attendance)		
<b>Conditions:</b> none		
<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: X-ray Diffraction Techniques</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2
<b>Assigned Courses:</b> <b>Method Course: X-ray Diffraction Techniques</b> (lecture)
<b>Part of the Module: Method Course: X-ray Diffraction Techniques (Practical Course)</b> <b>Mode of Instruction:</b> laboratory course <b>Language:</b> German <b>Contact Hours:</b> 4
<b>Assigned Courses:</b> <b>Method Course: X-ray Diffraction Techniques (Practical Course)</b> (internship)
<b>Examination</b> <b>Method Course: X-ray Diffraction Techniques</b> written exam / length of examination: 90 minutes



<b>Module PHM-0234: 2D Materials</b> <i>2D Materials</i>		6 ECTS/LP
Version 1.0.1 (since SoSe18) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<b>Contents:</b> Two-dimensional materials: graphene to emerging new materials, such as transition metal dichalcogenides <ol style="list-style-type: none"> <li>1. Fabrication</li> <li>2. Optical, electronic and vibrational properties</li> <li>3. Applications in advanced functional devices</li> </ol>		
<b>Learning Outcomes / Competences:</b> <ol style="list-style-type: none"> <li>1. Specify different classes of 2D solid state materials and their properties.</li> <li>2. Describe and explain preparation and nanofabrication methods for 2D materials.</li> <li>3. Understand and explain and differentiate between suitable optical and structural characterization methods for 2D materials.</li> <li>4. Understand and explain phonon properties of 2D materials.</li> <li>5. Understand and explain magneto quantum transport phenomena such as the quantum Hall effect in graphene</li> <li>6. Understand and explain absorption, excitonic and spin properties of transition metal dichalcogenides..</li> <li>7. Understand and explain and discuss applications of 2D materials and their heterostructures for electronic, optoelectronic, spintronics devices and solar energy conversion.</li> </ol>		
<b>Workload:</b> Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 60 h lecture (attendance) 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 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: 2D Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 4 <b>ECTS Credits:</b> 6.0		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		

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**Examination**

**2D Materials**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

2D Materials

<b>Module PHM-0235: Method Course: 2D Materials</b> <i>Method Course: 2D Materials</i>		8 ECTS/LP
Version 1.0.1 (since SoSe18) Person responsible for module: Prof. Dr. Hubert J. Krenner		
<b>Contents:</b> 1. Fabrication of monolayers of 2D Materials on different substrates 2. Characterization of the structural, optical and vibrational properties of 2D Materials 3. Modelling of selected physical properties of these materials		
<b>Learning Outcomes / Competences:</b> <ul style="list-style-type: none"> <li>• Knowledge and practical application of fabrication of selected monolayer 2D Materials</li> <li>• Knowledge and practical application of basic characterization methods for these materials</li> <li>• Practical application of simulation methods</li> <li>• Planning and conducting experiments</li> <li>• Data analysis</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) 30 h studying of course content using literature (self-study) 90 h studying of course content through exercises / case studies (self-study)		
<b>Conditions:</b> Basic knowledge of solid state physics, optics and quantum mechanics		<b>Credit Requirements:</b> written report, 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: 2D Materials</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English <b>Contact Hours:</b> 2		
<b>Assigned Courses:</b> <b>Method Course: 2D Materials</b> (lecture)		
<b>Part of the Module: Method Course: 2D Materials (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: 2D Materials (Practical Course)</b> (internship)		

**Examination**

**Method Course: 2D Materials**

report

**Description:**

written report

<b>Module PHM-0228: Symmetry concepts and their applications in solid state physics and materials science</b> <i>Symmetry concepts and their applications in solid state physics and materials science</i>	6 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. István Kézsmárki Deisenhofer, Joachim, Dr.	
<p><b>Contents:</b></p> <p>The topical outline of the course is as follows:</p> <ul style="list-style-type: none"> <li>• Introduction and common examples <ul style="list-style-type: none"> <li>o Motivating examples</li> <li>o Polar and axial vectors and tensors</li> <li>o Spatial and temporal symmetries and charge conjugation</li> <li>o Symmetries of measurable quantities and fields</li> <li>o Symmetries of physical laws (classical and quantum)</li> <li>o Conservation laws (linear and angular momentum, energy, etc.)</li> <li>o Symmetry of measurement configurations (reciprocity, etc.)</li> </ul> </li> <li>• Neumann principle <ul style="list-style-type: none"> <li>o Linear response theory and Onsager relations</li> <li>o Applications to vector and tensor quantities: electric and magnetic dipole moment of molecules; ferroelectricity, ferromagnetism, piezoelectricity and magnetoelectricity in crystals; wave propagation in anisotropic media (sound and light)</li> </ul> </li> <li>• Symmetry allowed energy terms <ul style="list-style-type: none"> <li>o On the level of classical free energy: Polar, nematic and magnetic order parameters (Landau expansion)</li> <li>o On the level of Hamiltonians: Molecular vibrations, crystal field potential, magnetic interactions</li> </ul> </li> <li>• Symmetry of physical states <ul style="list-style-type: none"> <li>o Spatial inversion and parity eigenstates</li> <li>o Discrete translations and the Bloch states</li> </ul> </li> <li>• Spontaneous symmetry breaking upon phase transitions (Landau theory)</li> <li>• Outlook: Symmetry guides for skyrmion-host materials, multiferroic compounds and axion insulators</li> </ul>	
<p><b>Learning Outcomes / Competences:</b></p> <p>The course aims at providing insights into the simple use of symmetry concepts to understand phenomena and material properties without performing detailed calculations. On the same basis, it gives some guides how to make minimal plans for experiments using the symmetry of the studied materials or vice versa how to determine the symmetry of materials from the output of experiments.</p>	
<p><b>Workload:</b></p> <p>Total: 180 h  60 h (attendance)  60 h exam preparation (self-study)  60 h studying of course content (self-study)</p>	
<p><b>Conditions:</b></p> <p>Background in basic quantum mechanics is required.</p>	

<b>Frequency:</b> nach Bedarf WS und SoSe	<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	

**Parts of the Module****Part of the Module: Symmetry concepts and their applications in solid state physics and materials science****Mode of Instruction:** lecture**Lecturers:** Prof. Dr. István Kézsmárki**Language:** English**Contact Hours:** 3**ECTS Credits:** 6.0**Examination****Symmetry concepts and their applications in solid state physics and materials science**

oral exam / length of examination: 30 minutes

**Parts of the Module****Part of the Module: Symmetry concepts and their applications in solid state physics and materials science (Tutorial)****Mode of Instruction:** exercise course**Language:** English**Contact Hours:** 1

<b>Module PHM-0223: Method Course: Tools for Scientific Computing</b> <i>Method Course: Tools for Scientific Computing</i>		8 ECTS/LP
Version 1.1.0 (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. 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> </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-0041 „Einführung in das Programmieren für Physiker und Materialwissenschaftler“.		<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: Tools for Scientific Computing</b> <b>Mode of Instruction:</b> lecture <b>Language:</b> English / German <b>Contact Hours:</b> 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.

**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)

**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.

**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-0224: Method Course: Theoretical Concepts and Simulation</b> <i>Method Course: Theoretical Concepts and Simulation</i>		8 ECTS/LP
Version 1.0.0 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-0225: Analog Electronics for Physicists and Materials Scientists</b> <i>Analog Electronics for Physicists and Materials Scientists</i>		6 ECTS/LP
Version 1.0.0 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. Electronic Networks</li> <li>4. Semiconductor Devices</li> <li>5. Implementation of transistors</li> <li>6. Operational amplifiers</li> <li>7. Optoelectronic Devices</li> <li>8. Measurement Devices</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 electronics,</li> <li>• have expertise in independent working on circuit problems. They can calculate and develop easy circuits.</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 winter 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: Analog Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture + exercise <b>Lecturers:</b> Andreas Hörner <b>Language:</b> English <b>Contact Hours:</b> 4 <b>ECTS Credits:</b> 6.0		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> see module description		
<b>Assigned Courses:</b>		

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**Analog Electronics for Physicists and Materials Scientists** (lecture + exercise)

**Examination**

**Analog Electronics Analog Electronics for Physicists and Materials Scientists**

oral exam / length of examination: 30 minutes

**Examination Prerequisites:**

Analog Electronics for Physicists and Materials Scientists

<b>Module PHM-0226: Digital Electronics for Physicists and Materials Scientists</b> <i>Digital Electronics for Physicists and Materials Scientists</i>		6 ECTS/LP
Version 1.0.0 Person responsible for module: Andreas Hörner		
<b>Contents:</b> <ol style="list-style-type: none"> <li>1. Boolean algebra and logic gates</li> <li>2. Digital electronics and calculation of digital circuits</li> <li>3. Converters (Analog – Digital, Digital – Analog)</li> <li>4. Principle of digital memory and communication,</li> <li>5. Microprocessors and Networks</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 and digital electronics,</li> <li>• have expertise in independent working on circuit problems. They develop easy digital circuits and program microprocessors</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 provided materials (self-study) 20 h studying of course content using literature (self-study) 60 h lecture and exercise course (attendance)		
<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: Digital Electronics for Physicists and Materials Scientists</b> <b>Mode of Instruction:</b> lecture + exercise <b>Lecturers:</b> Andreas Hörner <b>Language:</b> English <b>Contact Hours:</b> 4 <b>ECTS Credits:</b> 6.0		
<b>Learning Outcome:</b> see module description		
<b>Contents:</b> see module description		
<b>Literature:</b> see module description		
<b>Examination</b> <b>Digital Electronics Digital Electronics for Physicists and Materials Scientists</b> oral exam / length of examination: 30 minutes		

<b>Module PHM-0150: Method Course: Spectroscopy on Condensed Matter</b> <i>Method Course: Spectroscopy on Condensed Matter</i>		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Dr. Stephan Krohns		
<b>Contents:</b> Dielectric Spectroscopy [8] <ul style="list-style-type: none"> <li>• Methods</li> <li>• Cryo-techniques</li> <li>• Measurement quantities</li> <li>• Relaxation processes</li> <li>• Dielectric phenomena</li> </ul> Ferroelectric Materials [7] <ul style="list-style-type: none"> <li>• Mechanism of ferroelectric polarization</li> <li>• Hysteresis loop measurements</li> <li>• Dielectric spectroscopy</li> </ul> Glassy Matter [8] <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Glassy phenomena</li> <li>• Dielectric spectroscopy</li> </ul> Multiferroic Materials [7] <ul style="list-style-type: none"> <li>• Introduction</li> <li>• Microscopic origins of multiferroicity</li> <li>• Pyrocurrent measurements</li> <li>• Dielectric spectroscopy</li> </ul>		
<b>Learning Outcomes / Competences:</b> The students: <ul style="list-style-type: none"> <li>• learn about the basic concepts of dielectric spectroscopy and the phenomena examined with it. Therefore they are instructed in experimental methods for the investigation of the dielectric properties of condensed matter,</li> <li>• are trained in planning and performing complex experiments. They learn to evaluate and analyze the collected data,</li> <li>• 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>Remarks:</b> <b>ELECTIVE COMPULSORY MODULE</b>		
<b>Workload:</b> Total: 240 h		
<b>Conditions:</b> Recommended: basic knowledge in solid state physics, basic knowledge in physics of glasses and supercooled liquids		<b>Credit Requirements:</b> written report on the experiments (editing time 2 weeks)
<b>Frequency:</b> irregular (usu. 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>
<p><b>Part of the Module: Method Course: Spectroscopy on Condensed Matter</b></p> <p><b>Mode of Instruction:</b> lecture</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 2</p>
<p><b>Literature:</b></p> <ul style="list-style-type: none"> <li>• N.W. Ashcroft, N.D. Mermin, Festkörperphysik (Oldenbourg)</li> <li>• Ch. Kittel, Einführung in die Festkörperphysik (Oldenbourg)</li> <li>• C.J.F. Böttcher, P. Bordewijk, Theory of Electric Polarization (Elsevier)</li> <li>• J. R. Macdonald, Impedance Spectroscopy (Wiley)</li> <li>• H. Scholze, Glas (Springer)</li> <li>• S.R. Elliott, Physics of Amorphous Materials (Longman)</li> <li>• R. Zallen, The Physics of Amorphous Solids (Wiley)</li> </ul>
<p><b>Assigned Courses:</b></p> <p><b>Method Course: Spectroscopy on Condensed Matter</b> (lecture)</p>
<p><b>Part of the Module: Method Course: Spectroscopy on Condensed Matter (Practical Course)</b></p> <p><b>Mode of Instruction:</b> laboratory course</p> <p><b>Language:</b> English</p> <p><b>Contact Hours:</b> 4</p>
<p><b>Assigned Courses:</b></p> <p><b>Method Course: Spectroscopy on Condensed Matter (Practical Course)</b> (internship)</p>
<p><b>Examination</b></p> <p><b>Method Course: Spectroscopy on Condensed Matter</b> written exam / length of examination: 120 minutes</p> <p><b>Examination Prerequisites:</b> Method Course: Spectroscopy on Condensed Matter</p>

<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> <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	<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> <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	<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: Colloquium****Language:** English**Learning Outcome:**

see description of module

**Contents:**

see description of module

**Examination****Colloquium**

seminar / length of examination: 20 minutes

**Examination Prerequisites:**

Colloquium