University of Augsburg

Module Catalogue

Austauschstudium MNTF

Faculty of Mathematics, Natural Sciences, and Materials Engineering

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

Important additional information due to the corona pandemic:

Please note that due to the ongoing development of the coronavirus pandemic, the details relating to the format of examinations for each module within the module catalogue may not be up to date. The examination formats for each module will be clarified and determined during the course of the semester.

Valid Wintersemester 2022/2023 - Printed 28.11.2022

Index by Module Groups

1) Faculty of Mathematics, Natural Sciences, and Materials Engineering - Bachelor Level

2) Faculty of Mathematics, Natural Sciences, and Materials Engineering - Master Level

Module MRM-0086: Sustainable Chemistry of Materials and Resources - Modelling *Nachhaltige Chemie der Materialien und Ressourcen - Modellierung*		6 ECTS/LP
Version 1.2.0 (since SoSe16) Person responsible for module: Prof. Dr. Richard Weihrich		
Contents: • Basics of materials' modelling from structures of molecules and crystals • Aspects of computational modelling of materials and sustainability • Application of computer codes using density functional theory • Prediction of chemical structures, energy landscapes, and polymorphism • Electronic structures • Advanced properties: magnetism, EOS, dynamics • Bonding in direct space: ELF, AIM		
Learning Outcomes / Competences: • The students know the basic terms and concepts of modelling of molecular and crystal structures and properties • The students have the competence to explain input and output data from computational modelling and to apply them for their specific use. • The students are able to apply the knowledge on modelling different molecular and crystal structures and properties by themselves on common computer codes like CRYSTAL17 • The students are able to process input and output data from computational modelling • The students acquire scientific skills to search for scientific literature and to evaluate scientific content.		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: as needed	**Recommended Semester:** from 5.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 3	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Nachhaltige Chemie der Materialien und Ressourcen - Modellierung
Mode of Instruction: lecture
Language: English / German
Contact Hours: 2

Contents:
- Grundlagen der Modellierung von Molekül- und Festkörper-Strukturen
- Aspekte von Modellierung und Nachhaltigkeit
- Anwendung von Computercodes auf Basis von DFT (Dichtefunktionaltheorie)
- Vorhersage zu chemischen Strukturen, Energielandschaften und Polymorphie
- Berechnung elektronischer Strukturen
- Eigenschaftsvorhersage: Magnetismus, Dynamik, Zustandsgleichungen
- Bindung im Realraum: DFT und AIM

Literature:

- A. R. West, Solid State Chemistry and its Applications, 2nd Ed., Stud. Ed., 2014, ISBN: 978-1-119-94294-8
- R. Dronskowski, Computational Chemistry of Solid State Materials: A Guide for Materials Scientists, Chemists, Physicists and others: A Guide for Material Scientists, Chemists, Physicists and Others, Wiley-VCH, 2005
- L. Smart, E. A. Moore, Solid State Chemistry: An Introduction, Taylor & Francis Inc., ISBN: 978-1439847909
- U. Müller, Anorganische Strukturchemie, 6. Auflage, Verlag Teubner, ISBN: 978-3834806260
- R. A. Evarestov, Quantum Chemistry of Solids: LCAO Treatment of Crytals and Nanostructures, Springer, 2013, 978-3642303555
- T. E. Warner, Synthesis, Properties and Mineralogy of Important Inorganic Materials, Wiley, 2011, 978-0470746110
- C. Pisani: Lecture notes in Chemistry: Quantum-Mechanical Ab-initio Calculation of the Properties of Crystalline Materials, Springer, 2013, 978-3540616450

Examination

Nachhaltige Chemie der Materialien und Ressourcen - Modellierung

written exam, written exam / length of examination: 90 minutes

Parts of the Module

Part of the Module: Übung zu Nachhaltige Chemie der Materialien und Ressourcen - Modellierung

Mode of Instruction: exercise course

Language: English / German

Contact Hours: 1

Learning Outcome:

Kenntnisse:

Die Studierenden verstehen die Prinzipien der Modellierung von Materialien auf atomarer Basis

Fertigkeiten:

Die Studierenden können den Input für Computer-Modellierungen erstellen, Berechnungen mit modernen Programmen (hier: CRYSTAL17) durchführen und den Output interpretieren.

Kompetenzen:

Die Studierenden beherrschen die Bedienung und den Umgang mit Ein- und Ausgabedaten von modernen DFT-Modellierungsprogrammen (hier: CRYSTAL17) und können ihre Kenntnisse auf eigene oder neue Fragestellungen anwenden.

Module MRM-0118: Engineering mechanics *Technische Mechanik*		6 ECTS/LP
Version 2.0.0 (since WS22/23) Person responsible for module: Prof. Dr.-Ing. Christian Weißenfels		
Contents: 1. Classification of mechanical systems 2. Support loads and stress resultants of statically determinate systems 3. Calculation of displacements 4. Support loads and stress resultants of statically indeterminate systems 5. Calculation of stresses 6. Static and kinetic friction 7. Kinematics and kinetics of rigid bodies		
Learning Outcomes / Competences: • The students know the most important basic concepts and methods of engineering mechanics • The Students understand the relationship between load and response in static structures • The students are able to describe movements due to forces • The students are able to apply their knowledge to formulate engineering problems using mechanics and solve them independently • The students can evaluate engineering systems • Acquisition of key qualifications: logical thinking; independent and structured working		
Workload: Total: 180 h 45 h lecture and exercise course (attendance) 135 h studying of course content using provided materials (self-study)		
Conditions: Experimentalphysik I Ingenieurwissenschaften I		**Credit Requirements:** schriftliche Prüfung
Frequency: each winter semester	**Recommended Semester:** from 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 3	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Technische Mechanik **Mode of Instruction:** lecture **Language:** German **Contact Hours:** 2
Learning Outcome: Siehe Modulbeschreibung
Contents: Siehe Modulbeschreibung
Literature: • D. Gross, W. Hauger, J. Schröder, W.A. Wall: Technische Mechanik I-III (Spinger Vieweg, 2019) • P. Wriggers, U. Nackenhorst, S. Beuermann, H,. Spiess, S. Löhnert: Technische Mechanik kompakt (Teubner-Verlag, 2006)

Assigned Courses:

Technische Mechanik (lecture)

Examination

Technische Mechanik

written exam, written exam / length of examination: 90 minutes

Parts of the Module

Part of the Module: Übung zu Technische Mechanik

Mode of Instruction: exercise course

Language: German

Contact Hours: 1

Learning Outcome:

Siehe Modulbeschreibung

Contents:

Siehe Modulbeschreibung

Assigned Courses:

Übung Technische Mechanik (exercise course)

Module MRM-1000: Mathematics I *Mathematik I*	5 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Andreas Rathgeber	

Contents:

1. Basic principles: Brief repetition of the basic mathematical knowledge from the mathematics preliminary course
2. Sequences, series and continuity: in particular Cauchy sequences, Taylor series
3. Differentiation and functions: in particular exponential, logarithmic and trigonometric functions, Differentiation in R^n, vector fields and differential operators
4. Integration: special integration in R^n, integration on curves and surfaces, integer sets and vector fields
5. Differential equations: basics and introductory examples
6. Coordinate systems: in particular Euclidean spaces, fundamental transformations, complex numbers with associated ones coordinate system

Learning Outcomes / Competences:
In this accompanying course, students in the first semester are to acquire the necessary mathematical knowledge. The basics for engineering training are taught as part of your studies: Learning basic arithmetic operations for students of engineering courses, for the future professional career are indispensable. In particular, the school knowledge of analysis is here to images of R^n extended to R^n (esp. R^3 to R^3). Among other things, differentiation and integration in R^n are considered.

Workload:
Total: 150 h

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

Parts of the Module

Part of the Module: Mathematik I
Mode of Instruction: lecture
Lecturers: Prof. Dr. Andreas Rathgeber
Language: German
Contact Hours: 2

Lehr-/Lernmethoden:
Blackboard lecture and beamer presentation.

Literature:
Announced in lecture.

Assigned Courses:

Mathematik I - Ingenieurmathematik (lecture + exercise)

Examination
Mathematik I
written exam, written exam / length of examination: 60 minutes

Parts of the Module
Part of the Module: Übung Mathematik I **Mode of Instruction:** exercise course **Language:** German **Contact Hours:** 2

Module MRM-1001: Mathematics II *Mathematik II*	8 ECTS/LP

Version 1.2.0
Person responsible for module: Prof. Dr. Andreas Rathgeber
Prof. Klein

Contents:

Part Prof. Rathgeber: Stochastics

1. Descriptive statistics

a. Introduction

b. Evaluation methods for one- and multidimensional data material

2. Theory of Probability

a. Combinatorial basics

b. Random processes, events and probabilities

c. Random variables, distributions and distribution parameters, i.e. Law of large numbers and central limit theorem

3. Inductive statistics

a. Basics of inductive statistics

b. Significance tests

Part Prof. Klein: Linear Algebra and Optimization

1. Basics

a. Complex numbers

b. Sets and their operations

c. Binary relations

2. Linear Algebra

a. Matrices and vectors

b. Point sets

c. Vector spaces, i.e. systems of linear equations

e. Linear mappings

f. Determinants

G. Eigenvalue problems

3. Optimization

a. Linear optimization

b. Nonlinear optimization

Learning Outcomes / Competences:

In many economic problems, the evaluation of data and their further useof the evaluation results is essential. As part of the event, the students should on the one hand learn the theoretical basics as well as the application requirements

of the statistical methods. on the other handThe focus should also be on the application of these procedures in order to enable the students to enter the facilitate empirical work and enable them to carry out their own data evaluations. Through this they are also able to interpret the results obtained and the limitations of the methods usedto recognize.In addition, areas of mathematics are dealt with that are not already the subject of the technical courses are. In particular, the students should be able to answer questions and problems such as they occur at the interface of economics and material sciences, to describe them mathematically and toanalyze.		
Workload: Total: 240 h		
Conditions: Basic knowledge in Mathematics.		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 8	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Mathematik II

Mode of Instruction: lecture
Lecturers: Prof. Dr. Robert Klein, Prof. Dr. Andreas Rathgeber
Language: German
Contact Hours: 4
ECTS Credits: 8.0

Literature:

- Bamberg et al.: Statistik, Oldenbourg-Verlag, 15. Auflage 2009
- Bamberg et al.: Arbeitsbuch Statistik, Oldenbourg-Verlag, 8. Auflage 2008
- Opitz, O.; S. Etschberger, W.R. Burkart und R. Klein: Mathematik - Lehrbuch für das Studium der Wirtschaftswissenschaften. 12. Aufl., De Gruyter Oldenbourg, München, 2017.
- Opitz, O.; Klein, R.; Burkart, W. R.: Mathematik - Übungsbuch für das Studium der Wirtschaftswissenschaften. 8. Aufl., De Gruyter Oldenbourg, München, 2014

Examination

Mathematik II

written exam, written exam / length of examination: 90 minutes

Parts of the Module

Part of the Module: Übung Mathematik II

Mode of Instruction: exercise course
Language: German
Contact Hours: 4

Contents:

Wiederholung und Vertiefung der Lehrinhalte mithilfe von Übungen. Übungsblätter werden regelmäßig angeboten.

Module MRM-1002: Technical Physics I *Technische Physik I*	6 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr. Markus Sause

Contents:

1. mechanics of mass points and systems of mass points
2. mechanics and dynamics of extended rigid bodies
3. continuum mechanics
4. mechanical oscillations and waves
5. mechanics and dynamics of gases and liquids
6. thermodynamics

Learning Outcomes / Competences:

The students

- know the basic terms, concepts and phenomena of classical mechanics, oscillations and waves in mechanical systems and thermodynamics (thermodynamics and statistical interpretation) and their application in engineering
- have skills in simple model building, the formulation of mathematical-physical approaches and can apply these to tasks in the areas mentioned, especially for technical problems, and
- have skills in the independent processing of problems from the above-mentioned subject areas. They are able to assess the accuracy of observation and analysis.

Remarks:

Mathematical tools such as differentiation and integration, simple differential equations and complex numbers are integrated into the module depending on their occurrence.

Workload:

Total: 180 h

Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 5	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Technische Physik I
Mode of Instruction: lecture
Lecturers: Prof. Dr. Markus Sause
Language: German
Contact Hours: 4

Lehr-/Lernmethoden:

Tafelvortrag, Beamerpräsentation, Demonstration von Experimenten

Literature:

- U. Hahn; Physik für Ingenieure, Oldenburg Wissenschaftsverlag, ISBN: 978-3-486-27520-9
- W. Demtröder: Experimentalphysik Band 1-2, Springer Verlag
- D. Halliday, R. Resnick & J. Walker: Physik, Wiley-VCH, ISBN: 978-3527405992
- P. Tipler: Physik, Spektrum, ISBN: 978-3860251225
- D. Meschede: Gerthsen Physik, Springer, ISBN: 978-3540254218
- R.C. Hibbeler: Kurzlehrbuch Technische Mechanik 1, Pearson Studium, ISBN: 978-3-8273-7101-0

Assigned Courses:

Technische Physik I (lecture)

Examination

Technische Physik I

written exam, written exam / length of examination: 90 minutes

Parts of the Module

Part of the Module: Übung Technische Physik I

Mode of Instruction: exercise course

Language: German

Contact Hours: 1

Assigned Courses:

Übung zu Technische Physik I (exercise course)

Module MTH-1000: Linear Algebra I *Lineare Algebra I*	8 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Tatjana Stykel	

Contents:

Basic calculation methods and most important tools of linear algebra, such as solution methods for linear systems of equations or the principal axis transformation of symmetric matrices, the notion of dimension of a (sub)vector space and the use of the determinant, important approaches for proof techniques:

- sets
- relations and mappings
- rational, real and complex numbers
- vector spaces and linear mappings
- linear systems of equations
- linear and affine subspaces
- dimension of subspaces
- similarity of matrices
- determinants
- eigenvalues and eigenvectors
- principal axis transformation

Learning Outcomes / Competences:

The students learn the mathematical structure of vector spaces and linear mappings in an abstract way and in explicit description. They possess the skills to work independently on tasks from these areas and to recognize and use linear structures in problems. They learn common calculation methods for solving linear systems and their possible applications. They understand the importance of the problem of eigenvectors and eigenvalues.

Integrated acquisition of key skills: competence of logical reasoning, mathematical expression, scientific thinking, developing solution strategies for given problems, scientific communication skills.

Workload:

Total: 240 h

4 h lecture (attendance)

2 h exercise course (attendance)

Conditions: none		
Frequency: each winter semester	**Recommended Semester:** 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Lineare Algebra I

Language: German

Workload:

4 Std. Vorlesung (Präsenzstudium)

2 Std. Übung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 8.0

Learning Outcome:

The students learn the mathematical structure of vector spaces and linear mappings in an abstract way and in explicit description. They possess the skills to work independently on tasks from these areas and to recognize and use linear structures in problems. They learn common calculation methods for solving linear systems and their possible applications. They understand the importance of the problem of eigenvectors and eigenvalues.
Integrated acquisition of key skills: competence of logical reasoning, mathematical expression, scientific thinking, developing solution strategies for given problems, scientific communication skills.

Contents:

Basic calculation methods and most important tools of linear algebra, such as solution methods for linear systems of equations or the principal axis transformation of symmetric matrices, the notion of dimension of a (sub)vector space and the use of the determinant, important approaches for proof techniques:

- sets
- relations and mappings
- rational, real and complex numbers
- vector spaces and linear mappings
- linear systems of equations
- linear and affine subspaces
- dimension of subspaces
- similarity of matrices
- determinants
- eigenvalues and eigenvectors
- principal axis transformation

Prerequisites: none

Literature:

Th. Bröcker: Lineare Algebra und Analytische Geometrie (Birkhäuser)
H.J. Kowalsky: Lineare Algebra (de Gruyter)
S. Bosch: Lineare Algebra (Springer)

Assigned Courses:

Lineare Algebra I (lecture + exercise)

Examination

Linear Algebra I

module exam, Portfolio

Module MTH-1010: Linear Algebra II *Lineare Algebra II*			10 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Prof. Dr. Marco Hien			
Contents: • Classification of endomorphisms of finite dimensional vector spaces (Jordan's normal form). • Norms and bilinear forms on vector spaces. • Tensor product and wedge product of vector spaces. • Basic algebraic structures (groups, rings) - in particular the ring of polynomials over a field			
Learning Outcomes / Competences: Students will understand the classification of endomorphisms of a finite dimensional vector space (quadratic matrices) - Jordan's normal form. They learn how to use additional structures on vector spaces (such as norms or bilinear forms, eucilidian scalar products) for deeper investigations. Students will understand the concept of the tensor product and universal properties - an important notion in differential geometry, algebraic geometry, ... They will encounter and study basic algebraic structures (groups, rings) and in particular develop a deeper understanding and computational skills with respect to the ring of polynomials in one variable over a field. Additionally, students will improve their general skills with respect to handling mathematical problems.			
Workload: Total: 300 h 2 h exercise course (attendance) 4 h lecture (attendance)			
Conditions: Lineare Algebra I			
Frequency: each summer semester	**Recommended Semester:** 2.	**Minimal Duration of the Module:** 1 semester[s]	
Contact Hours: 6	**Repeat Exams Permitted:** any		

Parts of the Module
Part of the Module: Lineare Algebra II **Language:** German **Workload:** 2 Std. Übung (Präsenzstudium) 4 Std. Vorlesung (Präsenzstudium) **Contact Hours:** 6 **ECTS Credits:** 10.0

Contents:

Dieses Modul führt das Modul Lineare Algebra I fort, indem der Schwerpunkt mehr auf abstrakte Strukturen gelegt wird. So werden Matrizen je nach Situation als lineare Abbildungen oder Endomorphismen betrachtet, und es werden Konstruktionsmöglichkeiten für abstrakte Vektorräume. Die Klassifikation von Endomorphismen endlich-dimensionaler Vektorräume durch Normalformen wird diskutiert, insbesondere wird die Jordansche Normalform besprochen.

Linearformen und Bilinearformen
Euklidische und unitäre Vektorräume
Normierte Vektorräume
Normalformen von Endomorphismen, insbesondere Jordansche Normalform
Orthoginale und unitäre Endomorphismen
Selbstadjungierte Endomorphismen
Normale Endomorphismen
Singulärwertzerlegung

Literature:

Th. Bröcker: Lineare Algebra und Analytische Geometrie (Birkhäuser)
H.J. Kowalsky: Lineare Algebra (de Gruyter)
S. Bosch: Lineare Algebra (Springer)

Examination

Lineare Algebra II

oral exam / length of examination: 30 minutes

Module MTH-1020: Analysis I		8 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. Bernd Schmidt		
Learning Outcomes / Competences: Die Student(inn)en sind vertraut mit den Grundlagen der Analysis einer reellen Unabhängigen, insbesondere mit Grenzwertprozessen bei Folgen und Reihen sowie Stetigkeit und Differenzierbarkeit von Funktionen. Sie haben wichtige Anwendungen und Beispiele verstanden und kennen die wesentlichen Eigenschaften und Konsequenzen dieser Begriffe. Integrierter Erwerb von Schlüsselqualifikationen: Anhand des vermittelten Stoffes haben die Student(inn)en außerdem die Fähigkeit erworben, abstrakten mathematischen Schlüssen zu folgen und selbst rigorose Beweise zu führen.		
Workload: Total: 240 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Keine inhaltlichen Voraussetzungen.		
Frequency: each semester	**Recommended Semester:** 1. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Analysis I

Mode of Instruction: lecture, exercise course

Language: German

Workload:

4 Std. Vorlesung (Präsenzstudium)

2 Std. Übung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 8.0

Contents:

Dieses Vorlesung behandelt unter anderem die reelle Analysis einer Unabhängigen:

Reelle Zahlen und Vollständigkeit

Komplexe Zahlen

Konvergenz und Divergenz bei Folgen und Reihen

Potenz- und Taylor-Reihen

Stetigkeitsbegriffe

Differential- und Integralrechnung einer Veränderlichen

(Teile des Stoffes können in die Analysis II ausgelagert werden und Stoffteile der Analysis II vorgezogen werden.)

Lehr-/Lernmethoden:

Vorlesung und Übungen

Literature:

Forster. O.: Analysis 1: Differential- und Integralrechnung einer Veränderlichen. Vieweg+Teubner.

Hildebrandt, S.: Analysis 1. Springer Verlag, 2005.

Königsberger, K.: Analysis 1. Springer Verlag, 2003.

Dieudonné, J.: Grundzüge der modernen Analysis. Vieweg Verlagsgesellschaft.

Lang, S.: Undergraduate Analysis

Lang, S.: Real and Functional Analysis

Rudin, W.: Analysis, De Gruyter Oldenbourg Verlag, 2008.

Assigned Courses:

Analysis I (lecture + exercise)

Examination

Analysis I

module exam, Klausur oder Portfolio (semesterweise Angabe siehe LV im Digicampus)

Module MTH-1030: Analysis II *Analysis II*		10 ECTS/LP
Version 2.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Bernd Schmidt		
Learning Outcomes / Competences: Die Student(inn)en haben ihre gundlegenden Analysiskenntnisse vertieft und wesentlich erweitert. Insbesondere sind sie vertraut mit den Grundlagen der Differentialrechnung mehrerer Veränderlicher sowie grundlegenden toplogischen Begriffen. Integrierter Erwerb von Schlüsselqualifikationen: Die Student(inn)en sind in der Lage, eigenständig und problemorientiert an mathematischen Aufgabenstellungen zu arbeiten.		
Workload: Total: 300 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency: each semester	**Recommended Semester:** 2. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Analysis II

Mode of Instruction: lecture, exercise course

Language: German

Contact Hours: 6

ECTS Credits: 10.0

Contents:

Dieses Modul behandelt die reelle Analysis mehrerer Unabhängiger:

Differentialrechnung mehrerer Veränderlicher

Metrische Räume und grundlegende topologische Begriffe

Normierte (vollständige) Vektorräume

Voraussetzungen: Grundlagen der reellen eindimensionalen Analysis

Literature:

Otto Forster: Analysis 2: Differential- und Integralrechnung mehrerer Veränderlichen. Vieweg+Teubner.

J. Dieudonné: Grundzüge der modernen Analysis. Vieweg Verlagsgesellschaft.

Hildebrandt, S.: Analysis 1. Springer Verlag, 2005.

Hildebrandt, S.: Analysis 2. Springer Verlag, 2003.

Königsberger, K.: Analysis 1. Springer Verlag, 2003.

Königsberger, K.: Analysis 2. Springer Verlag, 2009.

Assigned Courses:

Analysis 2 (lecture + exercise)

Examination

Analysis II

oral exam / length of examination: 20 minutes

Module MTH-1040: Analysis III		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Bernd Schmidt		
Learning Outcomes / Competences: Die Student(inn)en haben sich ein solides Grundwissen der Analysis erarbeitet. Sie kennen das Lebesgue-Integration, grundlegende Eigenschaften von Mannigfaltigkeiten und die Integralsätze. Sie haben ihre Abstraktionsfähigkeit und ihre geometrische Anschauung für analytische Sachverhalte geschult.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency: each winter semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Analysis III

Mode of Instruction: lecture, exercise course

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Dieses Modul vertieft und setzt die Differential- und Integralgrechnung mehrerer Veränderlicher mit globalen Anwendungen auf Mannigfaltigkeiten fort:

Maßtheorie

Lebesque-Integration

Mannigfaltigkeiten

Differentialformen und Integralsätze

Voraussetzungen: Grundlagen der reellen eindimensionalen und mehrdimensionalen Analysis

Literature:

Forster, O.: Analysis III, Springer, 2012.

Königsberger, K.: Analysis II. Springer-Verlag, 2009.

H. Bauer: Maß- und Integrationstheorie (de Gruyter, 1990)

K. Jänich: Vektoranalysis (Springer, 2005)

Assigned Courses:

Analysis III (lecture + exercise)

Examination

Analysis III

portfolio exam, Klausur

Module MTH-1050: Introduction to algebra *Einführung in die Algebra*	9 ECTS/LP

Version 1.0.0 (since WS19/20)
Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen

Learning Outcomes / Competences:
Die Studenten verstehen Fragen über prinzipielle Lösbarkeit von Polynomgleichungen und ihre Anwendungen und können diese beantworten.
Die Studenten haben Kenntnisse der Geschichte und Entwicklung der Mathematik im Rahmen der Galoisschen Theorie erlangt.

Workload:
Total: 270 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:
Keine inhaltlichen Voraussetzungen abgesehen vom Abitur-Wissen.

Frequency: each winter semester	**Recommended Semester:** 1. - 5.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Algebra
Mode of Instruction: lecture, exercise course
Language: German
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6
ECTS Credits: 9.0

Contents:
Die Einführung in die Algebra beginnt mit einer leicht verständlichen Einführung in die Galoissche Theorie der Symmetrien der Lösungen einer Polynomgleichung. Anhand dieses konkreten Zuganges werden Begriffe aus der Gruppen-, Ring- und Körpertheorie motiviert und eingeführt. Am Ende werden Ausblicke auf den moderneren abstrakten Zugang und Verallgemeinerungen gegeben. Themen sind:
Zahlbereiche
Polynome
Symmetrien
Galoissche Theorie
Konstruktionen mit Zirkel und Lineal
Auflösbarkeit von Gleichungen
Es werden die Grundlagen für alle weiterführenden Module in Algebra, Zahlentheorie und Arithmetischer und Algebraischer Geometrie gelegt. Außerdem ist die Algebra eine sinnvolle Grundlage für Module in Komplexer Geometrie und Algebraischer Topologie.
Voraussetzungen: Keine inhaltlichen Voraussetzungen abgesehen vom Abitur-Wissen.

Literature:
Serge Lang: Algebra. Springer-Verlag.
H. Edwards: Galois Theory. Springer-Verlag.
I. Stewart: Galois Theory. Chapman Hall/CRC.
Marc Nieper-Wißkirchen: Galoissche Theorie.

Assigned Courses:
Einführung in die Algebra (lecture + exercise)
Examination
Einführung in die Algebra oral exam / length of examination: 20 minutes

Module MTH-1070: Introduction to Geometry *Einführung in die Geometrie*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: Verständnis der grundlegenden Konzepte und Methoden in der modernen Geometrie. Befähigung zum weiterführenden Studium geometrischer und topologischer Themen im Rahmen der Bachelor- und Masterausbildung.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency: each winter semester	**Recommended Semester:** 4. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Geometrie

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Aspekte der Geometrie, insbesondere Differentialgeometrie, etwa:

Krümmungsbegriffe

Riemannsche Metriken

Geodäten

Parallelverschiebung

innere und äußere Geometrie

Gruppen in der Geometrie

Voraussetzungen: Solide Grundkenntnisse in Analysis und Linearer Algebra

Examination

Einführung in die Geometrie

written exam / length of examination: 180 minutes

Module MTH-1080: Complex Analysis *Funktionentheorie*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Dr. Peter Quast		
Learning Outcomes / Competences: Die Studenten sollen ein Verständnis für die grundlegenden Konzepte und Methoden der komplexen Analysis entwickeln. Sie sollen die Befähigung zu selbständiger wissenschaftlicher Arbeit im Bereich der Funktionentheorie lernen.		
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Funktionentheorie **Language:** German **Workload:** 4 Std. Vorlesung (Präsenzstudium) 2 Std. Übung (Präsenzstudium) **Contact Hours:** 6 **ECTS Credits:** 9.0

Contents:

Funktionentheorie ist der traditionelle Name für die Theorie der komplexwertigen analytischen oder holomorphen Funktionen einer komplexen Veränderlichen. Diese Funktionen sind einerseits sehr gewöhnlich, in dem Sinne nämlich, daß man ihnen in vielen mathematischen Gebieten begegnet. Polynome sind zum Beispiel holomorph, ebenso Sinus und Kosinus, der Exponentialfunktionen, der Logarithmus usw., wenn sie als von einer komplexen Variablen abhängig aufgefaßt werden.

Andererseits haben die holomorphen Funktionen erstaunliche Eigenschaften und gehorchen merkwürdigen strikten Gesetzen, die sich nicht erahnen lassen, wenn diese Funktionen nur so im reellen Gewande der Analysis daherkommen gesehen werden.

Holomorphe Funktionen

Der Cauchysche Integralsatz

Erste Folgerungen aus dem Cauchyschen Integralsatz

Isolierte Singularitäten

Analytische Fortsetzung

Die Umlaufszahlversion des Cauchyschen Integralsatzes

Der Residuenkalkül

Folgen holomorpher Funktionen

Satz von Mittag-Leffler und Weierstraßscher Produktsatz

Der Riemannsche Abbildungssatz

Ausblicke

Voraussetzungen: Solide Grundkenntnisse in Linearer Algebra. Kenntnisse der reellen Analysis in einer Variablen. Kenntnisse der reellen Analysis in mehreren Variablen sind hilfreich.

Literature:

Jähnich, K.: Funktionentheorie.

Examination

Funktionentheorie

module exam, schriftliche Prüfung oder mündliche Prüfung oder Portfolioprüfung

Module MTH-1100: Funktionalanalysis		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Bernd Schmidt		
Learning Outcomes / Competences: Die Student(inn)en haben sich die funktionalanalytischen Grundlagen für viele vertiefte Analysismodule erarbeitet. Sie sind in der Lage, in abstrakten Problemen allgemeine Strukturen zu erkennen und zu analysieren.		
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Funktionalanalysis

Mode of Instruction: lecture, exercise course

Language: German

Workload:

- 4 Std. Vorlesung (Präsenzstudium)
- 2 Std. Übung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

- Normierte Vektorräume und Banachräume
- Funktionale
- lineare Operatoren und Grundprinzipien der Funktionalanalysis
- Voraussetzungen: Solide Grundkenntnisse in Analysis und Linearer Algebra

Examination

Funktionalanalysis

portfolio exam

Module MTH-1110: Ordinary differential equations *Gewöhnliche Differentialgleichungen*	9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Tatjana Stykel	

Contents:
* Solution methods for special classes of ordinary differential equations
* Existence and uniqueness of solutions
* Continuous dependence of solutions
* Basic principles of qualitative theory, stability theory
* Boundary value problems

Learning Outcomes / Competences:
Understanding of the basic problems of ordinary differential equations including existence and uniqueness of the solutions as well as qualitative analysis of the solution behavior and elementary solution techniques; acquisition of key qualifications: the students learn to formulate motion processes as differential equations, to develop suitable solution strategies and to implement them.

Workload:
Total: 270 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: Linear Algebra and Calculus		
Frequency: each winter semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Gewöhnliche Differentialgleichungen
Language: German / English
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6
ECTS Credits: 9.0

Learning Outcome:
Understanding of the basic problems of ordinary differential equations including existence and uniqueness of the solutions as well as qualitative analysis of the solution behavior and elementary solution techniques; acquisition of key qualifications: the students learn to formulate motion processes as differential equations, to develop suitable solution strategies and to implement them.

Contents:
* Solution methods for special classes of ordinary differential equations
* Existence and uniqueness of solutions
* Continuous dependence of solutions
* Basic principles of qualitative theory, stability theory
* Boundary value problems

Literature:

Aulbach: Gewöhnliche Differentialgleichungen. Spektrum, 2004.

Walter: Gewöhnliche Differentialgleichungen. Springer, 2000.

Heuser:Gewöhnliche Differentialgleichungen (Vieweg+Teubner, 2009)

Assigned Courses:

Gewöhnliche Differentialgleichungen (lecture)

Examination

Ordinary Differential Equations

module exam, Portfolio

Module MTH-1130: Introduction to Numerical Analysis *Einführung in die Numerik*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Tatjana Stykel		
Contents: Error analysis, solution of linear systems, linear least squares problems, nonlinear equations, interpolation and eigenvalue problems		
Learning Outcomes / Competences: Understanding of the fundamental problems of numerics including conditioning, stability theory, algorithms and convergence analysis; knowledge of the simplest procedures for solving linear and nonlinear systems of equations, least squares problems, interpolation as well as eigenvalue problems; integrated acquisition of key qualifications: students learn in small groups to define problems precisely, to develop numerical methods and strategies and to assess their suitability; in the process, the social competence to work together in a team is developed.		
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Linear Algebra and Calculus		
Frequency: each winter semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Einführung in die Numerik **Language:** German **Workload:** 4 Std. Vorlesung (Präsenzstudium) 2 Std. Übung (Präsenzstudium) **Contact Hours:** 6 **ECTS Credits:** 9.0
Learning Outcome: Understanding of the fundamental problems of numerics including conditioning, stability theory, algorithms and convergence analysis; knowledge of the simplest procedures for solving linear and nonlinear systems of equations, least squares problems, interpolation as well as eigenvalue problems; integrated acquisition of key qualifications: students learn in small groups to define problems precisely, to develop numerical methods and strategies and to assess their suitability; in the process, the social competence to work together in a team is developed.
Contents: Error analysis, solution of linear systems, linear least squares problems, nonlinear equations, interpolation and eigenvalue problems
Literature: Freund, R.W., Hoppe, R.H.W.: Stoer/Bulirsch: Numerische Mathematik I. Springer. Deuflhard, P., Hohmann, A.: Numerische Mathematik I. deGruyter. Schwarz, H.R., Köckler, N.: Numerische Mathematik. Teubner.
Assigned Courses:

Einführung in die Numerik (lecture + exercise)

Examination

Introduction to Numerical Analysis

module exam, Portfolio

Module MTH-1140: Introduction to Optimization

Einführung in die Optimierung (Optimierung I)

9 ECTS/LP

Version 1.1.0 (since WS15/16)
Person responsible for module: Prof. Dr. Mirjam Dür

Contents:
This course gives a general introduction to optimization. Specifically, the following fundamental topics are treated:
* Separation Theorems
* Simplex Algorithm
* Theory of polyhedra
* Duality Theory
* Parametric Optimization
* Ellipsoid method

Learning Outcomes / Competences:
Students learn how to model real world problems as mathematical optimization problems. They also acquire knowledge about polyhedra which appear as feasible sets in linear optimization.

Workload:
Total: 270 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:
Grundvorlesungen zur Analysis und Lineare Algebra

Credit Requirements:
Die Module MTH-1140 und MTH-1148 unterscheiden sich bei den ECTS/LP-Punkten, sind aber inhaltlich nahezu identisch. Daher dürfen Studiernede nur eines dieser beiden Module einbringen.

Frequency: each summer semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Einführung in die Optimierung (Optimierung I)
Mode of Instruction: lecture
Language: German
Workload:
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 4
ECTS Credits: 9.0

Examination
Einführung in die Optimierung (Optimierung I)
written exam / length of examination: 180 minutes

Parts of the Module

Part of the Module: Einführung in die Optimierung (Optimierung I) (Übung)
Mode of Instruction: exercise course
Language: German
Contact Hours: 2

Contents:

Übungen vertiefen und ergänzen den Vorlesungsstoff; die Teilnahme wird unbedingt empfohlen.

Module MTH-1150: Probability I *Einführung in die Stochastik (Stochastik I)*		9 ECTS/LP
Version 2.0.0 (since WS17/18) Person responsible for module: Prof. Dr. Vitali Wachtel		
Contents: • Ereignissysteme, • Sigma-Algebren, • Aufbau der Maß- und Integrationstheorie, • Zufallsvariablen, • Zufallsvektoren, • Wahrscheinlichkeitsverteilungen, • Numerische Charakteristika von Zufallsgrößen, • Konvergenzarten von Zufallsgrößen, • Grenzwertsätze der Wahrscheinlichkeitsrechnung		
Learning Outcomes / Competences: Fähigkeiten zur Übersetzung von stochastischen Problemstellungen in eine mathematische Sprache, Fähigkeiten zur Lösung von stochastischen Anwendungsproblemen in Naturwissenschaft, Technik und Wirtschaft, Kennenlernen der wichtigsten Verteilungen und deren Kenngrößen.		
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: Grundlagen der reellen eindimensionalen und mehrdimensionalen Analysis, Eigenschaften linearer Abbildungen zwischen endlichdimensionalen Vektorräumen, Matrizenkalkül inkl. Spektraleigenschaften. Module Linear Algebra I (MTH-1000) Module Linear Algebra II (MTH-1010) Module Analysis I (MTH-1020) Module Analysis II (MTH-1030)		
Frequency: each winter semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Einführung in die Stochastik (Stochastik I) **Mode of Instruction:** lecture + exercise **Lecturers:** Prof. Dr. Lothar Heinrich **Language:** German **Contact Hours:** 6 **ECTS Credits:** 9.0
Learning Outcome: Fähigkeiten zur Übersetzung von stochastischen Problemstellungen in eine mathematische Sprache, Fähigkeiten zur Lösung von stochastischen Anwendungsproblemen in Naturwissenschaft, Technik und Wirtschaft, Kennenlernen der wichtigsten Verteilungen und deren Kenngrößen.

Contents:

- Ereignissysteme,
- Sigma-Algebren,
- Aufbau der Maß- und Integrationstheorie,
- Zufallsvariablen,
- Zufallsvektoren,
- Wahrscheinlichkeitsverteilungen,
- Numerische Charakteristika von Zufallsgrößen,
- Konvergenzarten von Zufallsgrößen,
- Grenzwertsätze der Wahrscheinlichkeitsrechnung

Literature:

Wird in der Vorlesung bekannt gegeben

Assigned Courses:

Einführung in die Stochastik (Stochastik I) (lecture + exercise)

**

Examination

Einführung in die Stochastik (Stochastik I)

written exam

Module MTH-1160: Probability II *Statistik (Stochastik II)*		9 ECTS/LP
Version 2.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Lothar Heinrich		
Learning Outcomes / Competences: Beherrschung der grundlegenden Methoden des statistischen Schätzens und Testens, Erlernen aus Beobachtungen, Kenntnisse über eine unbekannte Verteilung zu erhalten, Erlernen statistische Tests auszuwählen, durchzuführen und zu interpretieren.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Analysis I Analysis II Lineare Algebra I Lineare Algebra II Einführung in die Stochastik (Stochastik I)		
Frequency: each summer semester	**Recommended Semester:** 4. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Einführung in die mathematische Statistik (Stochastik II)

Language: German

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Bedingte Erwartungen,
Grenzwertsätze der Wahrscheinlichkeitsrechnung,
Beschreibende Statistik,
Empirische Verteilungsfunktion,

Signifikantztests,
Parameterschätzungen,
Tests in normalverteilten Grundgesamtheiten

Examination

Einführung in die mathematische Statistik (Stochastik II)

written exam / length of examination: 180 minutes

Module MTH-1200: Introduction to Nonlinear and Combinatorial Optimization *Nichtlineare und kombinatorische Optimierung (Optimierung II)*		9 ECTS/LP
Version 1.3.0 (since WS15/16) Person responsible for module: Prof. Dr. Mirjam Dür		
Contents: This course treats both nonlinear optimization and gives an introduction to discrete optimization, in particular network optimization. Nonlinear Optimization: * Tangent cone, linearized tangent cone * Fritz-John and KKT points * Sensitivity analysis * Duality theory * Numerical methods Discrete Optimization: * Graphs, paths, cycles * Shortest paths * Trees * Flows		
Learning Outcomes / Competences: Students learn how to deal with real world problems and mathematical optimization problems under more general assumptions like nonlinearity of the functions or integrality of the variables involved.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Grundvorlesungen zur Analysis und Lineare Algebra, Einführung in die Optimierung (Optimierung I)		**Credit Requirements:** Die Module MTH-1200 und MTH 1208 unterscheiden sich bei den ECTS/LP-Punkten, sind aber inhaltlich nahezu identisch. Daher dürfen Studierende nur eines dieser beiden Module einbringen.
Frequency: each winter semester	**Recommended Semester:** 4. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Grundlagen der nichtlinearen und der kombinatorischen Optimierung (Optimierung II)

Mode of Instruction: lecture

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 4

ECTS Credits: 9.0

Contents:

Assigned Courses:

Grundlagen der nichtlinearen und kombinatorischen Optimierung (Optimierung II) (lecture)

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Examination

Grundlagen der nichtlinearen und der kombinatorischen Optimierung (Optimierung II)

written exam / length of examination: 180 minutes

Parts of the Module

Part of the Module: Nichtlineare und kombinatorische Optimierung (Optimierung II) (Übung)

Language: German

Contact Hours: 2

Contents:

Übungen vertiefen und ergänzen den Vorlesungsstoff; die Teilnahme wird unbedingt empfohlen.

Module MTH-1240: Numerical analysis of ordinary differential equations *Numerik gewöhnlicher Differentialgleichungen*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Verständnis der grundlegenden numerischen Verfahren zur Lösung gewöhnlicher Differentialgleichungen inkl. Kondition, Stabilität, Algorithmik und Konvergenzanalyse; integrierter Erwerb von Schlüsselqualifikationen: Die Studierenden lernen in Kleingruppe , Problemstellungen präzise zu definieren, numerische Lösungsstrategien zu entwickeln und deren Tauglichkeit abzuschätzen, dabei wird die soziale Kompetenz zur Zusammenarbeit im Team weiterentwickelt.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency: each summer semester	**Recommended Semester:** 4. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerik gewöhnlicher Differentialgleichungen

Mode of Instruction: lecture + exercise

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Knappe Zusammenfassung der benötigten Resultate der Theorie gewöhnlicher Differentialgleichungen

Kondition von Anfangswertproblemen, Fehleranalyse

Rekursionsgleichungen

Einschrittverfahren

Schrittweitensteuerung

Extrapolationsmethoden

Mehrschrittverfahren

Steife Differentialgleichungen

Empfohlene Voraussetzungen: Grundlagen der reellen eindimensionalen und mehrdimensionalen Analysis, Eigenschaften linearer Abbildungen zwischen endlichdimensionalen Vektorräumen, Matrizenkalkül inkl. Spektraleigenschaften, Programmierkenntnisse, grundlegende Kenntnisse der Numerik

Literature:

Deuflhard, P., Bornemann, F.: Numerische Mathematik II. Walter de Gruyter.

Stoer, J., Bulirsch, R.: Numerische Mathematik II. Springer.

Hairer, E., Wanner, G.: Solving Ordinary Differential Equations. Springer.

Examination

Numerik gewöhnlicher Differentialgleichungen

module exam, Portfolio

Module MTH-1350: Mathematical Seminar *Mathematisches Seminar*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Learning Outcomes / Competences: • Ability to work independently on scientific literature. • Competences in the independent understanding and solving of complex problems. • Skills in formulating and working on theoretical questions with the help of the mathematical methods learned. • Integrated acquisition of key qualifications: Working independently with scientific literature, trying out different presentation techniques and presentation media, conducting scientific discussions and communicating problem-solving approaches.		
Workload: Total: 180 h 2 h seminar (attendance)		
Conditions: none		
Frequency: each semester	**Recommended Semester:** 3. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematisches Seminar

Mode of Instruction: seminar
Language: German / English
Contact Hours: 2
ECTS Credits: 6.0

Contents:

Seminar über ein mathematisches Thema

Literature:

wird in der Veranstaltung bekanntgegeben

Assigned Courses:

Ausgewählte Kapitel der Topologie (seminar)
**

Bachelor-Seminar Mathematik (seminar)

Mathematisches Seminar (seminar)

Semianr zur Kommutative Algebra (seminar)
**

Seminar zu Geschichte der Mathematik (seminar)

Seminar zu endlichen Körpern und dem quadratischen Reziprozitätsgesetz (seminar)

Seminar zur Dynamik (seminar)

Seminar zur Kombinatorik (seminar)
**

Seminar zur Numerik (seminar)

Seminar zur Optimierung und Spieltheorie (seminar)

*(online/digital) *

Seminar zur Optimierung: Kombinatorische Probleme in der Netzwerkanalyse (seminar)

**

Seminar zur Stochastik (Bachelor) (seminar)

Seminar zur Stochastik (Bachelor) (seminar)

Examination

Mathematisches Seminar

module exam, Der konkrete Typ der Modulprüfung (Vortrag oder kombiniert schriftlich-mündliche Prüfung oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben.

Module MTH-2080: Evolution equations *Spezialisierung Evolutionsgleichungen*		15 ECTS/LP
Version 2.0.0 (since SoSe18) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: recent research topics, will be announced in digicampus before the term starts		
Learning Outcomes / Competences: The students receive an in-depth knowledge of selected topics of dynamical systems described by differential equations (e.g. ordinary, partial, stochastic). At the same time, a well-founded introduction to modern qualitative theory is considered. You will achieve the competence to penetrate independently into advanced topics of the just mentioned fields and, subsequently, to write a thesis in the field of in the field of dynamical systems or evolutionary equations. Integrated acquisition of key qualifications: Self-study of English-language scientific literature, scientific work, conducting scientific discussions and presenting mathematical theories.		
Workload: Total: 450 h		
Conditions: Good knowledge of ordinary differential equations and functional analysis.		**Credit Requirements:** Passing the module exam (usually presentation and oral exam)
Frequency: as needed	**Recommended Semester:** 4. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Seminar zu Evolutionsgleichungen **Language:** German / English **Contact Hours:** 2 **ECTS Credits:** 6.0
Learning Outcome: Durch Selbststudium mathematischer Themen im Bereich der Evolutionsgleichungen, Vortrag und wissenschaftlicher Diskussion sollen folgende Ziele erreicht werden: Befähigung zum selbständigen Erarbeiten wissenschaftlicher Literatur, Kompetenzen in der selbständigen Bearbeitung komplexer Problemstellungen, Fertigkeiten zur Formulierung und Bearbeitung von theoretischen Fragestellungen mithilfe der erlernten mathematischen Methoden Integrierter Erwerb von Schlüsselqualifikationen: Eigenständiges Arbeiten mit wissenschaftlicher Literatur, Erprobung verschiedener Präsentationstechniken und Präsentationsmedien, Führen wissenschaftlicher Diskussionen und die Vermittlung von Problemlösungsansätzen.
Contents: aktuelle wechselne Forschungsthemen.

Lehr-/Lernmethoden:

Eigenständige Einarbeitung in ein aktuelles Forschungsgebiet,
eigenständige Präsentation und wissenschaftliche Diskussion

Literature:

Wird in der jeweiligen Lehrveranstaltung vor Semesterbeginn bekannt gegeben.

Part of the Module: Lesekurs Evolutionsgleichungen

Language: German / English
Contact Hours: 2
ECTS Credits: 9.0

Learning Outcome:

Durch Selbststudium mathematischer Themen im Bereich der Evolutionsgleichungen,
Vortrag und wissenschaftlicher Diskussion sollen folgende Ziele erreicht werden:
Befähigung zum selbständigen Erarbeiten wissenschaftlicher Literatur,
Kompetenzen in der selbständigen Bearbeitung komplexer Problemstellungen,
Fertigkeiten zur Formulierung und Bearbeitung von theoretischen
Fragestellungen mithilfe der erlernten mathematischen Methoden
Integrierter Erwerb von Schlüsselqualifikationen:
Eigenständiges Arbeiten mit wissenschaftlicher Literatur,
Führen
wissenschaftlicher Diskussionen und die Vermittlung von Problemlösungsansätzen.

Contents:

aktuelle wechselne Forschungsthemen.

Lehr-/Lernmethoden:

Eigenständige Einarbeitung in ein aktuelles Forschungsgebiet und wissenschaftliche Diskussion

Literature:

Wird in der jeweiligen Lehrveranstaltung vor Semesterbeginn bekannt gegeben.

Examination

Abschlussprüfung

portfolio exam

Description:

Die Abschlussprüfung besteht aus einem Vortrag mit anschließender mündlicher Prüfung, und der aktiven Beteiligung an wissenschaftlichen Diskussionen in Seminar und Lesekurs

Module MTH-2550: Elementary algebraic geometry

Elementare Algebraische Geometrie

9 ECTS/LP

Version 1.0.0 (since SoSe20)
Person responsible for module: Prof. Dr. Marco Hien

Contents:

The main topics of this course are algebraic varieties over a field and foundations of commutative algebra.

The students will learn the main ingredients of commutative algebra (localization, modules over rings) necessary for algebraic geometry, the definition and properties of affine algebraic varieties, the projective space and projective varieties - Hilbert's Nullstellensatz, function fields, dimension and smoothness.

kommutative Algebra: Lokalisierung, Moduln über Ringen, Tensorprodukt und Flachheit, Algebren über Körper, Hilbertscher Nullstellensatz Zahlkörper und deren Ringe ganzer Zahlen.

Irreduzibilität, Morphismen, Glattheit, Käherdifferentiale, Dimensionsbegriff, Aufblasungen, Auflösung von Singularitäten, Computeralgebra, kohomologische Methoden, elliptische Kurven

Learning Outcomes / Competences:

The students acquire the konwledge to approach geometric questions from an algebraic point of view. Many geometric structures allow an algebraic description and affine or projective varieties provide a vast class of geometric objects which have been studied for a long time and still are important obejcts in algebraic geometry, complex geometry, symplectic geometry, ...

The students obtain the techniques to study these objects and their properties (in particular their topology, smoothness, dimension). To this purpose, some foundational results from commutative algebra are discussed as well.

Students will encounter important examples of algebraic varieties and see how to use computer algebra systems for computations and visualisation.

Remarks:

Elementare Algebraische Geometrie: Mündliche Prüfung, Dauer: 20 Minuten

Dieses Modul kann nicht gleichzeitig mit dem "Spezialisierungsmodul Algebraische Geometrie" eingebracht werden.

Workload:

Total: 270 h

Conditions: Kenntnisse über algebraische Grundbegriffe (Körper, Galoistheorie)		**Credit Requirements:** Bestehen der Modulprüfung
Frequency:	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Elementare Algebraische Geometrie

Language: German

Literature:

Eisenbud, Commutative Algebra with a View toward Algebraic Geometry Silverman: The Arithmetic of Elliptic Curves, Springer Reid, Undergraduate Algebraic Geometry, LondonMathSoc. Hulek, Elementare Algebraische Geometrie, Springer

Examination

MTH-2550 Elementare Algebraische Geometrie

oral exam / length of examination: 20 minutes

Module PHM-0001: Physics I (Mechanics, Thermodynamics) *Physik I (Mechanik, Thermodynamik)*	8 ECTS/LP

Version 2.0.0 (since SoSe22)
Person responsible for module: Andreas Hörner

Contents:

Mechanik:

1. Kinematik und Dynamik des Massenpunktes
2. Erhaltungsgrößen in der Mechanik
3. Massenpunktsysteme
4. Mechanik starrer Körper
5. Relativistische Mechanik
6. Mechanische Schwingungen und Wellen
7. Mechanik fester Körper, Flüssigkeiten, Gase

Thermodynamik

1. Temperatur, Wärme und der erste Hauptsatz der Thermodynamik
2. Kinetische Gastheorie
3. Entropie und der zweite Hauptsatz der Thermodynami

Learning Outcomes / Competences:

- Die Studierende wissen die grundlegenden Begriffe, Konzepte und Phänomene der klassischen Mechanik, von Schwingungen und Wellen in mechanischen Systemen und der Thermodynamik (Wärmelehre und statistische Deutung),
- besitzen Fertigkeiten in einfacher Modellbildung, der Formulierung mathematisch-physikalischer Ansätze und können diese auf Aufgabenstellungen in den genannten Bereichen anwenden und
- besitzen Kompetenzen in der selbständigen Bearbeitung von Problemstellungen aus den genannten Themenbereichen. Sie sind in der Lage, Genauigkeiten von Beobachtung und Analyse einschätzen zu können.
- Integrierter Erwerb von Schlüsselqualifikationen: analytisch-methodische Kompetenz, wissenschaftliches Denken, Abwägen von Lösungsansätzen, Training des logischen Denkens, Teamfähigkeit, Erlernen des eigenständigen Arbeitens mit (englischsprachiger) Fachliteratur

Workload:

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

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

Parts of the Module

Part of the Module: Physik I (Mechanik, Thermodynamik)
Mode of Instruction: lecture
Lecturers: Andreas Hörner
Language: German
Contact Hours: 4

Literature:

- Marcelo Alonso, Edward J. Finn: Physik (3., durchgesehene Aufl. - München [u.a.], Oldenbourg, 2000)
- Wolfgang Demtröder: Experimentalphysik I, Mechanik und Wärme (8. Auflage - Berlin [u.a.], Springer, 2018)
- David Halliday, Jearl Walker, Robert Resnick: Physik (3., vollständig überarbeitete und erweiterte Auflage - Weinheim, Wiley-VCH, 2018)
- Paul A. Tipler, Gene Mosca: Physik (8., korrigierte und erweiterte Auflage - Berlin, Springer Spektrum, 2019)
- Dieter Meschede: Gerthsen Physik (25. Aufl. - Berlin [u.a.], Springer Spektrum, 2015)

Bei allen Literaturvorschlägen stellt die angegebene Auflage nur die aktuellste in der Bibliothek vorhandene Version dar. Alle anderen Auflagen sind ebenso als Begleitung zum Modul geeignet.

Assigned Courses:

Physik I (Mechanik, Thermodynamik) (lecture)

Examination

Physik I (Mechanik, Thermodynamik)

written exam / length of examination: 150 minutes

Parts of the Module

Part of the Module: Übung zu Physik I

Mode of Instruction: exercise course

Language: German

Contact Hours: 2

Assigned Courses:

Übung zu Physik I - Übungsgruppe 01 (exercise course)

Module PHM-0003: Physics II (Electrodynamics, Optics) *Physik II (Elektrodynamik, Optik)*		8 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Andreas Hörner		

Contents:

Elektrodynamik

1. Elektrische Wechselwirkungen
2. Magnetische Wechselwirkungen
3. Elektrische Leitung
4. Materie in statischen elektrischen und magnetischen Feldern
5. Zeitabhängige elektromagnetische Felder

Optik

1. Harmonische Wellen im Raum
2. Elektromagnetische Wellen
3. Klassische Geometrische Optik

Learning Outcomes / Competences:

- Die Studierenden kennen die grundlegenden Begriffe, Konzepte und Phänomene der Elektrostatik und des Magnetismus; des weiteren die Grundbegriffe der Elektrodynamik sowie der elektromagnetischen Wellen und – daraus abgeleitet – der Optik,
- besitzen Fertigkeiten in der mathematischen Beschreibung elektromagnetischer Phänomene, Modellbildung, der Formulierung mathematisch-physikalischer Ansätze und können diese auf Aufgabenstellungen in den genannten Bereichen anwenden und
- besitzen Kompetenzen in der selbständigen Bearbeitung von Problemstellungen zu den genannten Themenbereichen. Sie sind in der Lage, Genauigkeiten von Beobachtung und Analyse einschätzen zu können.
- Integrierter Erwerb von Schlüsselqualifikationen: analytisch-methodische Kompetenz, wissenschaftliches Denken, Abwägen von Lösungsansätzen, Training des logischen Denkens, Teamfähigkeit, Erlernen des eigenständigen Arbeitens mit (englischsprachiger) Fachliteratur

Workload:

Total: 240 h

30 h studying of course content using provided materials (self-study)

30 h studying of course content using literarture (self-study)

90 h studying of course content through exercises / case studies (self-study)

90 h lecture and exercise course (attendance)

Conditions: Inhalte des Moduls Physik I		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Physik II (Elektrodynamik, Optik)

Mode of Instruction: lecture

Lecturers: Andreas Hörner

Language: German

Contact Hours: 4

Literature:

- Marcelo Alonso, Edward J. Finn: Physik (3., durchgesehene Aufl. - München [u.a.], Oldenbourg, 2000)
- Wolfang Demtröder: Experimentalphysik II, Elektrizität und Optik (8. Auflage - Berlin [u.a.], Springer, 2013)
- David Halliday, Jearl Walker, Robert Resnick: Physik (3., vollständig überarbeitete und erweiterte Auflage - Weinheim, Wiley-VCH, 2018)
- Paul A. Tipler, Gene Mosca: Physik (8., korrigierte und erweiterte Auflage - Berlin, Springer Spektrum, 2019)
- Dieter Meschede: Gerthsen Physik (25. Aufl. - Berlin [u.a.], Springer Spektrum, 2015)

Bei allen Literaturvorschlägen stellt die angegebene Auflage nur die aktuellste in der Bibliothek vorhandene Version dar. Alle anderen Auflagen sind ebenso als Begleitung zum Modul geeignet.

Examination

Physik II (Elektrodynamik, Optik)

written exam / length of examination: 150 minutes

Parts of the Module

Part of the Module: Übung zu Physik II

Mode of Instruction: exercise course

Language: German

Contact Hours: 2

Module PHM-0035: Chemistry I (General and Inorganic Chemistry) *Chemie I (Allgemeine und Anorganische Chemie)*		8 ECTS/LP
Version 1.1.0 (since WS09/10) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: • Einführung in die Allgemeine und Anorganische Chemie • Atombau und Periodensystem (Elemente, Isotope, Orbitale, Elektronenkonfiguration) • Thermodynamik, Kinetik • Massenwirkungsgesetz, Säure-Base-Gleichgewicht, Titrationskurven, Puffersysteme • Chemische Bindung (kovalente, ionische und Metallbindung; Dipolmoment; Lewis- Schreibweise; Kristallgitter; VSEPR-, MO-Theorie; Bändermodell) • Oxidationszahlen, Redoxreaktionen, Elektromototische Kraft, Galvanisches Element, Elektrolyse, Batterien, Korrosion • Großtechnische Verfahren der Chemischen Grundstoffindustrie • Stoffchemie der Hauptgruppenelemente und ihre Anwendung in der Materialchemie (Vorkommen, Darstellung der reinen Elemente, wichtige Verbindungen, Analogiebeziehungen, wichtige technische Anwendungen)		
Learning Outcomes / Competences: • Die Studierenden wissen die grundlegenden Methoden und Konzepten der Chemie und haben angemessene Kenntnisse über den Aufbau der Materie, die Beschreibung chemischer Bindungen und die Grundprinzipien der chemischen Reaktivität, • besitzen die Fertigkeit grundlegende chemische Fragestellungen unter Anwendung der erworbenen Kenntnisse zu formulieren und zu bearbeiten, • und besitzen die Kompetenz zur zielgerichteten Problemanalyse und Problembearbeitung in den genannten Teilgebieten. • Integrierter Erwerb von Schlüsselqualifikationen		
Workload: Total: 240 h 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using literarture (self-study) 30 h studying of course content using provided materials (self-study) 90 h lecture and exercise course (attendance)		
Conditions: none		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Chemie I (Allgemeine und Anorganische Chemie) **Mode of Instruction:** lecture **Language:** German **Contact Hours:** 4
Learning Outcome: siehe Modulbeschreibung

Contents:

siehe Modulbeschreibung

Literature:

- E. Riedel, C. Janiak, *Anorganische Chemie*, 9. Auflage, De Gruyter Verlag, Berlin 2015. ISBN-10: 3110355264.
- M. Binnewies, M. Jäckel, H. Willner, *Allgemeine und Anorganische Chemie*, 3. Auflage, Spektrum Akademischer Verlag, Heidelberg 2016. ISBN-10: 3662450666.
- T.L. Brown, H. E. LeMay, B.E. Bursten, *Chemie: Studieren kompakt*, 14. Auflage, Pearson Studium (Sept. 2018). ISBN-10: 3868943129.
- C.E. Mortimer, U. Müller, *Chemie* – Das Basiswissen der Chemie. Mit Übungsaufgaben., 13. Auflage, Georg Thieme Verlag Stuttgart, 2019. ISBN-10: 3132422746.
- Kewmnitz, Simon, Fischedick, Hartmann, Henning, *Duden Basiswissen Schule: Chemie Abitur*, Bibliographisches Institut, Mannheim, 5. Auflage (2020). ISBN-10: 3411045957.

Assigned Courses:

Chemie I (Allgemeine und Anorganische Chemie) (lecture)

Part of the Module: Übung zu Chemie I

Mode of Instruction: exercise course
Language: German
Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Assigned Courses:

Übung zu Chemie I (exercise course)

Examination

Chemie I (Allgemeine und Anorganische Chemie)

written exam / length of examination: 90 minutes

Module PHM-0036: Chemistry II (Organic Chemistry) *Chemie II (Organische Chemie)*	8 ECTS/LP

Version 1.5.0 (since WS09/10)
Person responsible for module: Prof. Dr. Dirk Volkmer

Contents:

- OE: Organisation und Einleitung
- A: Formeln, Strukturen und Nomenklatur
- B: Funktions- und Stoffklassen organischer Moleküle
- B1: Alkane und Cycloalkane
- B2: Halogenkohlenwasserstoffe, SN und Eliminierung
- B3: Alkene
- B4: Alkine
- B5: Aromaten
- B6: Alkohole
- B7: Aldehyde und Ketone
- B8: Carbonsäure und Carbonsäurederivate
- C: Stereochemie
- D: Molekulare Materialien

Learning Outcomes / Competences:

- Die Studierenden kennen die Methoden und Konzepte der organischen Chemie und sind mit den Grundlagen der organischen Synthese, Reaktionsmechanismen,Polymerchemie und molekularer Materialien vertraut,
- haben Fertigkeiten zur Formulierung und Bearbeitung organisch-chemischer Fragestellungen unter Anwendung der erlernten Methoden erworben,
- und besitzen die Kompetenz zur fundierten Problemanalyse und zur eigenständigen Bearbeitung von Problemstellungen in den genannten Bereichen.
- Integrierter Erwerb von Schlüsselqualifikationen

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

Conditions:
none

Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Chemie II (Organische Chemie)
Mode of Instruction: lecture
Language: German
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:

- Einführung
- Formeln, Strukturen und Nomenklatur organischer Moleküle
- Funktions- und Stoffklassen organischer Moleküle
- Stereochemie
- Spektroskopie und Strukturaufklärung
- Molekulare Materialien

Literature:

- C. Schmuck, Basisbuch Organische Chemie (2018) (ISBN-10: 3868943331)

Part of the Module: Übung zu Chemie II

Mode of Instruction: exercise course

Language: German

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Examination

Chemie II (Organische Chemie)

written exam / length of examination: 90 minutes

Module PHM-0191: Technical Physics II *Technische Physik II*	6 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Dr. Judith Moosburger-Will

Contents:

1. Electrostatics

2. Magnetism

3. Electrodynamics, Maxwell's equations

4. Optics

5. Evaluation of measurements

Learning Outcomes / Competences:

The students

- know the basic terms, concepts and phenomena of electrostatics and magnetism; of Furthermore, the basic concepts of electrodynamics and optics,
- have skills in the mathematical description of electromagnetic phenomena, modelling, the formulation of mathematical-physical approaches and can apply them to tasks in the above mentioned areas, and
- have competences in the independent solving of problems related to the mentioned subject areas. They are able to assess the accuracy of observation and analysis.

Remarks:

Mathematical tools such as differentiation & integration, simple differential equations and complex numbers are integrated into the module depending on their occurrence.

Workload:

Total: 180 h

Conditions: The lecture builds on the contents of the lecture Technical Physics I.		**Credit Requirements:** written exam
Frequency: each summer semester	**Recommended Semester:** 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Technische Physik II

Mode of Instruction: lecture
Lecturers: Dr. Judith Moosburger-Will
Language: German
Contact Hours: 3

Contents:

1. Elektrizitätslehre
2. Magnetismus
3. Elektrodynamik, Maxwell-Gleichungen
4. Optik
5. Auswertung von Messungen

Lehr-/Lernmethoden:

Tafelvortrag und Beamer-Präsentation

Literature:

- U. Hahn; Physik für Ingenieure, Oldenburg Wissenschaftsverlag, ISBN: 978-3-486-27520-9
- W. Demtröder: Experimentalphysik Band 1-2, Springer Verlag
- D. Halliday, R. Resnick & J. Walker: Physik, Wiley-VCH, ISBN: 978-3527405992
- P. Tipler: Physik, Spektrum, ISBN: 978-3860251225
- D. Meschede: Gerthsen Physik, Springer, ISBN: 978-3540254218

Examination

Technische Physik II

written exam, written exam / length of examination: 90 minutes

Parts of the Module

Part of the Module: Übung zu Technische Physik II

Mode of Instruction: exercise course

Language: German

Contact Hours: 1

Contents:

Wiederholung und Vertiefung der Lehrinhalte mithilfe von Übungen. Übungsblätter werden regelmäßig angeboten.

Module MRM-0021: Commodity Risk Management *Commodity Risk Management*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Andreas Rathgeber		
Learning Outcomes / Competences: At the end of the module students are able to understand the risks and challenges coming along with comodity trading. Furthermore students will be able to apply quantitative methods to analyse and measure comodity risks.		
Workload: Total: 180 h		
Conditions: Profound Knowledge in business and information systems engineering (esp. resource management), stochastics and und financial management		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Commodity Risk Management
Mode of Instruction: lecture
Lecturers: Prof. Dr. Andreas Rathgeber
Language: English / German
Contact Hours: 2

Contents:

Definitions of resource management and general necessity of risk management, with a special focus on resource risk management; characteristics of comodity trading; statistical analysis and management of commodity risks

Lehr-/Lernmethoden:

Folien, Tafelarbeit

Literature:

- Steiner, M./Bruns, C.: Wertpapiermanagement, Stuttgart: Schäffer-Poeschel, 2007
- Geman, H. (2005): Commodities and commodity derivatives, Chichester: John Wiley & Sons

Examination

Commodity Risk Management

written exam, written exam / length of examination: 60 minutes

Parts of the Module

Part of the Module: Übung zu Commodity Risk Management
Mode of Instruction: exercise course
Language: German / English
Contact Hours: 2

Module MRM-0126: Ceramic Matrix Composites *Keramische Faserverbundwerkstoffe*		6 ECTS/LP
Version 3.0.0 (since WS21/22) Person responsible for module: Prof. Dr.-Ing. Dietmar Koch		
Contents: • Introduction in ceramic matrix composites • Basics of processing of technical ceramics • Processing chain of ceramic matrix composites (CMC) from raw materials to product • Processing and properties of ceramic fibers • Principal mechanisms of reinforcement in CMC • Properties of CMC • Application of CMC		
Learning Outcomes / Competences: • The students know the basic concepts of mechanical behavior of ceramic matrix composites • The students have the competence to explain processing of ceramic fibers and ceramic matrix composites and describe their specific properties • The students know the Weibull statistics which describe the fiber strength distribution • The students know how to describe mechanical interactions between fiber and matrix • The students get the knowledge of application of ceramic matrix composites and are able to choose the according material for specific application. • The students acquire scientific skills to search for scientific literature and to evaluate scientific content		
Workload: Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Recommended: basic knowledge of materials		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Literature:

- N.P. Bansal, J. Lamon, Ceramic Matrix Composites: Materials, Modeling and Technology. John Wiley & Sons, Inc., 2015.
- W. Krenkel, Ceramic Matrix Composites. Wiley-VCH Verlag GmbH & Co. KGaA, 2008.
- K. K. Chawla, Composite Materials 3rd ed., Springer, 2012
- T. Ohji, M. Singh, Engineered Ceramics: Current Status and Future Prospects, ISBN: 978-1-119-10042-3, 2015

Assigned Courses:

Keramische Faserverbundwerkstoffe (lecture)

Examination

Keramische Faserverbundwerkstoffe

written exam, written exam / length of examination: 60 minutes

Parts of the Module

Part of the Module: Übung Keramische Faserverbundwerkstoffe

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

see description of module

Assigned Courses:

Keramische Faserverbundwerkstoffe (lecture)

Module MRM-0128: Bioinspired Composites *Bioinspired Composites*		6 ECTS/LP
Version 2.0.0 (since WS20/21) Person responsible for module: Prof. Dr.-Ing. Dietmar Koch		
Contents: • Introduction in bionics and bioinspiration • Basics of bionic principles • Fundamental approaches to develop technical components based on bioinspired ideas • Topology optimization • Bioinspired ceramic and polymer based components • Natural fiber based bioinspired materials • Application of bioinspired materials		
Learning Outcomes / Competences: • The students know the basic principles of bionics and bioinspiration • The students know the bionically motivated development of technical components • The students have the competence to explain topology optimization • The students understand general principles bioinspired composites • The students get the knowledge about manufacturing, properties and application of natural fiber based composites • The students acquire scientific skills to search for scientific literature and to evaluate scientific content		
Workload: Total: 180 h 120 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: basic knowledge of material science		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Bioinspired Composites **Mode of Instruction:** lecture **Lecturers:** Prof. Dr.-Ing. Dietmar Koch **Language:** English / German **Frequency:** each summer semester **Contact Hours:** 3
Contents: see description of module

Literature:

- B. Arnold, Werkstofftechnik für Wirtschaftsingenieure. 1. Auflage, Springer Verlag (2013)
- W. Bobeth (Ed.), Textile Faserstoffe - Beschaffenheit und Eigenschaft, Springer-Verlag (1993)
- W. Nachtigal, K. G. Blüchel, Das große Buch der Bionik – Neue Technologien nach dem Vorbild der Natur. 2. Auflage, Deutsche Verlags-Anstalt (2001)
- C. Hamm (Ed.), Evolution of Light Weight Structures - Analyses and Technical Applications, Springer-Verlag (2015)
- J. Müssig (Ed.), C. V. Stevens (Series Ed.), Industrial Applications of Natural Fibres: Structure, Properties and Technical Applications, Wiley Series in Renewable Resources (2010)

Examination

Bioinspired Composites

written exam, written exam / length of examination: 60 minutes

Parts of the Module

Part of the Module: Übung Bioinspired Composites

Mode of Instruction: exercise course

Language: German

Frequency: each summer semester

Contact Hours: 1

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

see description of module

Module MRM-0136: Mechanical Characterization of Materials *Mechanical Characterization of Materials*	6 ECTS/LP

Version 1.1.0 (since SoSe21)
Person responsible for module: Prof. Dr. Markus Sause

Contents:
The following topics are presented:

- Introduction to material characterization
- Linear material behaviour
- Non-linear material behaviour
- Material failure
- Measurement technologies
- Tensile testing
- Compression testing
- Shear testing
- Other static testing concepts
- Fracture mechanics
- Assembly testing
- Surface mechanics
- Creep testing
- Fatigue testing
- High-Velocity testing
- Component testing

Learning Outcomes / Competences:
The students:

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

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

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

Parts of the Module

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

Literature:

- Issler, L., & Häfele, H. R. P. (2003). Festigkeitslehre — Grundlagen. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-540-73485-7
- Dowling, N. E. (2019). Mechanical Behavior of Materials (4th ed.). Pearson.
- Gross, D., & Seelig, T. (2011). Fracture Mechanics. Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-19240-1
- J. Schijve. (2008). Fatigue of Structures and Materials (2nd Edition). Springer Science & Business Media.
- Sadd, M. H. (2018). Continuum Mechanics Modeling of Material Behavior. In Continuum Mechanics Modeling of Material Behavior. Elsevier. https://doi.org/10.1016/C2016-0-01495-X

Examination

Mechanical Characterization of Materials

written exam, written exam / length of examination: 90 minutes

Parts of the Module

Part of the Module: Mechanical Characterization of Materials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Module MRM-0142: Complex 3D Structures and Components from 2D Materials *Complex 3D Structures and Components from 2D Materials*	6 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr.-Ing. Suelen Barg	

Contents:

Introduction:

- Complex Materials in Nature
- Motivations in assembling 2D Materials in 3D with an overview of their demands for future technological applications (from energy to aerospace)

Nano and 2D Materials:

- Introduction to nano and 2D Materials
- Scaling laws and the evolution of properties with size
- Graphene structure, properties, and characterization
- 2D Transition Metal Carbides (MXenes)
- 2D Materials synthesis routes: top-down and bottom-up approaches

From 2D to 3D:

- Motivations, Challenges, and opportunities
- Colloidal processing routes with 2D Materials: Principles of wet processing
- Self-assembly, templating, and additive manufacturing (AM) routes
- Extrusion-based AM with 2D Materials
- Functionalities and Applications
- Aerogel supports for functional composite development
- 3D architectures for energy storage

Learning Outcomes / Competences:

By completing this unit, the students should be able to:

Knowledge and understanding:

- Define the classes of nanomaterials depending on their dimensionality.
- Identify the different families of 2D materials beyond graphene, including transition metal dichalcogenides (TMDs), carbides and/or nitrides (MXenes).
- Summarize top-down and bottom-up synthesis strategies towards 2D materials.
- Select appropriate syntheses routes for a given application based on property requirements and cost efficiency of the approach.
- Explain the basic principles, advantages and disadvantages of innovative colloidal processing routes applied to 2D materials-based 3D structures.

Intellectual skills:

- Solve problems involving the evolution of properties with size in nanomaterials by the application of simple spherical cluster approximation models.
- Evaluate the effect of microstructure and composition to develop new materials properties and/or control device efficiency using real examples from the literature.

Transferable and practical skills:

- Evaluate English language scientific content in the specialist literature.
- Apply analytical methods to solve problems.

Workload:

Total: 180 h

Conditions: materials science basic knowledge		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each winter semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Complex 3D Structures and Components from 2D Materials

Mode of Instruction: lecture

Lecturers: Prof. Dr.-Ing. Suelen Barg

Language: English

Contact Hours: 4

Learning Outcome:

See description of the module

Contents:

See description of the module

Literature:

- Sulabha K Kulkarni, Nanotechnology: principles and Practice, 3rd Ed., 2015 (Springer-Verlag GmbH).
- Leonard W. T. Ng, Guohua Hu, Richard C. T. Howe, Xiaoxi Zhu, Zongyin Yang, Printing of Graphene and Related 2D Materials, in: Technology, Formulation and Applications. 1st ed., 2019, (Springer-Verlag GmbH)
- Research papers presented in class

Examination

Complex 3D Structures and Components from 2D Materials

written exam, written exam / length of examination: 1 hours

Module MTH-1360: Seminar Analysis *Seminar zur Analysis*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: Differs for each of the seminar, please check in digicampus before the term starts.		
Learning Outcomes / Competences: Through self-study of mathematical topics in the field of analysis, talks and scientific discussion, the following goals are to be achieved: Ability to work with scientific literature, skills in formulating and presenting theoretical questions based on the mathematical methods learnt. Integrated acquisition of key qualifications: Working independently with scientific literature, trying out different presentation techniques and presentation media, conducting scientific discussions and communicating problem-solving approaches.		
Workload: Total: 180 h 2 h seminar (attendance)		
Conditions: none		**Credit Requirements:** One needs to pass one of the offered seminars. The precise form of the exam (talk/homework/etc) will be announced in digicampus for the individual seminar before the term starts.
Frequency: each semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Seminar zur Analysis **Mode of Instruction:** seminar **Language:** German / English **Contact Hours:** 2 **ECTS Credits:** 6.0
Learning Outcome: Durch Selbststudium mathematischer Themen im Bereich der Analysis und ihrer Anwendungen, Vortrag und wissenschaftlicher Diskussion sollen folgende Ziele erreicht werden: Befähigung zum selbständigen Erarbeiten wissenschaftlicher Literatur, Kompetenzen in der selbständigen Bearbeitung komplexer Problemstellungen, Fertigkeiten zur Formulierung und Bearbeitung von theoretischen Fragestellungen mithilfe der erlernten mathematischen Methoden Integrierter Erwerb von Schlüsselqualifikationen: Eigenständiges Arbeiten mit wissenschaftlicher Literatur, Erprobung verschiedener Präsentationstechniken und Präsentationsmedien, Führen wissenschaftlicher Diskussionen und die Vermittlung von Problemlösungsansätzen.

Contents:

aktuelle wechselne Forschungsthemen.

Wird in der jeweiligen Lehrveranstaltung vor Semesterbeginn bekannt gegeben.

Lehr-/Lernmethoden:

Eigenständige Einarbeitung in ein aktuelles Forschungsgebiet, eigenständige Präsentation und wissenschaftliche Diskussion

Literature:

Wird in der jeweiligen Lehrveranstaltung vor Semesterbeginn bekannt gegeben.

Assigned Courses:

Seminar zur Analysis (seminar)

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Examination

Seminar zur Analysis Seminar zur Analysis

module exam, wird in der jeweiligen Veranstaltung vor dem Semesterbeginn festgelegt

Module MTH-1380: Seminar in Geometry *Seminar zur Geometrie*		6 ECTS/LP
Version 1.0.1 (since WS15/16) Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: Selbststudium vertieften Wissens im Bereich der Geometrie und ihrer Anwendungen. Befähigung zum wissenschaftlichen Erarbeiten von Literaturquellen, Integrierter Erwerb von Schlüsselqualifikationen: Die Studierenden lernen und erproben verschiedene Präsentationstechniken und Präsentationsmedien; Sie erlernen das Führen wissenschaftlicher Diskussionen und die Vermittlung von Problemlösungsansätzen		
Workload: Total: 180 h 2 h seminar (attendance) 2 h seminar (attendance) 2 h seminar (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 4 semester[s]
Contact Hours: 8	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Seminar zur Geometrie

Language: German / English

Frequency: every 3rd semester

Workload:

2 Std. Seminar (Präsenzstudium)

Contact Hours: 2

ECTS Credits: 6.0

Contents:

(ohne Anspruch auf Vollständigkeit)

Lie-Gruppen und ihre Darstellungen: Dieses Seminar führt in die Theorie der Lie-Gruppen und ihre Darstellungen ein.

Geometrie und Topologie (Morsetheorie): Die Morsetheorie ist eines der fundamentalen Werkzeuge zur Untersuchung der Topologie glatter Mannigfaltigkeiten. Wir erarbeiten die Grundzüge dieser Theorie an Hand des klassischen Textes von Milnor und diskutieren Anwendungen auf die Klassifikation von Mannigfaltigkeiten (h-Kobordismussatz) und die Berechnung der Homotopiegruppen kompakter Liegruppen (Bott-Periodizität).

Voraussetzungen: Einführung in die Geometrie

Topologie

Die Voraussetzungen sind abhängig vom jeweiligen Seminarthema

Literature:

Bröcker, T., Dieck, T. Tom: Representations of Compact Lie Groups.

Fulton, W., Harris, J.: Representation theory.

Milnor, J.: Morse Theory. Annals of Mathematics Studies, Princeton University Press.

Milnor, J.: Lectures on the h-Cobordism Theorem. Princeton University Press.

Assigned Courses:

Master-Seminar: Surgery theory (seminar)

**

Semianr zur Kommutative Algebra (seminar)

**

Part of the Module: Seminar zur Topologie

Language: German

Contact Hours: 2

ECTS Credits: 6.0

Contents:

Aufbauend auf einführende Vorlesungen in der Topologie oder Geometrie werden weiterführende Themen im Bereich der Topologie behandelt. Diese können auch als Grundlage für Bachelorarbeiten dienen.

Voraussetzungen: Grundlage ist eine einführende Vorlesung im Bereich der Geometrie oder Topologie.

Assigned Courses:

Ausgewählte Kapitel der Topologie (seminar)

**

Part of the Module: Seminar zur Geometrie: Seminar Finsler-Geometrie

Language: German

Frequency: every 3rd semester

Workload:

2 Std. Seminar (Präsenzstudium)

Contact Hours: 2

ECTS Credits: 6.0

Contents:

Seminar über Finsler-Geometrie

Voraussetzungen: Einführung in die Geometrie

Topologie

Die Voraussetzungen sind abhängig vom jeweiligen Seminarthema

Literature:

Bröcker, T., Dieck, T. Tom: Representations of Compact Lie Groups.

Fulton, W., Harris, J.: Representation theory.

Milnor, J.: Morse Theory. Annals of Mathematics Studies, Princeton University Press.

Milnor, J.: Lectures on the h-Cobordism Theorem. Princeton University Press.

Part of the Module: Seminar zur Geometrie: Seminar Topics in Symplectic Geometry

Language: German

Frequency: every 3rd semester

Workload:

2 Std. Seminar (Präsenzstudium)

Contact Hours: 2

ECTS Credits: 6.0

Contents:

Seminar über Symplectic Geometry

Voraussetzungen: Einführung in die Geometrie

Topologie

Die Voraussetzungen sind abhängig vom jeweiligen Seminarthema

Literature:

Bröcker, T., Dieck, T. Tom: Representations of Compact Lie Groups.

Fulton, W., Harris, J.: Representation theory.

Milnor, J.: Morse Theory. Annals of Mathematics Studies, Princeton University Press.

Milnor, J.: Lectures on the h-Cobordism Theorem. Princeton University Press.

Assigned Courses:

Topics in Symplectic Geometry (seminar)

**

Examination

Seminar zur Geometrie

oral exam / length of examination: 90 minutes

Examination

Seminar zur Topologie

oral exam / length of examination: 90 minutes

Examination

Seminar zur Geometrie: Seminar Finsler-Geometrie

oral exam / length of examination: 90 minutes

Examination

Seminar zur Geometrie: Seminar Topics in Symplectic Geometry

oral exam / length of examination: 90 minutes

Module MTH-1510: Riemannian Geometry

Riemannsche Geometrie

9 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Bernhard Hanke

Contents:

What is the geometry of our space? Euclidean? But how are we to know whether two parallels behind the next bush still have the same distance? How are we to judge geometry on a large scale, even in outer space, when we can hardly move away from our patch of earth? Riemannian geometry introduces a concept flexible enough to describe a geometry that looks locally Euclidean, but about whose global structure we may have no knowledge. The distinguishing feature from Euclidean geometry is curvature, the most important concept in this theory. We will study this geometry in small and large scale. Naturally, we will also cover the basics of Einstein's General Relativity, in which the geometry of space and time is coupled with the mass distribution in the universe.

Submanifolds of Euclidean space
Covariant derivative (Levi-Civita derivative)
Curvature
General relativity
Geodesics in the small and large
Completeness
Role of curvature for topology

Learning Outcomes / Competences:

Combining geometric thinking with analytical methods, understanding the interrelationships of local and global geometry.

Workload:

Total: 270 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions:

Introduction to Geometry

Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Riemannsche Geometrie

Language: English
Frequency: every 3rd semester
Workload:

4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)

Contact Hours: 6
ECTS Credits: 9.0

Contents:

Literature:

J.-H. Eschenburg, J. Jost: Differentialgeometrie und Minimalflächen. Springer, 2007.

W. Kühnel: Differentialgeometrie. Vieweg, 1999.

S.Gallot, D.Hulin, J.Lafontaine: Riemannian Geometry. Springer, 1990.

J. Jost: Riemannian Geometry and Geometric Analysis. Springer, 2008.

M. Do Carmo: Riemannian Geometry. Birkhäuser, 1992.

D.Gromoll, W.Klingenberg, W.Meyer: Riemannsche Geometrie im Großen. Springer LN 55, 1975.

Assigned Courses:

Riemannsche Geometrie (lecture + exercise)

**

Examination

Riemannian Geometry

oral exam / length of examination: 30 minutes

Module MTH-1520: Differential Topology *Differentialtopologie*	9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Bernhard Hanke	

Contents:

This lecture is devoted to the theory of differentiable manifolds from the point of view of analysis and topology. The material covered is fundamental for a deeper understanding of differential geometry and global analysis.

Differentiable manifolds
Tangent space
Flows
Foliations
Fiber bundles
Transversality
de Rham cohomology
Chern-Weil theory
exotic spheres

Learning Outcomes / Competences:

Development and training of geometrical intuition while mastering modern mathematical language and reasoning. Understanding of the basic concepts of differential topology. Development of basic knowledge for special lectures in geometry and topology.

Workload:

Total: 270 h
4 h lecture (attendance)
2 h exercise course (attendance)

Conditions: Knowledge to elementary geometry and topology		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Differentialtopologie

Language: German / English
Frequency: every 3rd semester
Workload:
4 Std. Vorlesung (Präsenzstudium)
2 Std. Übung (Präsenzstudium)
Contact Hours: 6
ECTS Credits: 9.0

Contents:

Diese Vorlesung widmet sich der Theorie differenzierbarer Mannigfaltigkeiten vom Standpunkt der Analysis und Topologie. Der behandelte Stoff ist fundamental für ein vertieftes Verständnis der Differentialgeometrie und globalen Analysis.

Differenzierbare Mannigfaltigkeiten

Tangentialraum

Flüsse

Blätterungen

Faserbündel

Transversalität

de Rham-Kohomologie

Chern-Weil-Theorie

exotische Sphären

Voraussetzungen: Einführung in die Geometrie

Literature:

R. Bott, L. Tu: Differential Forms in Algebraic Topology. GTM Springer.

L. Conlon: Differentiable Manifolds - A First Course. Birkhäuser.

M. Hirsch: Differential Topology. GTM Springer.

J. Milnor: Topology from the Differentiable Viewpoint. Princeton University Press.

Examination

Differentialtopologie

oral exam / length of examination: 30 minutes

Module MTH-1530: Algebraic Topology *Algebraische Topologie*		9 ECTS/LP
Version 2.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Bernhard Hanke		
Contents: This module provides an introduction to algebraic topoolgy, that is, the systematic use of algebraic tools in the study of topological problems. Mathematical content includes: Fundamental group, covering spaces, categories, cellular complexes, cellular and singular homology and cohomology, homotopy theory, fiber bundles.		
Learning Outcomes / Competences: Students will be able to use algebraic tools that allow them to translate geometric notion into exact arguments.		
Workload: Total: 270 h		
Conditions: Basic knowledge in algebra and geometry.		
Frequency: every 3rd semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Topologie I
Language: English / German
Contact Hours: 6
ECTS Credits: 9.0

Contents:

Dieses Modul bietet eine Einführung in die Algebraische Topoolgie, also die systematische Nutzung algebraischer Hilfsmittel beim Studium topologischer Fragestellungen.

Mathematische Inhalte sind unter anderem: Fundamentalgruppe, Überlagerungen, Kategorien, Zellkomplexe, zelluläre und singuläre Homologie und Kohomologie, Homotopietheorie, (Ko-)Faserungen

Lehr-/Lernmethoden:

Vorlesung und Übung

Literature:

Bredon, G.E.: Topology and Geometry, vol. 139, Graduate Texts in Mathematics. Springer-Verlag, 1993.

Dold, A.: Lectures on Algebraic Topology, vol. 200. Grundlehren der mathematischen Wissenschaften in Einzeldarstellungen, Springer-Verlag, 1972.

Spanier, E.: Algebraic Topology. McGraw-Hill, 1966.

May, J.P.: A Concise Course in Algebraic Topology, University of Chicago Press, 1999.

Assigned Courses:

Algebraische Topologie (lecture + exercise)

**

Examination

Algebraische Topologie

portfolio exam

Module MTH-1560: Stochastic Differential Equations *Stochastische Differentialgleichungen*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: This module introduces the theory of stochastic differential equations. Ito formula, Ito isometry, Ito integral, martingales, Brownian motion, existence and uniqueness theorem, diffusion processes, partial differential equations, Black-Scholes formula, Option pricing		
Learning Outcomes / Competences: The students know the fundamental terms, concepts and phenomena of stochastic of stochastic analysis, especially of stochastic differential equations. Ability to independently compile further literature for applications in the field of financial mathematics and stochastic dynamics, Competences in the independent processing of problems, Skills in the formulation and processing of theoretical questions using the theoretical questions with the help of the methods learned Integrated acquisition of key qualifications: Independent work with (English-language) scientific literature, Scientific thinking, in-depth competences in the independent processing of problems, skills in formulating and processing theoretical questions.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: A good basic knowledge of probability theory and analysis is required. and calculus. Helpful, but not absolutely necessary, is previous knowledge of in ordinary differential equations and stochastic processes.		**Credit Requirements:** Oral exam
Frequency: every 3rd semester	**Recommended Semester:** 1. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Stochastische Differentialgleichungen

Mode of Instruction: lecture

Lecturers: Prof. Dr. Dirk Blömker

Language: German / English

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Dieses Modul führt in die Theorie der stochastischen Differentialgleichungen ein.
Ito-Formel
Ito-Isometrie
Ito-Integral
Martingale
Brownsche Bewegung
Existenz-und Eindeutigkeitssatz
Diffusionsprozesse
partielle Differentialgleichungen
Black-Scholes Formel
Optionspreisbewertung
Voraussetzungen: Notwendig ist ein gutes Grundwissen in der Wahrscheinlichkeitstheorie
und der Analysis.
Hilfreich, aber nicht zwingend notwendig, sind Vorkenntnisse
in gewöhnlichen Differentialgleichungen
und stochastischen Prozessen.

Literature:

Oksendal: Stochastic Differential Equations. Springer.
Karatzas Shreve: Brownian Motion and Stochastic Calculus. Springer.
Evans: An Introduction to Stochastic Differential Equations.
Steele: Stochastic Calculus and Financial Applications. Springer.

Assigned Courses:

Stochastische Differentialgleichungen (lecture + exercise)
**

Examination

Stochastische Differentialgleichungen
oral exam / length of examination: 30 minutes

Module MTH-1570: Dynamical Systems *Dynamische Systeme*	9 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Dirk Blömker

Contents:
among others: dynamical systems, attractors, invariant manifolds, semi-flows, Markov semigroups, invariant measures, iterated mappings, chaos

Learning Outcomes / Competences:
The students know the basic terms, concepts and phenomena in the field of
in the field of dynamical systems.
Ability to work independently on further literature,
Competences in the independent processing of problems,
Skills to formulate and work on theoretical questions using the
questions with the aid of the methods learnt.
Integrated acquisition of key qualifications:
Independent work with (English-language) scientific literature,
scientific thinking,
in-depth competences in the independent processing of problems,
Skills in formulating and working on theoretical questions.

Workload:
Total: 270 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions: Good knowledge of linear algebra and analysis. Basic knowledge of functional analysis and differential equations is helpful.		**Credit Requirements:** oral exam
Frequency: every 3rd semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Dynamische Systeme
Mode of Instruction: lecture
Language: German / English
Workload:
2 Std. Übung (Präsenzstudium)
4 Std. Vorlesung (Präsenzstudium)
Contact Hours: 6
ECTS Credits: 9.0

Contents:
unter anderem: dynamische Systeme (zufällig und nicht-autonom), Attraktoren, Halbflüsse, Markov Halbgruppen, invariante Maße, iterierte Abbildungen, Chaos

Assigned Courses:

Prüfungsmodul: Dynamische Systeme (lecture)
**

Examination

Dynamische Systeme

oral exam / length of examination: 30 minutes

Module MTH-1590: Numerical analysis of partial differential equations *Numerik partieller Differentialgleichungen*		9 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Understanding of finite differences as well as the ideas of the finite element method generally as well as construction of Lagrange elements with respect to simplicial triangulations and a posteriori error estimation for elliptic problems; convergence results, connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Recommended: analysis (particularly functional analysis), introduction to numerical analysis, numerical analysis of ordinary differential equations		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerik partieller Differentialgleichungen

Mode of Instruction: lecture + exercise

Lecturers: Prof. Dr. Malte Peter

Language: English / German

Frequency: each winter semester

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Es werden die Grundlagen der Standardmethoden zur numerischen Lösung partieller Differentialgleichungen behandelt.

Finite-Differenzen-Methode auf rechteckigen und nicht rechteckigen Gebieten
Finite-Elemente-Methode inkl. Triangulierung
Lagrange-Elemente
Adaptivität für elliptische Probleme

Literature:

Grossmann, C., Ross, H.-G.: Numerische Behandlung partieller Differentialgleichungen. Teubner, 2005 .
Hackbusch: Theorie und Numerik elliptischer Differentialgleichungen. Springer. 2010

Assigned Courses:

Numerik Partieller Differentialgleichungen (lecture + exercise)

**

Examination

Numerik partieller Differentialgleichungen

oral exam / length of examination: 30 minutes

Module MTH-1600: Multiscale methods *Multiskalenmethoden*		9 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Deeper understanding of the finite element method in its most important versions; connections between methods as well as their advantages and disadvantages, with respect to application to concrete problems in particular; understanding of the problems arising from multiple scales as well as basic solution ideas; complex algorithms; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Multiskalenmethoden

Mode of Instruction: lecture + exercise

Language: English / German

Frequency: irregular

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Aufbauend auf grundlegende Inhalte der Module Numerik partieller Differentialgleichungen bzw. Methoden der finiten Elemente werden weiterführende Aspekte der Finite-Elemente-Methode behandelt, insbesondere im Hinblick auf Multiskalenprobleme.

Finite-Elemente-Methode und parabolische Gleichungen

Discontinuous Galerkin Method

Einführung in Multiskalenprobleme

Multiskalen-Finite-Elemente-Methode

Voraussetzungen: Es wird empfohlen, die mit dem erfolgreichen Absolvieren einer der Module "Numerik partieller Differentialgleichungen" oder "Finite Elemente Methoden" einhergehenden Kompetenzen erworben zu haben.

Literature:

C. Grossmann, H.-G. Roos: Numerische Behandlung partieller Differentialgleichungen. Teubner.

Y. Efendiev, T. Y. Hou: Multiscale Finite Element Methods. Springer.

Examination

Multiskalenmethoden

module exam, mündliche Prüfung / length of examination: 30 minutes

Module MTH-1610: Mathematical modelling *Mathematische Modellierung*		9 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: Understanding of describing real-world processes in terms of mathematical objects; integrated acquisition of key qualifications: In small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Mathematische Modellierung **Mode of Instruction:** lecture + exercise **Language:** English / German **Frequency:** irregular **Contact Hours:** 6

Examination
Mathematische Modellierung oral exam / length of examination: 30 minutes

Module MTH-1630: Mathematical Game Theory *Mathematische Spieltheorie (Optimierung IV)*	9 ECTS/LP

Version 3.0.0 (since WS21/22)
Person responsible for module: Prof. Dr. Tobias Harks

Contents:

- Existence, complexity and computation of Nash equilibria in non-cooperative games
- Congestion games
- Pricing games
- Cooperative games
- Core
- Shapley value
- Auctions and mechanism design

Learning Outcomes / Competences:
This course offers an introduction into the main contents of mathematical and algorithmic game theory.

Workload:
Total: 270 h
2 h exercise course (attendance)
4 h lecture (attendance)

Conditions:

-

Module Introduction to Optimization (MTH-1140) - recommended
Module Introduction to Nonlinear and Combinatorial Optimization (MTH-1200) - recommended
Module Combinatorial Optimization (MTH-1620) - recommended

Frequency: Wintersemester alle 2 Jahre	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematische Spieltheorie (Optimierung IV)
Mode of Instruction: lecture
Language: English
Frequency: every 3rd semester
Contact Hours: 6
ECTS Credits: 9.0

Examination
Mathematische Spieltheorie (Optimierung IV)
module exam, Der konkrete Typ der Modulprüfung (Klausur oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben.

Module MTH-1730: Research Seminar Analysis *Oberseminar zur Analysis*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Dirk Blömker Beck, Peter, Schmidt		
Contents: The Oberseminar deals with recent scientific research texts in the field of analysis.The specific topics of the seminar vary according to the previous knowledge of the students.		
Learning Outcomes / Competences: Through self-study of mathematical topics in the field of calculus and its applications, lecture and scientific discussion the following goals are to be achieved: Ability to work independently and scientifically with current scientific literature in the field of analysis, skills to formulate and work on theoretical questions with the help of analytical theoretical questions with the help of analytical methods, Development of new mathematical methods. Integrated acquisition of key qualifications: Independent work with English-language scientific literature, scientific presentation techniques, conducting scientific discussions and teaching mathematical theories.		
Workload: Total: 180 h 2 h seminar (attendance)		
Conditions: Differential equations or functional analysis. At least two consecutive lectures or seminars in the field of advanced analysis are recommended		**Credit Requirements:** presentation
Frequency: each semester	**Recommended Semester:** 3. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Oberseminar zur Analysis **Mode of Instruction:** seminar **Lecturers:** Prof. Dr. Fritz Colonius, Prof. Dr. Malte Peter, Prof. Dr. Dirk Blömker, Prof. Dr. Bernd Schmidt, Prof. Dr. Lisa Beck **Language:** German **Workload:** 2 Std. Seminar (Präsenzstudium) **Contact Hours:** 2 **ECTS Credits:** 6.0
Contents: Das Oberseminar behandelt aktuelle wissenschaftliche Forschungstexte im Bereich der Analysis. Die Themen variieren nach den Vorkenntnissen der Studierenden.

Literature:

Nach Vereinbarung

Assigned Courses:

Oberseminar Differentialgleichungen

**

Examination

Vortrag

oral exam / length of examination: 90 minutes

Module MTH-1770: Mathematical software project *Mathematisches Softwareprojekt*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Learning Outcomes / Competences: The students acquire the competence to work out and prepare a mathematical problem in such a way that it enables a computer-aided solution. They learn to realise the solution on their own in the form of a software project while working with the computer and thereby acquire a targeted approach to a programming language or a mathematical software system.		
Workload: Total: 180 h 2 h preparation of written term papers (self-study)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 0	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Mathematisches Softwareprojekt

Language: German / English

Frequency: each semester

ECTS Credits: 6.0

Contents:

Ziel des Moduls ist die selbständige Erarbeitung eines mathematischen Problems und dessen rechnergestützte Lösung. Diese kann sowohl mithilfe in einer der üblichen Programmiersprachen (wie C/C++, Java, Python) eigenständig erstellten Software oder durch selbständig entwickelte Module zu bestehenden Software-Systemen und -Umgebungen (wie Mathematica, Maple, R, Sage) realisiert werden. Das Thema des Projekts wird von der jeweiligen Betreuerin/dem jeweiligen Betreuer vorgeschlagen. Es umfasst ein mathematisches Problem aus einem beliebigen, am Institut vertretenen Teilgebiet der Mathematik.

Voraussetzungen:

Examination

Mathematisches Softwareprojekt

practical exam / length of examination: 1 months

Module MTH-1810: Topological Combinatorics *Topologische Kombinatorik*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: Die Studierenden erkennen kombinatorische Probleme, zu deren Lösung topologische Hilfsmittel beitragen können, und können topologische Methoden auf sie anwenden.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Topologische Kombinatorik

Language: German

Workload:

2 Std. Übung (Präsenzstudium)

4 Std. Vorlesung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

Diese Vorlesung führt in die topologische Kombinatorik ein. Dieses junge Fachgebiet beschäftigt sich unter anderem damit, kombinatorische und kombinatorisch-geometrische Probleme mit Hilfe topologischer Methoden zu lösen. Wir werden einige solcher Beispiele kennen lernen. Die dazu notwendigen Hilfsmittel aus der Topologie und der Algebraischen Topologie werden wir in der Vorlesung entwickeln oder darstellen.

Massenpartitionen, insbesondere das Problem des Teilens von Perlenketten (siehe den Artikel `Necklace splitting problem' in der englischsprachigen Wikipedia).

Graphfärbungsprobleme, insbesondere die Kneser-Vermutung (siehe den Artikel `Topologische Kombinatorik' in der deutschsprachigen Wikipedia) und verwandte Resultate.

Der Satz von Tverberg (siehe den Artikel `Tverberg's theorem' in der englischsprachigen Wikipedia) und Verallgemeinerungen davon, darunter auch sehr neue Resultate.

Simplizialkomplexe und simpliziale Abbildungen.

Einfache Hilfsmittel aus der algebraischen Topologie wie Kettenkomplexe und in Ansätzen Homologie. Der Satz von Borsuk-Ulam und Verallgemeinerungen davon.

Voraussetzungen: Grundlegende Kenntnisse in Analysis

Grundlegende Kenntnisse in Lineare Algebra

Diese Vorlesung wendet sich an alle mit einem Interesse an kombinatorischen Fragestellungen oder topologischen Methoden. Es wird versucht, die Vorlesung so gut wie möglich an die Vorkenntnisse der Hörer anzupassen. Da die benötigten Ergebnisse und Methoden aus der Topologie eingeführt werden, ist kein Vorwissen, das über die Grundvorlesungen in Analysis und Linearer Algebra hinausgeht, nötig. Für die, die nur diese Kenntnisse mitbringen, wird aber die Menge an Neuem groß sein, daher ist eine gewisse mathematische Reife wünschenswert.

Literature:

Mark de Longueville: A course in topological combinatorics. Springer.

Jiri Matousek: Using the Borsuk-Ulam Theorem (2nd printing). Springer, 2008.

Examination

Topologische Kombinatorik

oral exam / length of examination: 30 minutes

Module MTH-1940: String Topology *String Topology*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Kai Cieliebak		
Learning Outcomes / Competences: Learning about methods for computing homology and homotopy groups, algebraic structures arising in the topology of loop spaces, and their applications in geometry.		
Workload: Total: 270 h 4 h lecture (attendance) 2 h exercise course (attendance)		
Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: as needed	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: String Topology

Language: English / German

Frequency: irregular

Workload:

4 Std. Vorlesung (Präsenzstudium)

2 Std. Übung (Präsenzstudium)

Contact Hours: 6

ECTS Credits: 9.0

Contents:

This course is an introduction to the algebraic topology of loop spaces, an area of growing importance in mathematics and physics. It covers the following topics: homology of based and free loop spaces, Pontrjagin product and Hopf algebras, Chas-Sullivan operations and Batalin-Vilkovisky algebras, Hochschild and cyclic homology of the de Rham complex, minimal models and applications to closed geodesics.

Voraussetzungen: Basic algebraic and and differential topology (singular homology, manifolds, differential forms)

Literature:

Cohen, R., Hess, K., Voronov, A.: String topology and cyclic homology. Birkhäuser.

Griffiths, P., Morgan, J.: Rational homotopy theory and differentiel forms. Birkhäuser.

Examination

String Topology

oral exam / length of examination: 30 minutes

Module MTH-2010: Numerics of stochastic differential equations *Numerik Stochastischer Differentialgleichungen*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: numerical method for stochastic differential equations, Euler-Maruyama, weak and strong convergence, error estimates		
Learning Outcomes / Competences: The students know the basic terms, concepts and phenomena of the numerical treatment of stochastic differential equations. of the numerical treatment of stochastic differential equations, can implement the corresponding algorithms and are familiar with the basics of stochastic analysis. Ability to work independently on further literature. Competences in the independent processing and implementation of numerical algorithms, Skills in formulating and working on theoretical and applied problems using the and applied questions with the help of the methods learnt. Integrated acquisition of key qualifications: Independent work with (English-language) scientific literature, working with scientific computers, in-depth competences in the independent processing of problems, Skills in formulating and working on applied questions.		
Workload: Total: 180 h 2 h exercise course (attendance) 2 h lecture (attendance)		
Conditions: knowledge in stochastic differential equations and numerical methods for ordinary differential equations are helpful		**Credit Requirements:** oral exam
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Numerik Stochastischer Differentialgleichungen

Language: German / English

Workload:

2 Std. Übung (Präsenzstudium)

2 Std. Vorlesung (Präsenzstudium)

Contact Hours: 4

ECTS Credits: 6.0

Contents:

Dieses Modul führt in die Theorie der numerischen Behandlung stochastischer Differentialgleichungen ein.
Stochastische Differentialgleichungen
Zeitdiskretisierung
Fehlerabschätzungen
Implementierung numerischer Verfahren
Spektrales Galerkinverfahren für stochastische partielle DGL
Voraussetzungen: Die Vorlesung verwendet die grundlegende Theorie stochastischer Differentialgleichungen.
Zwingend notwendig ist ein gutes Grundwissen in der Wahrscheinlichkeitstheorie,
stochastischen Prozessen und der Analysis.
Hilfreich, aber nicht zwingend notwendig, sind Vorkenntnisse
in gewöhnlichen Differentialgleichungen und Numerik gewöhnlicher Differentialgleichungen,
sowie Programmiererfahrung.

Examination

Numerik Stochastischer Differentialgleichungen

oral exam / length of examination: 30 minutes

Module MTH-2090: Seminar on numerical mathematics *Seminar zur Numerik*	6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter	

Learning Outcomes / Competences:
Development, analysis and implementation of modern numerical methods. The students have knowledge of various mathematical models of continuum mechanics and associated numerical solution strategies. They have the ability to work independently through problems from the field of mathematical modelling and the numerics of the associated differential equations by studying literature and presenting them in the form of a presentation. They have the competence to communicate the importance of corresponding problems and possible solutions to others.

Workload:
Total: 180 h
2 h seminar (attendance)

Conditions: none		
Frequency:	**Recommended Semester:** 2. - 6.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Seminar zur Numerik: Die TOP 10 Algorithmen
Mode of Instruction: seminar
Language: German
Frequency: jedes 3. Semester
Contact Hours: 2
ECTS Credits: 6.0

Contents:
Von den Editoren der Zeitschrift "Computing in Science and Engineering" wurden 2000 zehn Algorithmen ausgewählt, die ihrer Ansicht nach die größte Bedeutung für Wissenschaft und Technik im 20. Jahrhundert hatten. In diesem Seminar sollen diese Algorithmen und ihre Anwendungen näher betrachtet werden.
Empfohlene Voraussetzungen: Kenntnisse in Numerik I.

Literature:
Special Issue of the Computing in Science and Engineering, J. Dongarra, F. Sullivan, eds., 2000

Examination
Seminar zur Numerik: Die TOP 10 Algorithmen
module exam, Der konkrete Typ der Modulprüfung (Vortrag oder kombiniert schriftlich-mündliche Prüfung oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben.

Parts of the Module

Part of the Module: Seminar zur Numerik: Seminar zur Numerischen Mathematik

Mode of Instruction: seminar
Language: German / English
Frequency: jedes 3. Semester
Workload:
2 Std. Seminar (Präsenzstudium)
Contact Hours: 2
ECTS Credits: 6.0

Contents:

Seminar über ein Thema der Numerischen Mathematik
(ohne Anspruch auf Vollständigkeit)
Fortgeschrittene Lösungsverfahren für große lineare Gleichungssysteme bzw. Eigenwertprobleme
Regelung dynamischer Systeme
Modellierung und Differentialgleichungen (Themen aus der mathematischen Modellierung mit Differentialgleichungen und der zugehörigen Theorie von Differentialgleichungen)
Modellierung und Numerische Analysis (Themen aus der Mathematischen Modellierung mit Differentialgleichungen und der Numerik der zugehörigen Differentialgleichungen)
Voraussetzungen: keine besonderen Voraussetzungen

Literature:

Billingham, J., King, A.C.: Wave motion. Cambridge.
Braun, M.: Differential equations and their applications. Springer.
Eck, C., Garcke, G., Knabner, P.: Mathematische Modellierung. Springer.
Dautray, R., Lions, J.-L.: Mathematical Analysis and Numerical Methods for Science and Technology. Springer.
Hinrichsen, D., Pritchard, A.J.: Mathematical Systems Theory I. Springer.
Hornung, U.: Homogenization and Porous Media. Springer.
Meister, A.: Numerik linearer Gleichungssysteme. Vieweg.
Saad, Y.: Iterative methods for sparse linear systems. SIAM.
Saad, Y.: Numerical methods for large eigenvalue problems. SIAM.

Assigned Courses:

Seminar zur Numerik (seminar)
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Seminar zur Numerik (seminar)
**

Seminar: Seminar zur Numerik (seminar)
**

Examination

Seminar zur Numerik: Seminar zur Numerischen Mathematik
module exam, kombiniert schriftlich-mündliche Prüfung. Bearbeitungszeit: 3 Monate, Dauer der mündlichen Darstellung: 75 Minuten.

Parts of the Module

Part of the Module: Seminar zur Numerik: Seminar zur Numerischen Linearen Algebra

Mode of Instruction: seminar
Language: German
Frequency: jedes 3. Semester
Contact Hours: 2
ECTS Credits: 6.0

Contents:

Das Seminar behandelt aktuelle wissenschaftliche Forschungstexte im Bereich der Numerischen Linearen Algebra. Die Themen variieren nach den Vorkenntnissen der Studierenden.

Empfohlene Voraussetzungen: Kenntnisse in Numerik I

Assigned Courses:

Seminar zur Numerik (Master) (seminar)

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Examination

Seminar zur Numerik: Seminar zur Numerischen Linearen Algebra

module exam, Der konkrete Typ der Modulprüfung (Vortrag oder kombiniert schriftlich-mündliche Prüfung oder mündliche Prüfung oder Portfolio) wird jeweils spätestens eine Woche vor Beginn der Veranstaltung bekannt gegeben.

Module MTH-2210: Stochastic Evolution Equations *Stochastische Evolutionsgleichungen*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: Infinite dimensional spaces Fourier series and transforms cylindrical Wiener processes analytic semigroups stochastic evolution equations stochastic dynamical systems		
Learning Outcomes / Competences: The students know the basic terms, concepts and phenomena in the field of stochastic evolution equations and stochastic dynamic systems. Ability to work independently on further research literature, competences in the independent processing of problems, skills in the formulation and processing of theoretical questions with the help of the methods learned. Integrated acquisition of key qualifications: Independent work with (English-language) scientific literature, scientific thinking, deepened competences in the independent processing of problems.		
Workload: Total: 270 h		
Conditions: Knowledge of calculus on infinite dimensional spaces and basic knowledge of stochastics.		
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Stochastische Evolutionsgleichungen **Language:** German **Contact Hours:** 6 **ECTS Credits:** 9.0
Contents: Unendlich dimensionale Räume Fourierreihen und -transformation zylindrische Wienerprozesse analytische Halbgruppen stochastische Evolutionsgleichungen stochastische dynamische Systeme Voraussetzungen: Kenntnisse in Analysis auf unendlich.-dimen. Räumen und Grundkenntnisse in Stochastik

Examination
Stochastische Evolutionsgleichungen oral exam / length of examination: 30 minutes

Module MTH-2215: Evolution Equations *Evolutionsgleichungen*		9 ECTS/LP
Version 1.0.0 (since SoSe19) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: Theory of parabolic and/or hyperbolic partial differential equations, existence and uniqueness of solutions, weak and mild solutions, semigroups, dynamical systems, stability, attractors and other topics.		
Learning Outcomes / Competences: Students know the basic terms, concepts and phenomena in the field of evolutionary equations. Ability to work independently on further research literature, competences in the independent processing of problems. of problems, skills in formulating and working on theoretical questions with the help of the methods questions with the help of the methods learnt. Integrated acquisition of key qualifications: Independent work with (English-language) scientific literature, scientific thinking, deepened competences in the independent processing of problems.		
Conditions: Knowledge of calculus on infinite dimensional spaces, basic knowledge of ordinary differential equations.		**Credit Requirements:** oral exam
Frequency: irregular	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: * LV-Gruppe neu*****
Language: German

Examination
***** Prf neu *****
oral exam / length of examination: 30 minutes

Module MTH-2250: Symplectic Geometry *Symplectic Geometry*	9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Kai Cieliebak	

Learning Outcomes / Competences:
Learning about techniques of symplectic geometry and their applications in the theory of classical mechanical systems.

Workload:
Total: 270 h

Conditions: none		**Credit Requirements:** Passing the module exam.
Frequency: every 3rd semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Symplectic Geometry and Hamiltonian Dynamics
Language: English / German
Contact Hours: 6
ECTS Credits: 9.0

Contents:

This course is an introduction to symplectic techniques in the theory of Hamiltonian systems. It covers the following topics: Hamilton's equations, symplectic manifolds, symmetries and Noether's theorem, symplectic reduction, rigid bodies, integrable systems, stability and the KAM theorem, chaos, applications to celestial mechanics, fluid dynamics, and quantum mechanics.

Voraussetzungen: Basic differential geometry (manifolds, differential forms)

Literature:

V.I.Arnold, Mathematical Methods of Classical Mechanics (Springer)

H.Hofer and E.Zehnder, Symplectic Invariants and Hamiltonian Dynamics (Birkhaeuser)

Assigned Courses:

Symplectic Geometry (lecture + exercise)

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Examination

Symplectic Geometry and Hamiltonian Dynamics

oral exam / length of examination: 30 minutes

Module MTH-2270: Advanced Topics in Algebraic Topology *Algebraische Topologie (Vertiefung)*		9 ECTS/LP
Version 2.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Bernhard Hanke		
Learning Outcomes / Competences: Es werden vertiefte Kenntnisse in der algebraischen Topologie vermittelt. Die Studierenden werden befähigt, sich eigenständig mit Literatur im Gebiet der algebraischen Topologie zu befassen. Dieser Modul dient auch als Vorbereitung zu weiterführenden Seminaren und Abschlussarbeiten.		
Workload: Total: 270 h		
Conditions: none		
Frequency:	**Recommended Semester:** 2. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Algebraische Topologie (Vertiefung)

Language: German / English
Frequency: irregular
Contact Hours: 6
ECTS Credits: 9.0

Contents:

Dieser Modul baut auf den Modul Algebraische Topologie auf. Es werden weiterführende Themen der algebraischen Topologie behandelt wie Kohomologie, Poincaré-Dualität, Homotopietheorie, Vektorbündel, Bordismus, K-Theorie.

Voraussetzungen: Algebraische Topologie

Literature:

Bredon, G.E.: Topology and Geometry, vol. 139, Graduate Texts in Mathematics. Springer-Verlag, 1993.

Dold, A.: Lectures on Algebraic Topology, vol. 200. Grundlehren der mathematischen Wissenschaften in Einzeldarstellungen, Springer-Verlag, 1972.

May, J. P.: A Concise Course in Algebraic Topology, University of Chicago Press.

Spanier, E.: Algebraic Topology. McGraw-Hill, 1966.

Examination

Algebraische Topologie (Vertiefung)

portfolio exam / length of examination: 120 minutes

Module MTH-2440: Approximation Algorithms

Approximationsalgorithmen

3 ECTS/LP

Version 1.0.0 (since SoSe16)
Person responsible for module: Prof. Dr. Tobias Harks

Contents:

- Greedy algorithms
- Facility location
- Steiner tree
- Scheduling
- TSP
- Set cover
- Clustering

Learning Outcomes / Competences:
This course offers an introduction to the main contents of polynomial time algorithmswith worst-case performance guarantees for NP-hard optimization problems.

Conditions: Module Introduction to Optimization (MTH-1140) - recommended		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Approximationsalgorithmen

Mode of Instruction: lecture
Language: German / English
Contact Hours: 2
ECTS Credits: 4.0

Literature:

Die Vorlesung wird u.a. einige Kapitel aus folgendem Buch behandeln.

Williamson/Shmoys. The design of approximation algorithms (Download unter http://www.designofapproxalgs.com/ möglich)

Examination

MTH-2222 Approximationsalgorithmen

module exam, Die genaue Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben

Module MTH-2510: Advanced Methods in Machine Learning *Advanced Methods in Machine Learning*		3 ECTS/LP
Version 1.0.0 (since WS20/21) Person responsible for module: Prof. Dr. Gernot Müller		
Contents: basics of machine learning, learnability, bias-complexity tradeoff, VC-dimension, deep feedforward networks, several case studies		
Learning Outcomes / Competences: Understanding of advanced concepts of machine learning; ability to apply these concepts to data and to interpret the results		
Workload: Total: 90 h 1 h exercise course (attendance) 1 h lecture (attendance)		
Conditions: Stochastik I, Stochastik II		**Credit Requirements:** Passing the module exam
Frequency: every 3rd semester / 4th semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Advanced Methods in Machine Learning
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Gernot Müller
Language: German / English
Contact Hours: 2
ECTS Credits: 3.0

Contents:

Grundlagen des Machine Learnings, Lernbarkeit, Der Konflikt zwischen Bias und Komplexität, Die VC-Dimension, Deep Feedforward Networks, Case Studies

Literature:

Aktuelle Veröffentlichungen zum Thema Machine Learning, insbesondere zur Erklärbarkeit und zu verbundenem Lernen

Examination

Advanced Methods in Machine Learning

module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 60 Minuten / length of examination: 60 minutes

Module MTH-2511: Advanced Methods in Machine Learning II *Advanced Methods in Machine Learning II*		3 ECTS/LP
Version 1.0.0 (since WS21/22) Person responsible for module: Prof. Dr. Gernot Müller		
Contents: linear predictors, half-spaces, Perceptron algorithm, boosting, AdaBoost, support vector machines		
Learning Outcomes / Competences: Understanding of advanced concepts of machine learning; ability to apply these concepts to data and to interpret the results		
Workload: Total: 90 h 1 h exercise course (attendance) 1 h lecture (attendance)		
Conditions: Stochastik I, Stochastik II, AMML (MTH-2510)		**Credit Requirements:** Passing the module exam
Frequency: every 3rd semester / 4h semester	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Advanced Methods in Machine Learning II **Mode of Instruction:** lecture + exercise **Lecturers:** Prof. Dr. Gernot Müller **Language:** German / English **Contact Hours:** 2 **ECTS Credits:** 3.0
Contents: Lineare Prädiktoren,Halbräume, Perceptron algorithm, Boosting, AdaBoost, Support Vector Machines
Literature: Aktuelle Veröffentlichungen zum Thema Machine Learning, insbesondere zur Erklärbarkeit und zu verbundenem Lernen
Examination **Advanced Methods in Machine Learning II** module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 60 Minuten / length of examination: 60 minutes

Module MTH-2590: Topics in Galois Fields *Topics in Galois Fields*		9 ECTS/LP
Version 1.0.0 (since WS21/22) Person responsible for module: apl. Prof. Dr. Dirk Hachenberger		

Contents:

1. Algebraic and number theoretical foundation
2. Multiplicative group, existence and uniqueness
3. Mappings for extensions of finite fields and normal bases
4. The algebraic closure of a finite field
5. Irreducible polynomials over finite fields
6. Factorization of univariate polynomials over finite fields
7. Nomal bases and cyclotomic modules
8. Characters, Gauss sums and the DFT
9. Primitive normal bases
10. Basis representation and arithmetics
11. Primitive elements in affine hyperplanes

Learning Outcomes / Competences:
"Finite fields" (resp. "Galois fields") belong to the fundamental structures which play an important role in modern applications, such as Coding Theory, Cryptography or Signal processing. After establishing the classical results on finite fields, our focus will be on developments from the last 25 years.

Remarks:
Concerning the contents, the previous modules MTH-2240 and MTH-2490 are nearly identical to MTH-2590. It is therefore possible to earn credit points only for one of these modules.

Conditions: Linear Algebra; foundations of Algebra, Combinatorics and elementary Number Theory.		**Credit Requirements:** This module can only be credited, when module MTH-2240 or module MTH-2490 have not already been credited.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Topics in Galois Fields: Lectures and Exercises
Mode of Instruction: lecture + exercise
Lecturers: apl. Prof. Dr. Dirk Hachenberger
Language: English
Contact Hours: 6
ECTS Credits: 9.0

Learning Outcome:
"Finite fields" (resp. "Galois fields") belong to the fundamental structures which play an important role in modern applications, such as Coding Theory, Cryptography or Signal processing. After establishing the classical results on finite fields, our focus will be on developments from the last 25 years.

Contents:

1. Algebraic and number theoretical foundation
2. Multiplicative group, existence and uniqueness
3. Mappings for extensions of finite fields and normal bases
4. The algebraic closure of a finite field
5. Irreducible polynomials over finite fields
6. Factorization of univariate polynomials over finite fields
7. Nomal bases and cyclotomic modules
8. Characters, Gauss sums and the DFT
9. Primitive normal bases
10. Basis representation and arithmetics
11. Primitive elements in affine hyperplanes

Literature:

Dirk Hachenberger and Dieter Jungnickel, Topics in Galois Fields, Springer Nature Switzerland, Cham, 2020.

Examination

Topics in Galois Fields

term paper

Module MTH-2640: Category Theory *Kategorientheorie*		9 ECTS/LP
Version 1.0.0 (since WS17/18) Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Contents: • Set-theoretical basics • Categories, functors, natural transformations • Examples • Limits and colimits • Adjoint functors • Kan-extensions • Ends and coends • Monoidal categories • Localisation of categories • Applications		
Learning Outcomes / Competences: The students have gained an overview of the essential concepts of category theory. They recognise universal constructions in other subfields of mathematics and can profitably apply category theory in other disciplines. They further perceive categories as algebraic objects that can be invariants of other structures. Finally, the students understand the basic theoretical problems that arise from a too naive notion of a set and have seen applications outside mathematics, e.g. in theoretical computer science.		
Conditions: • To successfully complete the module, participants only need a certain mathematical maturity and an interest in dealing with abstract structures.		**Credit Requirements:** Passing the module exam
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Kategorientheorie
Mode of Instruction: lecture
Language: German / English

Part of the Module: Übungen zur Kategorientheorie
Mode of Instruction: exercise course
Language: German / English

Examination
Modulprüfung
portfolio exam
Description:
Es sind schriftliche Übungsaufgaben zu bearbeiten, mündlich an der Tafel vorzurechnen und am Ende eine kurze mündliche Prüfung zu bestehen.

Module MTH-2650: Homotopy Type Theory *Homotopietypentheorie*		9 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Marc Nieper-Wißkirchen		
Contents: Initially, mathematical work within an intuitionistic type theory is taught. A special focus is placed on the concept of equality. Equality in elementary types is characterised. Homotopy theory concepts, the axiom of univalence and examples of higher inductive types are introduced. Higher inductive types are introduced. This homotopy-theoretic extension of the type theory is used to calculate selected homotopy groups and to develop abstract variants of classical results of algebraic topology.		
Learning Outcomes / Competences: • Mathematical reasoning and proving in a dependent type theory. This knowledge is a basis for the use of most computer-assisted proof systems. • Fundamental understanding of issues and techniques in abstract homotopy theory. The ideas gained are transferable to other approaches such as higher category theory. • Application of univalence and higher inductive types to homotopy theory problems. A study of advanced topics homotopy type theory becomes possible.		
Conditions: Experience with abstract mathematics, such as that gained in the context of introductory modules in the fields of topology and algebra. Elementary knowledge of these areas is helpful, but not required.		**Credit Requirements:** Pass the module exam
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Homotopietypetheorie **Mode of Instruction:** lecture **Language:** German / English **Contact Hours:** 4
Part of the Module: Übungen zur Homotopietypentheorie **Mode of Instruction:** exercise course **Language:** German / English **Contact Hours:** 2

Examination
Modulprüfung portfolio exam

Module MTH-3000: Topics in Geometry *Spezielle Kapitel der Geometrie*			6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Kai Cieliebak			
Contents: Advanced topics such as fibre bundles, gauge theory, or characteristic classes.			
Learning Outcomes / Competences: Independent work with scientific literature, scientific reasoning, problem solving, presentation of results.			
Remarks: The modules MTH-3000 and MTH-3001 are mutually exclusive.			
Workload: 2 h lecture (attendance)			
Conditions: An advanced lecture on geometry or algebra such as Einführung in die Geometrie, Differentialtopologie, Differentialgeometrie, Kommutative Algebra		**Credit Requirements:** Passing the module exam. Exclusion condition: This module may not be brought in, if the module MTH-3001 has already been taken!	
Frequency: irregular	**Recommended Semester:** 1. - 3.	**Minimal Duration of the Module:** semester[s]	
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program		

Parts of the Module
Part of the Module: Spezielle Kapitel der Geometrie **Language:** German / English **Contact Hours:** 2 **ECTS Credits:** 6.0
Examination **Spezielle Kapitel der Geometrie** oral exam / length of examination: 20 minutes

Module MTH-3240: Morse Homology *Morse Homologie*		9 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Urs Frauenfelder		
Contents: Morse functions, Gradient flow equation, Fredholm theory		
Workload: Total: 270 h		
Conditions: none		**Credit Requirements:** passing the module exam
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Morse Homologie **Language:** German / English **Contact Hours:** 6 **ECTS Credits:** 9.0
Contents: Morse-Funktionen, Gradientenflussgleichung, Fredholmtheorie
Examination **Morse Homologie** oral exam / length of examination: 30 minutes

Module MTH-3270: Algebraic K-Theory *Algebraische K-Theorie*		3 ECTS/LP
Version 1.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Wolfgang Steimle		
Learning Outcomes / Competences: The participants learn the basic definitions and theorems in algebraic K-theory. Some applications to geometry and algebra will be discussed.		
Workload: Total: 90 h		
Conditions: Keine.		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Algebraische K-Theorie **Language:** German / English **Contact Hours:** 2 **ECTS Credits:** 3.0
Learning Outcome: Die Studenten lernen grundlegende Definitionen und Resultate aus der algebraischen K-Theorie und einige Anwendungen in der Geometrie und Algebra kennen. The participants learn the basic definitions and theorems in algebraic K-theory. Some applications to geometry and algebra will be discussed.

Examination
Algebraische K-Theorie module exam, Die Prüfungsform wird in der jeweiligen Veranstaltung bekannt gegeben.

Module MTH-3280: Nonlinear Functional Analysis *Nonlinear Functional Analysis*		9 ECTS/LP
Version 1.0.0 (since WS17/18) Person responsible for module: Prof. Dr. Kai Cieliebak		
Contents: This course is an introduction to nonlinear functional analysis and its applications. It covers the following topics: Banach manifolds, nonlinear Fredholm operators, implicit function theorem, Sard-Smale theorem, Leray-Schauder degree, Frechet manifolds, Nash-Moser implicit function theorem, scaled Banach spaces, applications to ordinary and partial differential equations.		
Learning Outcomes / Competences: Learning about the basic techniques of nonlinear functional analysis and their applications to differential equations.		
Workload: Total: 270 h 270 h lecture and exercise course (attendance)		
Conditions: Module Funktionalanalysis (MTH-1100)		**Credit Requirements:** Passing the module exam
Frequency: as needed	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Nonlinear Functional Analysis
Mode of Instruction: lecture + exercise
Lecturers: Prof. Dr. Kai Cieliebak
Language: English / German
Contact Hours: 6
ECTS Credits: 9.0

Learning Outcome:
Learning about the basic techniques of nonlinear functional analysis and their applications to differential equations.

Contents:
This course is an introduction to nonlinear functional analysis and its applications. It covers the following topics: Banach manifolds, nonlinear Fredholm operators, implicit function theorem, Sard-Smale theorem, Leray-Schauder degree, Frechet manifolds, Nash-Moser implicit function theorem, scaled Banach spaces, applications to ordinary and partial differential equations.

Literature:
K. Deimling, Nonlinear Functional Analysis

Examination
Nonlinear Functional Analysis
oral exam / length of examination: 30 minutes

Module MTH-3290: Introduction to Celestial Mechanics *Einführung in die Himmelsmechanik*		3 ECTS/LP
Version 1.1.1 (since WS17/18) Person responsible for module: Prof. Dr. Urs Frauenfelder		
Contents: Newton equations, Conserved quantities, Restricted Three-Body problem, Regularizations, Special solutions		
Conditions: none		**Credit Requirements:** passing the module exam
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Einführung in die Himmelsmechanik **Mode of Instruction:** lecture **Lecturers:** Prof. Dr. Urs Frauenfelder **Language:** English / German **Contact Hours:** 2 **ECTS Credits:** 3.0
Examination **Himmelsmechanik Einführung in die Himmelsmechanik** individual oral exam

Module MTH-3560: Ausgewählte Kapitel der Variationsrechnung		9 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. Bernd Schmidt		
Learning Outcomes / Competences: Die Student(inn)en kennen moderne Zugänge zu freien Randwertproblemen, insbesondere die Theorie der Funktionen von beschränkter Variation in mehreren Dimensionen. Sie sind in der Lage, aufbauend auf den Inhalten der Vorlesung, Forschungsliteratur in diesem Gebiet zu lesen, sich selbstständig in weiterführende Aspekte einzuarbeiten sowie die erlernte Theorie in anwendungsorientierten Problemen einzusetzen.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: none		**Credit Requirements:** Bestehen der Modulprüfung
Frequency:	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** any	

Parts of the Module

Part of the Module: Ausgewählte Kapitel der Variationsrechnung

Language: German / English
Frequency: irregular
Contact Hours: 6
ECTS Credits: 9.0

Literature:

Luigi Ambrosio, Nicola Fusco, and Diego Pallara. Functions of bounded variation and free discontinuity problems. Oxford Mathematical Monographs. The Clarendon Press, Oxford University Press, New York, 2000.
Lawrence C. Evans and Ronald F. Gariepy. Measure theory and fine properties of functions. Textbooks in Mathematics. CRC Press, Boca Raton, FL, revised edition, 2015.

Herbert Federer. Geometric measure theory. Die Grundlehren der mathematischen Wissenschaften, Band 153. Springer-Verlag New York Inc., New York, 1969.

Examination

Ausgewählte Kapitel der Variationsrechnung

portfolio exam

Module MTH-3570: Reading Course Dynamical Systems *Lesekurs Dynamische Systeme*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Dirk Blömker		
Contents: Students will gain an in-depth knowledge of current research topics in dynamical systems and at the same time a sound introduction to modern qualitative theory.		
Learning Outcomes / Competences: You will achieve the competence to work independently on advanced subject areas and current research topics. research topics. Integrated acquisition of key qualifications: Self-study of English-language scientific literature, scientific work, conducting scientific discussions and presenting mathematical theories.		
Conditions: Some knowledge of dynamic systems		**Credit Requirements:** presentation and/or oral exam
Frequency: irregular	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Lesekurs Dynamische Systeme **Mode of Instruction:** **Language:** German **Contact Hours:** 2 **ECTS Credits:** 6.0

Examination
Lesekurs portfolio exam, Vortrag und aktive Mitarbeit / length of examination: 90 minutes

Module MTH-3590: Computational uncertainty quantification for partial differential equations *Numerische Methoden für partielle Differentialgleichungen mit Unsicherheiten*		9 ECTS/LP
Version 1.0.0 Person responsible for module: Prof. Dr. Daniel Peterseim		
Contents: Basics of the theory of partial differential equations with uncertain input data. Approximation theory and numerics of high-dimensional problems. Monte Carlo methods, stochastic collocation and Galerkin methods, method of statistical moments, Bayesian methods.		
Learning Outcomes / Competences: Deeper understanding of uncertainty quantification in partial differential equations with uncertainties in their most important forms. Connections as well as advantages and disadvantages of the methods, also with regard to the application to concrete problems. Understanding of the difficulties intrinsic to high-dimensional problems as well as basic solution approaches. Complex algorithms. Integrated acquisition of key qualifications: in small groups, students learn to define problems precisely, to develop numerical solution strategies and to assess their suitability, while developing social skills for working together in a team.		
Workload: Total: 270 h 2 h exercise course (attendance) 4 h lecture (attendance)		
Conditions: Recommendation: Numerik partieller Differentialgleichungen		**Credit Requirements:** Passed module examination.
Frequency: irregular	**Recommended Semester:** 1. - 4.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Computational uncertainty quantification for partial differential equations **Language:** English / German **Contact Hours:** 6 **ECTS Credits:** 9.0
Contents: Basics of the theory of partial differential equations with uncertain input data. Approximation theory and numerics of high-dimensional problems. Monte Carlo methods, stochastic collocation and Galerkin methods, method of statistical moments, Bayesian methods.
Literature: R.G. Ghanem, P.D. Spanos: Stochastic finite elements: a spectral approach. Springer-Verlag, 1991 O.P. Le Maître, O.M. Knio: Spectral methods for uncertainty quantification. Springer, 2010 M.B. Giles: Multilevel Monte Carlo methods, Acta Numerica 24 (2015), 259–328 T.J. Sullivan: Introduction to uncertainty quantification, Springer, 2015

Examination

MTH-3590 Computational uncertainty quantification for partial differential equations

portfolio exam

Description:

Precise examination modalities will be announced at the beginning of the course.

Module MTH-3610: Complements on analysis *Ergänzungen zu Analysis*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: The complements module is dedicated to targeted familiarisation with the fundamentals of the analytical subject areas as well as the analytical background of the mathematical elective modules of the module groups B1 to B7 or E.		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Passing of the module examination
Frequency: as needed	**Recommended Semester:** 1. - 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Ergänzungen zu Analysis **Language:** English / German **Contact Hours:** 4 **ECTS Credits:** 6.0

Examination

Ergänzungen zu Analysis

oral exam / length of examination: 15 minutes, not graded

Module MTH-3620: Complements on functional analysis/partial differential equations *Ergänzungen zu Funktionalanalysis/Partielle Differentialgleichungen*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: The complements module is dedicated to targeted familiarisation with the fundamentals of the functionalanalytical subject areas as well as the functionalanalytical background related to partial differential equations of the mathematical elective modules of the module groups B1 to B7 or E.		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Passing of the module examination
Frequency: as needed	**Recommended Semester:** 1. - 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Ergänzungen zu Funktionalanalysis/Partielle Differentialgleichungen **Language:** English / German **Contact Hours:** 4 **ECTS Credits:** 6.0

Examination
Ergänzungen zu Funktionalanalysis/Partielle Differentialgleichungen oral exam / length of examination: 15 minutes, not graded

Module MTH-3630: Complements on stochastics *Ergänzungen zu Stochastik*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: The complements module is dedicated to targeted familiarisation with the fundamentals of the stochastic subject areas as well as the stochastic background of the mathematical elective modules of the module groups B1 to B7 or E.		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Passing of the module examination
Frequency: as needed	**Recommended Semester:** 1. - 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Ergänzungen zu Stochastik **Language:** English / German **Contact Hours:** 4 **ECTS Credits:** 6.0

Examination
Ergänzungen zu Stochastik oral exam / length of examination: 15 minutes, not graded

Module MTH-3640: Complements on numerics *Ergänzungen zu Numerik*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Malte Peter		
Learning Outcomes / Competences: The complements module is dedicated to targeted familiarisation with the fundamentals of the numerical subject areas as well as the numerical background of the mathematical elective modules of the module groups B1 to B7 or E.		
Workload: Total: 180 h		
Conditions: none		**Credit Requirements:** Passing of the module examination
Frequency: as needed	**Recommended Semester:** 1. - 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** any	

Parts of the Module
Part of the Module: Ergänzungen zu Numerik **Language:** English / German **Contact Hours:** 4 **ECTS Credits:** 6.0

Examination

Ergänzungen zu Numerik

oral exam / length of examination: 15 minutes, not graded

Module PHM-0046: Theoretical Solid State Physics *Theoretische Festkörperphysik*	8 ECTS/LP

Version 2.1.0 (since WS16/17)
Person responsible for module: Prof. Dr. Liviu Chioncel

Contents:

- Kristallstruktur, reziprokes Gitter
- Nichtwechselwirkende Elektronen im periodischen Potential: Bloch-Theorem, Störungstheorie, stark gebundene Elektronen
- Semiklassische Dynamik von Blochelektronen: Zener-Durchbruch, Semiklassik im konstanten Magnetfeld, Drude-Theorie, Diffusion
- Gitterdynamik: Born-Oppenheimer-Näherung, Phononen, Debye- und Einstein-Modell
- Elektron-Elektron-Wechselwirkung: Hartree-Fock-Näherung, Dichtefunktionaltheorie, Abschirmung
- Formalismus der zweiten Quantisierung

Learning Outcomes / Competences:

- Die Studierenden kennen die Grundlagen und Methoden der quantentheoretischen Beschreibung von Festkörpern und ihren Eigenschaften im Rahmen nicht wechselwirkender Vielteilchensysteme bzw. effektiver Einteilchentheorien,
- sind in der Lage, physikalische Fragestellungen der Festkörperphysik theoretisch zu formulieren und durch Anwendung geeigneter Näherungsmethoden zu untersuchen,
- haben die Fähigkeit, Problemstellungen in den genannten Teilgebieten selbständig zu bearbeiten.
- Integrierter Erwerb von Schlüsselqualifikationen: eigenständiges Arbeiten mit englischsprachiger Fachliteratur, Erfassen komplexer Zusammenhänge und deren modellhafte Darstellung mit Hilfe mathematischer Strukturen, Methodenkompetenz

Workload:
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 literarture (self-study)
90 h lecture and exercise course (attendance)

Conditions:
Das Modul baut insbesondere auf den Inhalten der Bachelor-Vorlesungen Theoretische Physik II + III und Physik IV auf.

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

Parts of the Module

Part of the Module: Theoretische Festkörperphysik
Mode of Instruction: lecture
Language: German
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:
siehe Modulbeschreibung

Literature:

- N. W. Ashcroft and N. D. Mermin, Solid State Physics (Rinehart and Winston)
- J. Callaway, Quantum Theory of the Solid State (Academic)
- P. Coleman, Introduction to Many Body Physics (Cambridge)
- P. Fulde, Electron Correlations in Molecules and Solids (Springer)
- G. Giuliani and G. Vignale, Quantum Theory of the Electron Liquid (Cambridge)
- C. Kittel, Quantum Theory of Solids (Wiley)
- P. L. Taylor and O. Heinonen, A Quantum Approach to Condensed Matter Physics (Cambridge)
- J. M. Ziman, Prinzipien der Festkörpertheorie (Harri Deutsch)

Assigned Courses:

Theoretische Festkörperphysik (lecture)

**

Part of the Module: Übung zu Theoretische Festkörperphysik

Mode of Instruction: exercise course

Language: German

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Assigned Courses:

Übung zu Theoretische Festkörperphysik (exercise course)

**(online/digital) **

Examination

Theoretische Festkörperphysik

written exam / length of examination: 150 minutes

Description:

Ausnahme WS 20/21: Prüfungsform mündliche Prüfung

siehe Anlage 1a der Corona-Satzung

Module PHM-0048: Physics and Technology of Semiconductor Devices *Physics and Technology of Semiconductor Devices*		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: 1. Basic properties of semiconductors (electronic bandstructure, doping, carrier excitations and carrier transport) 2. Semiconductor diodes and transistors 3. Semiconductor technology		
Learning Outcomes / Competences: • Basic knowledge of solid-state and semiconductor physics such as electronic bandstructure, doping, carrier excitations, and carrier transport. • Application of developed concepts (effective mass, quasi-Fermi levels) to describe the basic properties of semiconductors. • Application of these concepts to describe and understand the operation principles of semiconductor devices such as diodes and transistors • Knowledge of the technologically relevant methods and tools in semiconductor micro- and nanofabrication. • Integrated acquisition of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.		
Workload: Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: recommended prerequisites: basic knowledge in solid state physics, statistical physics and quantum mechanics.		
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Physics and Technology of Semiconductor Devices **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: see module description

Literature:

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

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Contents:

see module description

Examination

Physics and Technology of Semiconductor Devices

written exam / length of examination: 90 minutes

Examination Prerequisites:

Physics and Technology of Semiconductor Devices

Module PHM-0049: Nanostructures / Nanophysics *Nanostructures / Nanophysics*		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. István Kézsmárki		
Contents: 1. Semiconductor quantum wells, wires and dots, low dimensional electron systems 2. Magnetotransport in low-dimensional systems, Quantum-Hall-Effect, Quantized conductance 3. Optical properties of nanostructures and their application in modern optoelectonic devices, Nanophotonics 4. Fabrication and detection techniques of nanostructures 5. Ferroic properties of nanostructures (Ferroelectricity, Magnetism, Multiferroicity)		
Learning Outcomes / Competences: • The students gain basic knowledge of the fundamental concepts in modern nanoscale science. • The students have detailed knowledge of low-dimensional semiconductor structures and how these systems can be applied for novel functional devices for high-frequency electronics and optoelectronics • The students gain competence in selecting different fabrication and characterization approaches for specific nanostructures. • The students are able apply these concepts to tackle present problems in nanophysics. • The students acquire scientific skills to search for scientific literature and to evaluate scientific content.		
Workload: Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study)		
Conditions: recommended prerequisites: basic knowledge in solid-state physics and quantum mechanics.		
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Nanostructures / Nanophysics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: see module description
Contents: see module description
Literature: • Yu und Cardona: Fundamentals of Semiconductors • Singh:Electronic and Optoelectronic Properties of Semiconductor Structures (Cambridge University Press) • Davies: The Physics of low-dimensional Semiconductors (Cambridge University Press)

Examination

Nanostructures / Nanophysics

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Nanostructures / Nanophysics

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

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

Contents:

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

Learning Outcomes / Competences:
The students:

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

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

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

Parts of the Module

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

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

Examination

Electronics for Physicists and Materials Scientists

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Electronics for Physicists and Materials Scientists

Module PHM-0051: Biophysics and Biomaterials *Biophysics and Biomaterials*		6 ECTS/LP
Version 1.1.0 (since SoSe22) Person responsible for module: Dr. Stefan Thalhammer Westerhausen, Christoph, Dr.		
Contents: • Transcription and translation • Membranes • DNA and proteins • Enabling technologies • Microfluidics • Radiation Biophysics		
Learning Outcomes / Competences: The students know: · basic terms, concepts and phenomena of biological physics · models of the (bio)polymer-theory, microfluidics, radiation biophysics, nanobiotechnology, sequencing strategies, membranes and proteins The students obtain skills · for independent processing of problems and dealing with current literature. · to translate a biological observation into a physical question. The students improve the key competences: · self-dependent working with English specialist literature. · processing and interpretation of experimental data. · interdisciplinary thinking and working.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study)		
Conditions: Mechanics, Thermodynamics, Statistical Physics		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Biophysics and Biomaterials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3

Learning Outcome:

See module description.

Contents:

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

Literature:

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

Part of the Module: Biophysics and Biomaterials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Contents:

See module description.

Examination

Biophysics and Biomaterials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Biophysics and Biomaterials

Module PHM-0052: Solid State Spectroscopy with Synchrotron Radiation and Neutrons *Solid State Spectroscopy with Synchrotron Radiation and Neutrons*		6 ECTS/LP
Version 1.2.0 (since WS09/10) Person responsible for module: Prof. Dr. Christine Kuntscher		
Contents: 1. Electromagnetic radiation: description, generation, detection [5] 2. Spectral analysis of electromagnetic radiation: monochromators, spectrometer, interferometer [2] 3. Excitations in the solid state: Dielectric function [2] 4. Infrared spectroscopy 5. Ellipsometry 6. Photoemission spectroscopy 7. X-ray absorption spectroscopy 8. Neutrons: Sources, detectors 9. Neutron scattering		
Learning Outcomes / Competences: The students: • know the basics of spectroscopy and important instrumentation and methods, • have acquired the skills of formulating a mathematical-physical ansatz in spectroscopy and can apply these in the field of solid state spectroscopy, • have the competence to deal with current problems in solid state spectroscopy autonomously, and are able to judge proper measurement methods for application. • Integrated acquirement of soft skills.		
Workload: Total: 180 h 20 h studying of course content using literarture (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)		
Conditions: basic knowledge in solid-state physics		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Solid State Spectroscopy with Synchrotron Radiation and Neutrons **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: see module description

Literature:

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

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

Module PHM-0053: Chemical Physics I *Chemical Physics I*	6 ECTS/LP

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

Contents:

- Basics of quantum chemical methods
- Molecular symmetry and group theory
- The electronical structure of transition metal complexes

Learning Outcomes / Competences:

The students:

- know the basics of the extended-Hückel-method and the density functional theory,
- know the basics of group theory,
- are able to apply the knowledge gained through consideration of symmetry from vibration-, NMR-, and UV/VIS-spectroscopy, and
- are able to interpret and predict the basical geometric, electronical and magnetical properties of transition metal complexes.
- Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.

Remarks:

It is possible for students to do EHM calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.

Workload:

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

Conditions:

It is recommended to complete the experiments FP11 (IR-spectroscopy) and FP17 (Raman-spectroscopy) of the module "Physikalisches Fortgeschrittenenpraktikum".

Frequency: each winter semester not in winter term 22/23	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Chemical Physics I
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:

see module description

Contents:

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

Literature:

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

Part of the Module: Chemical Physics I (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Chemical Physics I

written exam / length of examination: 90 minutes

Examination Prerequisites:

Chemical Physics I

Module PHM-0054: Chemical Physics II *Chemical Physics II*		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Scherer PD Dr. Georg Eickerling		
Contents: • Introduction to computational chemistry • Hartree-Fock Theory • DFT in a nutshell • Prediction of reaction mechanisms • calculation of physical and chemical properties		
Learning Outcomes / Competences: The students: • know the basic quantum chemical methods of chemical physics to interpret the electronic structures in molecules and solid-state compounds, • have therefore the competence to autonomously perform simple quantum chemical calculations using Hartree-Fock and Density Functional Theory (DFT) and to interpret the electronic structure of functional molecules and materials with regard to their chemical and physical properties • Integrated acquirement of soft skills: ability to specialize in a scientific topic and to apply the acquired knowledge for solving scientific problems.		
Remarks: It is possible for students to do quantum chemical calculations autonomously and analyze electronical structures of molecules on a computer cluster within the scope of the tutorial.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: It is highly recommended to complete the module Chemical Physics I first.		
Frequency: each summer semester not in summer term 23	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Literature:

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

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

Module PHM-0056: Ion-Solid Interaction *Ion-Solid Interaction*	6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: apl. Prof. Dr. Helmut Karl

Contents:

- Introduction (areas of scientific and technological application, principles)
- Fundamentals of atomic collision processes (scattering, cross-sections, energy loss models, potentials in binary collision models)
- Ion-induced modification of solids (integrated circuit fabrication with emphasis on ion induced phenomena, ion implantation, radiation damage, ion milling and etching (RIE), sputtering, erosion, deposition)
- Transport phenomena
- Analysis with ion beams

Learning Outcomes / Competences:

The students:

- know the physical principles and the basical mechanisms of the interaction between particles and solid state bodies in the energy range of eV to MeV,
- are able to choose adequate physical models for specific technological and scientific applications, and
- have the competence to work extensively autonomous on problems concerning the interaction between ions and solid state bodies.
- Integrated acquirement of soft skills.

Workload:

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

Conditions:
Basic Courses in Physics I–IV, Solid State Physics, Nuclear Physics

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

Parts of the Module

Part of the Module: Ion-Solid Interaction
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

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

Module PHM-0057: Physics of Thin Films *Physics of Thin Films*	6 ECTS/LP

Version 1.6.0 (since WS09/10)
Person responsible for module: PD Dr. German Hammerl

Contents:

- Thin film growth: basics, thermodynamic considerations, surface kinetics, growth mechanisms
- Thin film growth techniques: vacuum technology, physical vapor deposition, chemical vapor deposition
- Analysis and characterization of thin films: in-sit methods, ex-situ methods, direct methods
- Properties and applications of thin films

Learning Outcomes / Competences:
The students:

- know a broad spectrum of methods of thin film technology and material properties and applications of thin films,
- have the competence to deal with current problems in the field of thin film technology largely autonomous,
- are able to choose the right substrates and thin film materials for epitaxial thin film growth to achieve desired application conditions,
- aquire skills of combining the various technologies for growing thin layers with respect to their properties and applications, and
- aquire scientific soft skills to search for scientific literature, unterstand technical english, work with literature in the field of thin films, interpret experimental results.

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

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

Parts of the Module

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

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

Examination

Physics of Thin Films

written exam / length of examination: 90 minutes

Examination Prerequisites:

Physics of Thin Films

Module PHM-0058: Organic Semiconductors *Organic Semiconductors*		6 ECTS/LP
Version 1.3.0 (since WS09/10) Person responsible for module: Prof. Dr. Wolfgang Brütting		
Contents: Basic concepts and applications of organic semiconductors Introduction • Materials and preparation • Structural properties • Electronic structure • Optical and electrical properties Devices and Applications • Organic metals • Light-emitting diodes • Solar cells • Field-effect transistors		
Learning Outcomes / Competences: The students: • know the basic structural and electronic properties of organic semiconductors as well as the essential function of organic semiconductor devices, • have acquired skills for the classification of the materials taking into account their specific features in the functioning of components, • and have the competence to comprehend and attend to current problems in the field of organic electronics. • Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results		
Workload: Total: 180 h 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 literarture (self-study)		
Conditions: It is strongly recommended to complete the module solid-state physics first. In addition, knowledge of molecular physics is desired.		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Learning Outcome:

see module description

Contents:

see module description

Literature:

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

Part of the Module: Organic Semiconductors (Tutorial)

Mode of Instruction: exercise course

Language: English

Frequency: every 3rd semester

Contact Hours: 1

Examination

Organic Semiconductors

written exam / length of examination: 90 minutes

Examination Prerequisites:

Organic Semiconductors

Module PHM-0059: Magnetism

Magnetism

6 ECTS/LP

Version 1.0.0 (since WS09/10)
Person responsible for module: Dr. Hans-Albrecht Krug von Nidda

Contents:

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

Learning Outcomes / Competences:
The students:

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

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

Conditions:
basics of solid-state physics and quantum mechanics

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

Parts of the Module

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

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

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

Module PHM-0060: Low Temperature Physics *Low Temperature Physics*	6 ECTS/LP

Version 1.1.0 (since WS09/10)
Person responsible for module: Prof. Dr. Philipp Gegenwart

Contents:

- Introduction
- Properties of matter at low temperatures
- Cryoliquids and superfluidity
- Cryogenic engineering
- Thermometry
- Quantum transport, criticality and entanglement in matter

Learning Outcomes / Competences:

The students:

- know the basic properties of matter at low temperatures and the corresponding experimental techniques,
- have acquired the theoretical knowledge to perform low-temperature measurements,
- and know how to experimentally investigate current problems in low-temperature physics.

Workload:

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

Conditions:
Physik IV - Solid-state physics

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

Parts of the Module

Part of the Module: Low Temperature Physics
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Learning Outcome:
see module description

Contents:

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

Literature:

C. Enss, S. Hunklinger, Tieftemperaturphysik (Springer)

F. Pobell, Matter and Methods at Low Temperatures (Springer)

Part of the Module: Low Temperature Physics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Low Temperature Physics

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Low Temperature Physics

Module PHM-0063: Physics of the Atmosphere I *Physik der Atmosphäre I*		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Michael Bittner		
Contents: • Allgemeine Einführung • Strahlung: Planck-Funktion, Strahlungsbilanz der Atmosphäre, Heizraten, Treibhauseffekt, Strahlungsmodelle • Dynamik: Navier-Stokes-, Kontinuitäts- und Adiabatengleichung, atmosphärische Wellen • Chemie: Absorptions- & Emissionsspektren, Heizraten • Darstellung der Prozesse in Modellen		
Learning Outcomes / Competences: • Die Studierenden kennen die grundlegenden Eigenschaften und Phänomene der atmosphärischen Prozesse im Bereich Strahlung und Dynamik sowie (eingeschränkt) der Chemie, • haben Fertigkeiten zur Formulierung moderner Fragestellungen der Atmosphärenphysik erworben • und besitzen die Kompetenz, aktuelle Problemstellungen aus den Bereichen der Atmosphärenphysik, der Fernerkundung und Modellierung weitgehend selbständig zu beurteilen und Lösungsansätze aufzuzeigen. • Integrierter Erwerb von Schlüsselqualifikationen		
Remarks: Im jeweils folgenden Sommersemester wird in der Regel das Vertiefungsmodul Physik der Atmosphäre II angeboten.		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: Die Vorlesung baut auf den Inhalten der Experimentalphysik-Vorlesungen des Bachelorstudiengangs Physik auf.		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Physik der Atmosphäre I **Mode of Instruction:** lecture **Language:** German **Contact Hours:** 2
Learning Outcome: siehe Modulbeschreibung
Contents: siehe Modulbeschreibung

Literature:

• G. Visconti, 2016. Fundamentals of physics and chemistry of the atmosphere (Springer, 2. Auflage)
• D. G. Andrews, 2010. An introduction to atmospheric physics (Cambridge, 2. Auflage)
• J. T. Houghton, 2002. The physics of atmospheres (Cambridge, 3. Auflage)
• L. D. Landau, E. M. Lifschitz, 2007. Lehrbuch der theoretischen Physik: Hydrodynamik (Harri Deutsch, 5. Auflage)
• H. Pichler, 1997. Dynamik der Atmosphäre (Spektrum, 2. Auflage)
• W. Rödel, 2000. Physik unserer Umwelt: Die Atmosphäre (Springer, 3. Auflage)
• M. Z. Jacobson, 2005. Fundamentals of atmospheric modeling (Cambridge, 2. Auflage)
• W. G. Rees, 2013. Physical principles of remote sensing: 1. Remote sensing (Cambridge, 3. Auflage)

Assigned Courses:

Physik der Atmosphäre I (lecture + exercise)
**

Part of the Module: Übung zu Physik der Atmosphäre I

Mode of Instruction: exercise course
Language: German
Contact Hours: 2

Learning Outcome:
siehe Modulbeschreibung

Assigned Courses:

Übung zu Physik der Atmosphäre I (exercise course)
**

Examination

Physik der Atmosphäre I
oral exam / length of examination: 30 minutes

Module PHM-0065: Physics of the Atmosphere II *Physik der Atmosphäre II*	6 ECTS/LP

Version 2.0.0 (since SoSe16)
Person responsible for module: Prof. Dr. Michael Bittner
PD Dr. habil. Sabine Wüst

Contents:

- Dynamik der Atmosphäre (Grundlagen, Wellen)
- Chemie der Stratosphäre (Ozonabbau)
- Atmosphärenfernerkundung (satellitenbasierte Methoden, bodengestützte Messtechniken)
- Numerische Methoden

Learning Outcomes / Competences:

- Die Studierenden kennen die grundlegenden Prozesse im Bereich der atmosphärischen Dynamik mit Schwerpunkt auf Wellen, im Bereich der stratosphärischen Ozonchemie und sie kennen die grundlegenden messtechnischen Verfahren zur Fernerkundung der Atmosphäre sowie deren numerische Umsetzung
- haben Fertigkeiten zur Formulierung moderner Fragestellungen der Atmosphärenphysik erworben
- und besitzen die Kompetenz, aktuelle Problemstellungen aus dem Bereich der Atmosphärenphysik weitgehend selbständig zu beurteilen und Lösungsansätze aufzuzeigen.
- Integrierter Erwerb von Schlüsselqualifikationen

Remarks:
Jeweils im Wintersemester wird das Modul Physik der Atmosphäre I angeboten.

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

Conditions:
Das Modul baut auf den Inhalten der Experimentalphysik-Vorlesungen des Bachelorstudiengangs Physik sowie dem Modul "Physik der Atmosphäre I" auf.

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

Parts of the Module

Part of the Module: Physik der Atmosphäre II
Mode of Instruction: lecture
Lecturers: Prof. Dr. Michael Bittner
Language: German
Contact Hours: 2

Learning Outcome:
siehe Modulbeschreibung

Contents:
siehe Modulbeschreibung

Literature:

- G. Visconti, 2016. Fundamentals of physics and chemistry of the atmosphere (Springer, 2. Auflage)
- D. G. Andrews, 2010. An introduction to atmospheric physics (Cambridge, 2. Auflage)
- J. T. Houghton, 2002. The physics of atmospheres (Cambridge, 3. Auflage)
- L. D. Landau, E. M. Lifschitz, 2007. Lehrbuch der theoretischen Physik: Hydrodynamik (Harri Deutsch, 5. Auflage)
- H. Pichler, 1997. Dynamik der Atmosphäre (Spektrum, 2. Auflage)
- W. Rödel, 2000. Physik unserer Umwelt: Die Atmosphäre (Springer, 3. Auflage)
- M. Z. Jacobson, 2005. Fundamentals of atmospheric modeling (Cambridge, 2. Auflage)
- W. G. Rees, 2013. Physical principles of remote sensing: 1. Remote sensing (Cambridge, 3. Auflage)

Part of the Module: Physik der Atmosphäre II: Numerische Verfahren

Mode of Instruction: lecture
Lecturers: PD Dr. habil. Sabine Wüst
Language: German
Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Contents:

Ergänzend zum ersten Modulteil werden numerische Methoden behandelt.

Literature:

- M. Jacobson, 2005. Fundamentals of Atmospheric Modeling (Cambridge)
- G. Brasseur, D. Jacob, 2017. Modeling of Atmospheric Chemistry (Cambridge)
- H. Pichler, 1997. Dynamik der Atmosphäre (Spektrum, 2. Auflage)
- J. Houghton, 2015. Global Warming (Cambridge, 5. Auflage)
- G. Visconti, 2016 Fundamentals of physics and chemistry of the atmosphere (Springer)

Examination

Physik der Atmosphäre II

oral exam / length of examination: 30 minutes

Module PHM-0066: Superconductivity
Superconductivity

6 ECTS/LP

Version 1.0.0 (since WS11/12)
Person responsible for module: Prof. Dr. Philipp Gegenwart

Contents:

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

Learning Outcomes / Competences:
The students:

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

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

Conditions:

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

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

Parts of the Module

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

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

Assigned Courses:

Superconductivity (lecture)
**(online/digital) **

Examination

Superconductivity
oral exam / length of examination: 30 minutes

Examination Prerequisites:
Superconductivity

Module PHM-0067: Complex materials: Fundamentals and Applications *Complex Materials: Fundamentals and Applications*		8 ECTS/LP
Version 1.0.0 (since SoSe14) Person responsible for module: Prof. Dr. Manfred Albrecht		
Contents: • structural phase formation, nucleation, phase diagrams • amorphous materials • ferrimagnetism • ferroelectrica • multiferroica • thermoelectric materials • low dimensional material systems (e.g., quantum dots) • material characterization methods		
Learning Outcomes / Competences: • students learn the basic concepts of modern solid state physics • have a well-founded understanding of fundamental physical relationships in complex materials and their applications • have knowledge of qualitative physical observations, quantitative measurements and mathematical descriptions of physical effects of selected complex material systems • acquisition of key qualifications: learning how to work independently with English-language specialist literature • practicing presentation techniques, ability to work in a team, ability to document experimental results, interdisciplinary thinking		
Workload: Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literarture (self-study) 90 h studying of course content through exercises / case studies (self-study)		
Conditions: Basics in solid state physics		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Complex Materials: Fundamentals and Applications **Mode of Instruction:** lecture **Language:** English / German **Contact Hours:** 4
Learning Outcome: siehe Modulbeschreibung
Contents: siehe Modulbeschreibung

Literature:

wird in der Vorlesung bekannt gegeben

Part of the Module: Complex Materials: Fundamentals and Applications (Tutorial)

Mode of Instruction: exercise course

Language: English / German

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Examination

Complex Materials: Fundamentals and Applications

oral exam / length of examination: 30 minutes

Module PHM-0068: Spintronics *Spintronics*	6 ECTS/LP

Version 1.7.0 (since SoSe14)
Person responsible for module: PD Dr. German Hammerl

Contents:

- Basic micromagnetic interactions (exchange, anisotropy, DMI, stray fields, external fields) and where they come from
- Emergence of spin textures such as domain walls and bubbles/skyrmions
- Torques acting on the local magnetization (magnetic field torque, current in-plane spin-transfer torque, spin-Hall effect and spin-orbit torques)
- Switching
- Motion of spin textures, 1D model and Thiele equation
- Magneto-resistance and Hall effects and their utility in electrical readout
- Ultrafast effects
- Device applications
- Experimental techniques in the field of spintronics

Learning Outcomes / Competences:
The students:

- know the fundamental interactions in magnetic materials, the basic spintronic effects, and the related device structures,
- have the competence to deal with current problems in the field of spintronics largely autonomously,
- are able to choose materials in order to achieve demanding properties in spintronic applications,
- are able to design device components to achieve spin polarization,
- acquire scientific skills in finding and understanding current literature dealing with spintronic devices and applications, identifying suitable materials and material combinations with respect to their applicability for spintronic devices.

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

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

Parts of the Module

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

Learning Outcome:
see module description

Contents:

see module description

Literature:

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

Part of the Module: Spintronics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Spintronics

written exam / length of examination: 90 minutes

Examination Prerequisites:

Spintronics

Module PHM-0069: Applied Magnetic Materials and Methods *Applied Magnetic Materials and Methods*		6 ECTS/LP
Version 1.1.0 (since WS14/15) Person responsible for module: Prof. Dr. Manfred Albrecht		
Contents: • Basics of magnetism • Ferrimagnets, permanent magnets • Magnetic nanoparticles • Superparamagnetism • Exchange bias effect • Magnetoresistance, sensors • Experimental methods (e.g. Mößbauer Spectroscopy, mu-SR)		
Learning Outcomes / Competences: • The students know the basic terms and concepts of magnetism, • get a profound understanding of basic physical relations and their applications, • acquire the ability to describe qualitative observations, interpret quantitative measurements, and develop mathematical descriptions of physical effects of chosen magnetic material systems. • Integrated acquirement of soft skills: autonomous working with specialist literature in English, acquisition of presentation techniques, capacity for teamwork, ability to document experimental results, and interdisciplinary thinking and working.		
Workload: Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Basics in solid state physics		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Applied Magnetic Materials and Methods **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: see module description
Contents: see module description
Literature: Stephan Bundell, Magnetism in Condensed Matter, Oxford University Press, ISBN: 0-19-850591-4 (Pbk) J.M.C. Coey, Magnetism and Magnetic Materials, Cambridge University Press, ISBN: 978-0-521-81614-4 (hardback)

Part of the Module: Applied Magnetic Materials and Methods (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Applied Magnetic Materials and Methods

oral exam / length of examination: 30 minutes

Examination Prerequisites:

Applied Magnetic Materials and Methods

Module PHM-0070: Many-Body Theory *Vielteilchentheorie*	8 ECTS/LP

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

Contents:

- Quantenmechanik für Vielteilchensysteme (2. Quantisierung)
- Zweizeitige Green-Funktionen
- Lineare Responsetheorie (verallgemeinerte Suszeptibilitäten)
- Vielteilchensysteme ohne dynamische Korrelationen
- Das Wicksche Theorem
- Näherung des effektiven Feldes
- BCS-Theorie der Supraleitung
- Diagrammatische Störungsrechnung
- Statistische Physik des Nichtgleichgewichts
- Fermionische und bosonische Modellsysteme

Learning Outcomes / Competences:

- Die Studierenden kennen die grundlegenden Konzepte zur Beschreibung von quantenmechanischen Vielteilchensystemen.
- Sie sind in der Lage, approximative Methoden der Vielteilchenphysik zur Berechnung von spektroskopischen Meßgrößen und Transportkoeffizienten anzuwenden und
- sind kompetent, Problemstellungen aus den genannten Bereichen selbständig zu bearbeiten.
- Integrierter Erwerb von Schlüsselqualifikationen

Workload:
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 literarture (self-study)
90 h lecture and exercise course (attendance)

Conditions: Kenntnisse der Theoretischen Festkörperphysik		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Vielteilchentheorie
Mode of Instruction: lecture
Language: German / English
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:
siehe Modulbeschreibung

Literature:

- W. Nolting, Grundkurs Theoretische Physik, Band 7, “Vielteilchentheorie“ (Verlag Zimmermann Neufang)
- A. Messiah, “Quantum Mechanics“, Band 2
- R.D. Mattuck, “A Guide to Feynman Diagrams in the Many Body Problem“ (Dover Publications)
- A.L. Fetter, I.D. Walecka, “Quantum Theory of Many-Particle Systems“ (McGraw Hill)
- A.A. Abrikosov, L.P. Gorkov, I. Dzyaloshinsky, “Methods of Quantum Field Theory“ (Dover Publications)
- S. Doniach, E.H. Sondheimer, Frontiers in Physics Lecture Note Series 44, “Green
- G.D. Mahan, “Many-Particle Physics“ (Plenum Press)
- I.W. Negele, H. Orland, “Quantum Many-Particle Physics“, Frontiers in Physics Lecture Note Series 68 (Addison Wesley).

Part of the Module: Übung zu Vielteilchentheorie

Mode of Instruction: exercise course

Language: German / English

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Examination

Vielteilchentheorie

oral exam / length of examination: 30 minutes

Module PHM-0071: Nonequilibrium Statistical Physics *Nonequilibrium Statistical Physics*	8 ECTS/LP

Version 1.1.0 (since WS09/10)
Person responsible for module: Prof. Dr. Christoph Alexander Weber

Contents:

- Coarse graining (BKKY, Boltzmann, Navier-Stokes)
- Transport theory derived by symmetries & conservation laws
- Nonequilibrium steady states
- Irreversible Thermodynamics and Onsager linear response
- Passive and active systems (Active Ising model, Collective Motion)
- Coarsening kinetics in conserved and nonconserved systems
- Hydrodynamic Instabilities

Learning Outcomes / Competences:

Students...

- learn about the complexity and diversity of nonequilibrium phenomena of systems composed of many particles and degrees of freedom
- will understand the differences between physics at thermodynamic equilibrium and out of equilibrium
- learn systems maintained out of equilibrium, including active matter systems that are state-of-the-art research
- obtain solid expertise in the theoretical techniques required to treat phenomena far from equilibrium, and are able to apply these methods to concrete problems,
- and will become competent to acquaint themselves with modern scientific questions.

Integrated acquirement of soft skills:

- autonomous working with scientific literature in English,
- improving written and spoken English during lectures and exercises,
- interdisciplinary thinking, and working

Workload:

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

Conditions:

It is assumed that the students are familiar with the contents of a four-semester course in theoretical physics, including Thermodynamics and Statistical Physics.

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

Parts of the Module

Part of the Module: Nonequilibrium Statistical Physics (lecture)
Mode of Instruction: lecture
Language: English
Contact Hours: 4

Learning Outcome:
see module description

Contents:
see module description

Literature:

- **Non-Equilibrium Thermodynamics,** S. R. De Groot and P. Mazur, Dover Publications, Dover ed edition, ISBN 486647412
- **From Macrophysics to Microphysics Part 1 und 2**, Roger Balian, Springer, ISBN 3540454780
- **Principles of Condensed Matter Physics,** P. M. Chaikin and T. C. Lubensky, Cambridge, ISBN 521794501
- **A Kinetic View of Statistical Physics,** Pavel L. Krapivsky, Sidney Redner, and Eli Ben–Naim, Cambridge, ISBN 486647412
- **Basic concepts for Simple and Complex Liquids,** Jean-Louis Barrat and Jean-Pierre Hansen, Cambridge, ISBN 521789532
- **Physical Hydrodynamics,** Etienne Guyon, Jean-Pierre Hulin, Luc Petit, Catalin D. Mitescu, Oxford, ISBN 521851033

Assigned Courses:

Nonequilibrium Statistical Physics (lecture)
**

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

Learning Outcome:
see module description

Assigned Courses:

Nonequilibrium Statistical Physics (Tutorial) (exercise course)
**

Examination
PHM-0071 Nonequilibrium Statistical Physics
oral exam / length of examination: 45 minutes

Module PHM-0073: Relativistic Quantum Field Theory *Relativistische Quantenfeldtheorie*		8 ECTS/LP
Version 1.5.0 (since WS09/10) Person responsible for module: Prof. Dr. Gert-Ludwig Ingold		
Contents: • Reminder of the covariant formulation of special relativity and of classical field theory • Free Klein-Gordon field • Free Dirac field • Free electromagnetic field • Quantum electrodynamics • Electroweak interaction		
Learning Outcomes / Competences: • Students know basic aspects of elementary particle physics, in particular the relativistic field theoretical description of fermions and bosons, the description of interactions with quantum electrodynamics as an example and group theoretical aspects. • They can make connections between relativistic quantum field theory and the quantum field theoretical description of condensed matter. • They are able to apply their knowledge to the analysis of concrete problems. • Integrated acquirement of soft skills: Students learn in small groups to define given problems in a precise way, to develop solution strategies and to assess their suitability. In addition, the social competences required for working in a team are further developed.		
Workload: Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literarture (self-study) 90 h studying of course content through exercises / case studies (self-study)		
Conditions: Knowledge typically acquired in a 4 semester course on Theoretical Physics in a bachelor programme of physics.		**Credit Requirements:** The module examination needs to be passed.
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Relativistic Quantum Field Theory **Mode of Instruction:** lecture **Language:** German / English **Contact Hours:** 4
Learning Outcome: • Students know basic aspects of elementary particle physics, in particular the relativistic field theoretical description of fermions and bosons, the description of interactions with quantum electrodynamics as an example and group theoretical aspects. • They can make connections between relativistic quantum field theory and the quantum field theoretical description of condensed matter.

Contents:

see module description

Literature:

- F.Mandl, G. Shaw, *Quantum Field Theory* (Wiley, 2010)
- M. E. Peskin, D. V. Schroeder, *An Introduction to Quantum Field Theory* (CRC Press, 1995)
- M. Kaku, *Quantum field theory* (Oxford University Press, 1993)
- W. Greiner u. a., *Theoretische Physik, Bände 7, 7A, 8* (Europa-Lehrmittel, 1994)

Part of the Module: Exercises on Relativistic Quantum Field Theory

Mode of Instruction: exercise course

Language: German / English

Contact Hours: 2

Learning Outcome:

- Students are able to apply their knowledge to the analysis of concrete problems.
- Integrated acquirement of soft skills: Students learn in small groups to define given problems in a precise way, to develop solution strategies and to assess their suitability. In addition, the social competences required for working in a team are further developed.

Contents:

see module description

Literature:

see literature entry for lecture

Examination

Relativistic Quantum Field Theory

oral exam / length of examination: 30 minutes

Module PHM-0077: Theory of Magnetism *Theorie des Magnetismus*	8 ECTS/LP

Version 1.1.0 (since WS09/10)
Person responsible for module: Prof. Dr. Arno Kampf

Contents:

- Magnetism and electronic interactions
- Spin-exchange coupling
- Para- and diamagnetism
- Quantum Hall effect
- Ising model
- Heisenberg model
- Hubbard model
- Kondo problem

Learning Outcomes / Competences:

- The students recognize the basic mechanisms which lead to magnetism in solids,
- get to know the quantum mechanical models and strategies for their solution,
- identify the connection between magnetism and electronic correlations
- and are capable to solve problems in this context on their own.
- Acquiring key qualifications: independent studies with specialized literature in English, conception of complex contexts and their mathematical modelling, competence in theoretical methods

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

Conditions:
Basic knowledge of condensed matter theory is recommended.

Frequency: every 3rd semester starting WS 21/22	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Theorie des Magnetismus
Mode of Instruction: lecture
Language: German / English
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:
siehe Modulbeschreibung

Literature:

- P. Fazekas, Electron Correlation and Magnetism (World Scientific)
- W. Nolting, Quantentheorie des Magnetismus (Teubner)
- K. Yosida, Theory of Magnetism (Springer)

Part of the Module: Übung zu Theorie des Magnetismus

Mode of Instruction: exercise course

Language: German / English

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Examination

Theory of Magnetism

oral exam / length of examination: 30 minutes

Module PHM-0080: Theory of Superconductivity *Theorie der Supraleitung*	8 ECTS/LP

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

Contents:

- Historie, wichtige Experimente
- Bardeen-Cooper-Schrieffer-Theorie
- Elektrodynamik von Supraleitern
- Ginzburg-Landau-Theorie
- Josephson-Effekt
- Fluktuationen des Ordnungsparameters
- Gorkov-Gleichungen, Nambu-Formalismus
- Schmutzige Supraleiter

Learning Outcomes / Competences:

- Die Studierenden kennen die grundlegenden Eigenschaften und Phänomene supraleitender Materialien sowie die wichtigsten theoretischen Methoden und Konzepte zu ihrer Beschreibung, wie die BCS-Theorie und die Methode der Greenschen Funktionen,
- haben Fertigkeiten zur Formulierung und Bearbeitung von modernen Fragestellungen der Vielteilchenphysik, insbesondere im Rahmen der Mean-Field-Näherung, erworben,
- und besitzen die Kompetenz, aktuelle Problemstellungen aus der Theorie der Supraleitung weitgehend selbständig zu bearbeiten.
- Integrierter Erwerb von Schlüsselqualifikationen: eigenständiges Arbeiten mit englischsprachiger Fachliteratur, Erfassen komplexer Zusammenhänge und deren modellhafte Darstellung mit Hilfe mathematischer Strukturen, Methodenkompetenz

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

Conditions:
Es wird empfohlen, das Modul Theoretische Festkörperphysik zuerst zu absolvieren. Außerdem sind Kenntnisse aus der Vielteilchentheorie wünschenswert.

Frequency: irregular	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Theorie der Supraleitung
Mode of Instruction: lecture
Language: German / English
Frequency: every 3rd semester
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:

siehe Modulbeschreibung

Literature:

- N. W. Ashcroft, N. D. Mermin, Solid State Physics (Holt, Rinehart and Winston)
- M. Tinkham, Introduction to Superconductivity (McGraw-Hill)
- A. A. Abrikosov, Fundamentals of the Theory of Metals (Academic)
- E. M. Lifschitz, L. P. Pitaevskii, Statistical Physics Part 2 (Pergamon)
- P. G. de Gennes, Superconductivity in Metals and Alloys (Westview)
- R. D. Parks (editor), Superconductivity, Vol. 1 & 2 (Marcel Dekker)

Part of the Module: Übung zu Theorie der Supraleitung

Mode of Instruction: exercise course

Language: German / English

Frequency: every 3rd semester

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Examination

Theorie der Supraleitung

oral exam / length of examination: 30 minutes

Module PHM-0083: Computational Physics and Materials Science *Computational Physics and Materials Science*		8 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Liviu Chioncel		
Contents: • Basic Numerical Methods • Ordinary and Partial Differential Equations • Density Functional Theory and Molecular Dynamics • Advanced Methods for Many-Particle Systems • Monte Carlo Simulations		
Learning Outcomes / Competences: • The students know the numerical methods suitable for solving physical and material science problems, in particular methods for solving ordinary and partial differential equations as well as molecular dynamics and Monte Carlo simulations, are able to implement these methods in practice, and possess the competence to work on theoretical-numerical problems from various areas of physics and materials science under supervision. • Integrated acquisition of key qualifications: independent work with English-language technical literature, grasp of complex relationships and their model representation with the help of mathematical structures, methodological competence.		
Workload: 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 literarture (self-study) 90 h lecture and exercise course (attendance)		
Conditions: The module requires the contents of the bachelor module "Numerical Methods" (BaPhy-45-01) as well as elementary programming skills (for example Fortran, C/C++, Python, ...).		
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Computational Physics and Materials Science **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: siehe Modulbeschreibung

Contents:

- Basic Numerical Methods
  - Programing languages: Fortran, C++, Perl, Python, compilation and execution
  - Differentiation and integration, interpolations and approximations
  - Zeros and extremes of a single-variable function
  - Matrices in physics: Gauss elimination, LU decomposition, Cholesky factorization, recursive algorithm
- Ordinary and Partial Differential Equations
  - The Euler method, the second and fourth order Runge-Kutta method
  - Simple pendulum, double pendulum, Poincare plots, chaotic regime
  - Boundary value and eigen value problems: elastic waves in a vibrating rod, the shooting method
  - One dimensional Schrödinger equation, Numerov algorithm
- Density Functional Theory and Molecular Dynamics
  - Density Functional Theory for solids: the muffin-tin concept
  - Electronic structure calculations with APW, KKR and LMTO methods
  - Molecular dynamics simulations, the Verlet algorithm
  - Structure and dynamics of real materials, ab-initio molecular dynamics
- Advanced Methods for Many-Particle Systems
  - The second quantization and the Hartree-Fock method
  - Models and many body Hamiltonians and their numerical representation
  - Exact diagonalization, the power method, Lanczos method
  - Lehmannn representation, Green functions, dynamic correlations
- Monte Carlo Simulations
  - Random numbers, high dimensional integrals, Importance sampling, Diffusion limited aggregation.
  - Markov chains, Metropolis algorithm, Ising model, Wang-Landau algorithm, simulated annealing, traveling salesman problem
  - Quantum Monte Carlo methods, path integrals and path integral Monte Carlo, QMC on the lattice, Heisenberg model, world-line approach
  - Determinantal QMC, the Hirsch-Fye algorithm, continuous time QMC

Literature:

- Tao Pang, An Introduction to Computational Physics (Cambridge University Press)
- J. M. Thijssen, Computational Physics (Cambridge University Press)
- S. Koonin, D. Meredith, Computational Physics (Addison-Wesley)
- W. H. Press et al., Numerical Recipes (Cambridge University Press) [available on-line at http://www.nr.com/]
- D. C. Rapaport, The Art of Molecular Dynamics Simulation (Cambridge University Press)
- R. H. Landau, M. J. Paez, C. Bordeianu, Computational Physics (Wiley-VCH)

Part of the Module: Computational Physics and Materials Science (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Contents:

siehe Modulbeschreibung

Literature:

siehe zugehörige Vorlesung

Examination

Computational Physics and Materials Science

oral exam / length of examination: 30 minutes

Module PHM-0084: Condensed Matter Theory *Theorie der kondensierten Materie*	8 ECTS/LP

Version 1.1.0 (since SS10)
Person responsible for module: Prof. Dr. Markus Heyl

Contents:

- Landau Fermi liquid theory
- Transport theory: the Boltzmann equation
- Theory of magnetism
- Theory of superconductivity
- Further special topics will be covered such as: Quantum Hall effect, topolog insulators, disordered systems, phase transitions

Learning Outcomes / Competences:

- The students acquire understanding of the basic principles and methods for the quantum theoretical description of condensed matter systems.
- They have the skills to theoretically formulate physical problems in condensed matter physics and to investige their properties with suitable techniques.
- The students have the competence to independently work on physical problems related to the covered topics.
- Integrated acquisition of key qualifications: ability to work independently with literature in English professional language as well as to capture complex problems and their modeling with mathematical structures.

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

Conditions: This lecture builds on the content of the bachelor modules Theoretische Physik II + III, Physik IV as well we the master module Theoretische Festkörperphysik.		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: every 3rd semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Theorie der kondensierten Materie
Mode of Instruction: lecture
Language: German / English
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:
siehe Modulbeschreibung

Literature:

- N. W. Ashcroft and N. D. Mermin, Solid State Physics (Rinehart and Winston)
- P. M. Chaikin and T. C. Lubensky, Principles of Condensed Matter Physics (Cambridge University Press)
- G. Giuliani and G. Vignale, Quantum Theory of the Electron Liquid (Cambridge University Press)
- H. Bruus and K. Flensberg, Many-Body Quantum Theory in Condensed Matter Physics: An Introduction (Oxford Graduate Texts)
- G. D. Mahan, Many-Particle Physics (Springer)
- P. Phillips, Advanced Solid State Physics (Cambridge University Press)
- P. Fazekas, Lecture Notes on Electron Correlation and Magnetism (World Scientific)
- M. Z. Hasan and C. L. Kane, Colloquium: Topological insulators, Rev. Mod. Phys. **82**, 3046 (2010)
- P. G. de Gennes, Superconductivity of Metals and Alloys (Addison-Wesley)
- M. Tinkham, Introduction to Superconductivity (Dover)

Part of the Module: Übung zu Theorie der kondensierten Materie

Mode of Instruction: exercise course

Language: German / English

Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Examination

Theorie der kondensierten Materie

oral exam / length of examination: 30 minutes

Module PHM-0086: Dynamics of Nonlinear and Chaotic Systems *Dynamik nichtlinearer und chaotischer Systeme*		8 ECTS/LP
Version 1.0.0 (since WS12/13) Person responsible for module: Prof. Dr. Christoph Alexander Weber		
Contents: • Bifurcations • Strange attractors and fractal dimensions • Chaos in Hamiltonian Systems • Intermittence, Control of Chaos • Dynamic chaos in biological systems • Chaos in quantum chaos		
Learning Outcomes / Competences: • Students know the basic physical and mathematical properties of chaotic systems • Students understand the difference to linear systems and know the conditions when chaos emerges in non-linear systems • Students can ask research questions on non-linear systems • Students can develop simple non-linear models for biological or quantum systems • Students can read and understand scientific literature		
Workload: Total: 240 h 90 h lecture and exercise course (attendance) 30 h studying of course content using literarture (self-study) 30 h studying of course content using provided materials (self-study) 90 h studying of course content through exercises / case studies (self-study)		
Conditions: Theoretical Physics I (Mechanics / Non-linear Dynamics)		
Frequency: annually	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Dynamic of nonlinear and chaotic systems
Mode of Instruction: lecture
Language: English / German
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:
siehe Modulbeschreibung

Literature:
wird in der Vorlesung bekanntgegeben

Part of the Module: Tutorials: Dynamic of nonlinear and chaotic systems
Mode of Instruction: exercise course
Language: English
Contact Hours: 2

Learning Outcome:

siehe Modulbeschreibung

Contents:

see module description

Literature:

see module description

Examination

Dynamic of nonlinear and chaotic systems

oral exam / length of examination: 30 minutes

Module PHM-0087: Basics of Quantum Computing *Basics of Quantum Computing*		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Markus Heyl		
Contents: • Qubits and their realizations • Quantum gates and quantum circuits • DiVincenzo criteria • Quantum algorithms • Digital quantum simulation		
Learning Outcomes / Competences: • The students acquire basic understanding of the principles of quantum computers and their applications. • They have the skills to construct and simulate concrete quantum circuits and algorithms. • They have the competence to identify and translate suitable problems into quantum circuits as well as to follow the modern developments in quantum computing. • Integrated acquisition of key qualifications: Abstraction skills through the translation of physics problems onto quantum computing language, familiarization with English professional language		
Workload: Total: 240 h 90 h lecture and exercise course (attendance) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literarture (self-study)		
Conditions: Good knowledge of quantum mechanics		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Basics of Quantum Computing **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Learning Outcome: see module description
Contents: see module description
Literature: • D. DiVincenzo, Quantum Computation, Science **270**, 255-261 (1995) • M. Nielsen and I. Chuang, Quantum Computation and Quantum Information (Cambridge University Press, 2000) • J. Stolze and D. Suter, Quantum Computing (Wiley-VCH, 2004)

Part of the Module: Basics of Quantum Computing (Tutorial)
Mode of Instruction: exercise course
Language: English
Contact Hours: 2

Examination
Basics of Quantum Computing
oral exam / length of examination: 30 minutes

Module PHM-0088: Seminar Journal Club *Seminar Journal Club*		4 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Achim Wixforth		
Contents: Aktuelle Forschungsergebnisse und ‚Klassiker' der Physik sollen von den Studierenden zusammengefasst und in Form eines Vortrags vorgestellt werden. Dazu eine kurze Zusammenfassung der erarbeiteten Literatur als schriftliche Hausarbeit.		
Learning Outcomes / Competences: • Die Studierenden erarbeiten sich Kenntnisse in der Präsentation wissenschaftlicher Ergebnisse anhand der Vorstellung aktueller Veröffentlichungen, • haben Fertigkeiten, komplexe experimentelle Forschungsergebnisse aufzuarbeiten und in kurzer, prägnanter Form in einem Vortrag und einem ‚Term paper' darzustellen, und • besitzen die Kompetenz, übergreifende Problemstellungen im Bereich der experimentellen Festkörperphysik selbständig zu bearbeiten. • Integrierter Erwerb von Schlüsselkompetenzen: Erlernen des eigenständigen Arbeitens mit englischsprachiger Fachliteratur / Erlernen von Präsentationstechniken / kritische Reflexion experimenteller Ergebnisse im internationalen wissenschaftlichen Kontext / Präsentation eigener Ergebnisse auf wissenschaftlichen Konferenzen / Grundsätze guter wissenschaftlicher Praxis		
Workload: Total: 120 h 30 h seminar (attendance) 90 h preparation of presentations (self-study)		
Conditions: Solide Kenntnisse in den Grundlagen der Physik, insbesondere Festkörper- und Nanophysik		**Credit Requirements:** Seminarvortrag (ca. 30 - 45 min)
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Seminar Journal Club **Mode of Instruction:** seminar **Language:** German / English **Contact Hours:** 2
Learning Outcome: siehe Modulbeschreibung
Contents: siehe Modulbeschreibung
Literature: Die zu bearbeitende Literatur wird den Studierenden zur Verfügung gestellt.

Examination
Seminar Journal Club seminar / length of examination: 45 minutes, not graded

Module PHM-0096: Seminar on Glass Physics *Seminar on Glass Physics*		4 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: PD Dr. Peter Lunkenheimer		

Contents:

- Technical glasses
- Polymers
- Metallic glasses
- Relaxation phenomena
- Models of the glass transition
- Aging phenomena in glasses
- Non-structural glasses
- Ionic conductivity
- Electrons in glasses

Learning Outcomes / Competences:

- The students know the phenomenology of the glass state and the glass transition, the material properties of glasses, their technical applications and the most important models of glassy matter. They have acquired knowledge concerning the preparation of scientific presentations.
- They are able to independently acquaint themselves with a physical or material-science topic using various sources of information. They are capable of preparing a graphically attractive scientific talk using modern, computer-based presentation techniques. They are able to present a talk in a clear and informative way, adhering to a fixed time limit.
- The students have the competence to distinguish between important and less important contents when preparing a scientific talk and to edit and restructure the chosen contents in order to provide a didactically sound presentation.
- Integrated acquisition of key qualifications: Learning to work with English textbooks and scientific literature, acquisition of abstraction capabilities using the example of the physical definitions of glass, ability to comparatively assess competing models for the explanation of experimental results, learning of presentation techniques, getting practice in the technical language English.

Workload:

Total: 120 h

90 h preparation of presentations (self-study)

30 h seminar (attendance)

Conditions: Basic knowledge of condensed-matter physics		**Credit Requirements:** Pass of module exam (seminar talk with discussion, 60 min)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar on Glass Physics

Mode of Instruction: seminar

Language: English

Contact Hours: 2

Learning Outcome:

see module description

Contents:

see module description

Literature:

- H. Scholze, Glas: Natur, Struktur und Eigenschaften (Springer, Berlin, 1988).
- S.R. Elliott, Physics of Amorphous Materials (Longman, London, 1990).
- R. Zallen, The Physics of Amorphous Solids (Wiley-VCH, Weinheim, 1998).
- J. Zarzycki (ed.), Material Science and Technology, Vol. 9: Glasses and Amorphous Materials (VCH, Weinheim, 1991).
- J. Zarzycki, Glasses and the Vitreous State (Cambridge University Press, Cambridge, 1991).

Examination

Seminar on Glass Physics

seminar / length of examination: 60 minutes, not graded

Module PHM-0099: Seminar on Plasmas in Research and Industry *Seminar über Plasmen in Forschung und Industrie*		4 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: apl. Prof. Dr.-Ing. Ursel Fantz		
Contents: • Basics of low-temperature plasmas • Plasma diagnostics • Plasma processing • Industrial applications of plasmas		
Learning Outcomes / Competences: • The students have in-depth knowledge of the ways of thinking and methods in a special field of plasma physics. • They have the ability, after consultation with the respective supervisor, to familiarize thereselves with a limited subject area and to comprehend it. They are able to present the topic clearly for a student audience. • The students are competent in working independently on a given topic. They can present their results in a structured way and defend them in the discussion. • Integrated acquisition of key qualifications: learning how to present application-oriented topics scientifically, developing one's own point of view on complex issues, ability to engage in scientific discussion.		
Remarks: Student ideas for talk topics can be taken into consideration.		
Workload: Total: 120 h 30 h seminar (attendance) 90 h preparation of presentations (self-study)		
Conditions: Knowledge of the lecture on plasma physics is desirable but not mandatory.		**Credit Requirements:** Talk in Seminar
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Seminar on Plasmas in Research and Industry **Mode of Instruction:** seminar **Language:** German / English **Contact Hours:** 2
Learning Outcome: see description of the module
Contents: see description of the module

Literature:

- M. Kaufmann: Plasmaphysik und Fusionsforschung (Teubner, 2003)
- R. J. Goldston, P.H. Rutherford: Introduction to Plasma Physics (IOP Publishing, 1997)
- F. F. Chen: Introduction to Plasma Physics and Controlled Fusion (Plenum Press, 1990)
- M. A. Lieberman, A. J. Lichtenberg: Principles of Plasma Discharges and Materials Processing (Wiley, 2005)
- G. Janzen: Plasmatechnik (Hüthig, 1992)
- R. Hippler: Low Temperature Plasmas (Wiley-VCH, 2008)
- J. R. Roth: Industrial Plasma Engineering (IOP Publishing, 1995)
- A. Grill: Cold Plasma in Materials Fabrication (IEEE Press, 1994)

Examination

Seminar on Plasmas in Research and Industry

seminar / length of examination: 60 minutes, not graded

Module PHM-0106: Seminar on Thermoelectric Properties of Nano- and Heterostructures	4 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. Fabian Pauly

Contents:

- Thermodynamic description of thermoelectric effects, Onsager relations
- Boltzmann theory of thermoelectric effects
- Band-structure based calculations of transport coeffcients
- Electron-phonon and phonon-phonon scattering
- Spin caloritronics, spin-orbit interaction
- Charge, spin, and heat transport in nanostructures and quantum wires
- Charge, spin, and heat transport in heterostructures and layered systems
- Materials aspects, design of thermoelectric devices

Learning Outcomes / Competences:

- The students are familiar with the experimental and theoretical concepts in a modern research field, which has significant applications for converting waste heat to electrical energy.
- They acquire the skill to familiarize themselves independently with a current research topic, using modern methods of literature search. They are able to present the topic, using the appropriate media, clearly and convincingly.
- The students are competent in treating a given special topic in an autonomous way. They are able to present this topic in a structured way, to develop their own assessment, and to present and defend their opinion in the discussion with their fellow students.
- Integrated acquirement of key qualifications: The students will gain experience in working with books and articles in English, and improve their presentation techniques as well as their English speaking skills.

Remarks:
Once in a while and if time permits, the seminar will be supplemented by lectures from external experts.

Workload:
Total: 120 h
30 h seminar (attendance)
90 h preparation of presentations (self-study)

Conditions: Good knowledge of quantum mechanics, statistical physics, and solid state physics		**Credit Requirements:** presentation (60 min)
Frequency: annually	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar on Thermoelectric Properties of Nano- and Heterostructures
Mode of Instruction: seminar
Language: English
Contact Hours: 2

Learning Outcome:
see module description

Contents:

see module description

Literature:

- Herbert B. Callen, *Thermodynamics* (Wiley), esp. chapters 16 and 17
- Neil W. Ashcroft and N. David Mermin, *Solid State Physics* (Holt, Rinehart and Winston), esp. chapters 12, 13 and 16
- J. M. Ziman, *Principles of the Theory of Solids* (Cambridge University Press), esp. chapters 6 and 7
- J. M. Ziman, *Electrons and Phonons - The Theory of Transport Phenomena in Solids* (Oxford University Press), esp. chapters VII - XI
- Jaroslav Fabian, Alex Matos-Abiague, Christian Ertler, Peter Stano, and Igor Zutic, *Semiconductor Spintronics*, acta physica slovaca **57**, 565-907 (2007)
- Gerrit E. W. Bauer, Eiji Saitoh, and Bart J. van Wees, *Spin Caloritronics*, Nature Materials **11**, 391-399 (2012)
- L. D. Hicks and M. S. Dresselhaus, Thermoelectric Figure of Merit of a One-Dimensional Conductor, Phys. Rev. B **47**, 16631 (1993)
- Georg K. H. Madsen and David J. Singh, *BoltzTrap. A Code for Calculating Band-Structure Dependent Quantities*, Comp. Phys. Commun. **175**, 67-71 (2006)
- David J. Singh, *Oxide Thermoelectrics*, Mater. Res. Soc. Symp. Proc. 1044, 1044-U02-05 (2008)
- Mildred S. Dresselhaus, et al., *New Directions for Low-Dimensional Thermoelectric Materials*, Adv. Mater. **19**, 1043-1053 (2007)
- Karol I. Wysokinski, *Thermoelectric Transport in the Three Terminal Quantum Dot*, J. Phys. Condens. Matter **24**, 335303 (2012) (8 pp.)

Examination

Seminar on Thermoelectric Properties of Nano- and Heterostructures

seminar / length of examination: 60 minutes, not graded

Module PHM-0107: Practical Training *Fachpraktikum*		15 ECTS/LP
Version 1.0.1 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl bzw. Vorsitzender des Prüfungsausschusses		
Contents: entsprechend der gewählten Methodik		
Learning Outcomes / Competences: • Die Studierenden kennen ausgewählte Methoden, die in einer der Arbeitsgruppen des Instituts für Physik Anwendung finden, • besitzen die Fertigkeit, diese Methoden in laufende wissenschaftliche Untersuchungen einzubringen, sowie die Fähigkeit, eine wissenschaftliche Methode und ihre beispielhafte Anwendung angemessen schriftlich darzustellen, • und sind grundsätzlich kompetent, sich in moderne experimentelle oder theoretische Methoden einzuarbeiten. • Integrierter Erwerb von Schlüsselqualifikationen: Teamfähigkeit, Methodenkompetenz, Fähigkeit, ein Thema schriftlich darzustellen		
Remarks: Das Fachpraktikum wird im SoSe 2020 angeboten, sobald es die aktuelle Situation erlaubt. Es wird empfohlen, dieses Modul vor dem Modul Projektarbeit oder parallel dazu zu absolvieren. Die thematische Wahl des Moduls Fachpraktikum sollte im Hinblick auf das angestrebte Thema der Masterarbeit erfolgen.		
Workload: Total: 450 h 150 h preparation of written term papers (self-study) 300 h internship / practical course (attendance)		
Conditions: werden vom jeweiligen Betreuer/von der jeweiligen Betreuerin bekannt gegeben		**Credit Requirements:** mindestens mit "ausreichend" bewerteter Abschlussbericht
Frequency: each semester Siehe Bemerkungen	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 12	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Fachpraktikum **Mode of Instruction:** internship **Language:** German / English
Learning Outcome: siehe Modulbeschreibung
Lehr-/Lernmethoden: Erarbeitung spezieller wissenschaftlicher Methoden anhand konkreter Fragestellungen; in der Regel Mitarbeit in der jeweiligen Arbeitsgruppe
Literature: wird vom jeweiligen Betreuer/von der jeweiligen Betreuerin bekannt gegeben

Examination

Fachpraktikum

project work, schriftlicher Abschlussbericht, ca. 20 Seiten / work period for assignment: 4 weeks

Module PHM-0108: Project Work *Projektarbeit*		15 ECTS/LP
Version 1.0.1 (since WS09/10) Person responsible for module: apl. Prof. Dr. Helmut Karl bzw. Vorsitzender des Prüfungsausschusses		
Contents: entsprechend dem gewählten Thema		
Learning Outcomes / Competences: • Die Studierenden sind mit einem aktuellen Forschungsthema und der zugehörigen Literatur vertraut, • sind in der Lage, ein Forschungsthema kritisch zu reflektieren und mit angemessener Medienunterstützung überzeugend darzustellen, • besitzen die Kompetenz, ein kleineres Forschungsprojekt unter Anleitung mit wissenschaftlichen Methoden zu bearbeiten. • Integrierter Erwerb von Schlüsselqualifikationen: Teamfähigkeit, eigenständiges Arbeiten, Präsentationstechniken, Fähigkeit, ein Thema in der Diskussion zu vertreten		
Remarks: Die Projektarbeit wird im SoSe 2020 angeboten, sobald es die aktuelle Situation erlaubt. In diesem Modul bearbeitet der Student/die Studentin in der Regel einen kleineren, genau definierten Teilaspekt der laufenden wissenschaftlichen Forschungen einer Arbeitsgruppe. Es wird empfohlen, dieses Modul nach dem Modul Fachpraktikum oder parallel dazu zu absolvieren. Die thematische Wahl des Moduls Projektarbeit sollte im Hinblick auf das angestrebte Thema der Masterarbeit erfolgen.		
Workload: Total: 450 h 90 h studying of course content through exercises / case studies (self-study) 300 h lecture and exercise course (attendance) 30 h studying of course content using literarture (self-study) 30 h studying of course content using provided materials (self-study)		
Conditions: werden vom jeweiligen Betreuer/von der jeweiligen Betreuerin bekannt gegeben		**Credit Requirements:** mit "bestanden" bewertete mündliche Präsentation
Frequency: each semester Siehe Bemerkungen	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 12	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Projektarbeit **Mode of Instruction:** internship **Language:** German / English
Learning Outcome: siehe Modulbeschreibung
Literature: wird vom jeweiligen Betreuer/von der jeweiligen Betreuerin bekannt gegeben

Examination

Projektarbeit

project work, mündliche Präsentation mit Diskussion / length of examination: 90 minutes, not graded

Module PHM-0110: Materials Chemistry *Materials Chemistry*	6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Henning Höppe	

Contents:

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

Learning Outcomes / Competences:

The students will

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

Workload:

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

Conditions:

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

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

Parts of the Module

Part of the Module: Materials Chemistry

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

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

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

Part of the Module: Materials Chemistry (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

see associated lecture

Assigned Courses:

Materials Chemistry (Tutorial) (exercise course)

Examination

Materials Chemistry

written exam / length of examination: 90 minutes

Examination Prerequisites:

Materials Chemistry

Module PHM-0113: Advanced Solid State Materials *Advanced Solid State Materials*	6 ECTS/LP
Version 1.0.0 (since WS10/11) Person responsible for module: Prof. Dr. Henning Höppe	

Contents:

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

Learning Outcomes / Competences:

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

Workload:

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

Conditions:

Contents of the modules Chemie I, and Chemie II or Festkörperchemie (Bachelor Physik, Bachelor Materialwissenschaften)

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

Parts of the Module

Part of the Module: Advanced Solid State Materials

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

Learning Outcome:

see module description

Contents:

see module description

Literature:

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

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Contents:

see module description

Literature:

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

Examination

Advanced Solid State Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Advanced Solid State Materials

Module PHM-0114: Porous Functional Materials *Porous Functional Materials*		6 ECTS/LP
Version 1.0.0 (since SS11 to WS22/23) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: • Overview and historical developments • Structural families of porous frameworks • Synthesis strategies • Adsorption and diffusion • Thermal analysis methods • Catalytic properties • Advanced applications and current trends		
Learning Outcomes / Competences: • The students shall acquire knowledge about design principles and synthesis of porous functional materials, • broaden their capabilities to characterize porous solid state materials with special emphasis laid upon sorption and thermal analysis, • become introduced into typical technical applications of porous solids. • Integrated acquirement of soft skills		
Remarks: **This module and the exams for this module will be offered in WS 2022/23 for the last time !**		
Workload: Total: 180 h 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study)		
Conditions: participation in the course Materials Chemistry		**Credit Requirements:** one written examination, 90 min
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Porous Functional Materials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Contents: see module description
Literature: • Paul A. Wright, Microporous Framework Solids (RSC Materials Monographs, 2008) • selected reviews and journal articles cited on the slides
Assigned Courses: **Porous Functional Materials** (lecture)

Examination

Porous Functional Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Porous Functional Materials

Module PHM-0116: Advanced Materials Physics *Advanced Materials Physics*		6 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: • Magnetic materials • Superconductivity • Thermodynamics of materials • Thermal properties • Atomic transport		
Learning Outcomes / Competences: • The students know the physical and chemical fundamentals and the different resulting material properties, • are able to characterize Materials according to their magnetic, thermal, and transportation properties, and to do correspondent calculations using simple models, • have the competence to deal extensively autonomous with scientific problems of the • above mentioned areas. • Integrated acquirement of soft skills: Working with specialist literature, literature search and interdisciplinary thinking.		
Workload: Total: 180 h 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Basic knowledge of solid state physics		
Frequency: irregular (usu. summer semester)	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Contents:

- Magnetic materials
  - Magnetization
  - Atomic origin of magnetic moments
  - Paramagnetism
  - Ferromagnetism
  - Anisotropy
  - Ferromagnetic materials, hard and soft magnets
  - Magnetooptics
- Superconductivity
  - Basic phenomena
  - Meissner effect
  - Energy gap
  - London equation
  - Basic ideas of the BCS theory, Cooper pairs
  - Type I/II superconductors
  - High temperature superconducting materials, flux pinning
- Thermodynamics of materials
  - Review of basic terms
  - Equilibrium conditions
  - Phase diagrams
  - Multiphase-multicomponent equilibria
  - Thermodynamics of point defects
  - Thermodynamics of interfaces
- Thermal Properties
  - Specific Heat
  - Thermal Expansion
  - Thermal Transport
  - Thermal Radiation
  - Thermoelectricity
- Atomic transport
  - Diffusion
  - Electro-, thermo-, stress migration

Literature:

- Charles Kittel: Introduction to Solid State Physics (Wiley & Sons)
- Werner Buckel und Reinhold Kleiner: Supraleitung (Wiley-VCH)

Part of the Module: Advanced Materials Physics (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see module description

Examination

Materials Physics II

written exam / length of examination: 90 minutes

Examination Prerequisites:

Materials Physics II

Module PHM-0117: Surfaces and Interfaces *Surfaces and Interfaces*		6 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Manfred Albrecht		

Contents:

Introduction

- The importance of surfaces and interfaces

Some basic facts from solid state physics

- Crystal lattice and reciprocal lattice
- Electronic structure of solids
- Lattice dynamics

Physics at surfaces and interfaces

- Structure of ideal and real surfaces
- Relaxation and reconstruction
- Transport (diffusion, electronic) on interfaces
- Thermodynamics of interfaces
- Electronic structure of surfaces
- Chemical reactions on solid state surfaces (catalysis)
- Interface dominated materials (nano scale materials)

Methods to study chemical composition and electronic structure, application examples

- Scanning electron microscopy
- Scanning tunneling and scanning force microscopy
- Auger – electron – spectroscopy
- Photo electron spectroscopy

Learning Outcomes / Competences:

The students:

- have knowledge of the structure, the electronical properties, the thermodynamics, and the chemical reactions on surfaces and interfaces,
- acquire the skill to solve problems of fundamental research and applied sciences in the field of surface and interface physics,
- have the competence to solve certain problems autonomously based on the thought physical basics.
- Integrated acquirement of soft skills.

Workload:

Total: 180 h

20 h studying of course content using literarture (self-study)

20 h studying of course content using provided materials (self-study)

80 h studying of course content through exercises / case studies (self-study)

60 h lecture and exercise course (attendance)

Conditions: The module "Physics IV - Solid State Physics" of the Bachelor of Physics / Materials Science program should be completed first.		
Frequency: each winter semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Surfaces and Interfaces

Mode of Instruction: lecture

Language: English

Frequency: annually

Contact Hours: 3

Learning Outcome:

see module description

Contents:

see module description

Literature:

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

Assigned Courses:

Surfaces and Interfaces (lecture)

(online/digital)

Part of the Module: Surfaces and Interfaces (Tutorial)

Mode of Instruction: exercise course

Language: English

Frequency: annually

Contact Hours: 1

Assigned Courses:

Surfaces and Interfaces (Tutorial) (exercise course)

(online/digital)

Examination

Surfaces and Interfaces

written exam / length of examination: 90 minutes

Examination Prerequisites:

Surfaces and Interfaces

Module PHM-0118: Physics of Surfaces and Interfaces *Physics of Surfaces and Interfaces*		5 ECTS/LP
Version 1.0.0 (since WS09/10) Person responsible for module: Prof. Dr. Siegfried Horn Dozenten: Dr. Aladin Ullrich, Dr. Judith Moosburger-Will		

Contents:

Introduction

- The importance of surfaces and interfaces

Some basic facts from solid state physics

- Crystal lattice and reciprocal lattice
- Electronic structure of solids
- Lattice dynamics

Physics at surfaces and interfaces

- Structure of ideal and real surfaces
- Relaxation and reconstruction
- Transport (diffusion, electronic) on interfaces
- Thermodynamics of interfaces
- Electronic structure of surfaces
- Chemical reactions on solid state surfaces (catalysis)
- Interface dominated materials (nano scale materials)

Methods to study chemical composition and electronic structure, application examples

- Scanning electron microscopy
- Scanning tunneling and scanning force microscopy
- Auger – electron – spectroscopy
- Photo electron spectroscopy

Learning Outcomes / Competences:

The students:

- have knowledge of the structure, the electronical properties, the thermodynamics, and the chemical reactions on surfaces and interfaces,
- acquire the skill to solve problems of fundamental research and applied sciences in the field of surface and interface physics,
- have the competence to solve certain problems autonomously based on the thought physical basics.
- Integrated acquirement of soft skills.

Workload:

Total: 150 h

Conditions: The module "Physics IV - Solid State Physics" of the Bachelor of Physics / Materials Science program should be completed first.		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

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

Learning Outcome:
see module description

Literature:

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

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

Examination

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

Examination Prerequisites:
Physics of Surfaces and Interfaces

Module PHM-0121: Processing of Materials *Processing of Materials*		5 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Ferdinand Haider		
Contents: • Processing of polymers • Processing of thin films • Processing of semiconductors • Processing of composites • Processing of metals and alloys		
Learning Outcomes / Competences: • Die Studierenden kennen die wichtigsten Methoden der Materialbe- und -verarbeitung für die unterschiedlichen Klassen von Materialien – Halbleiter, Dünnschichtmaterialien, Polymere, Metalle, Verbundmaterialien, • beherrschen neben industriellen Verfahren auch Methoden, die bislang eher im Labormassstab realisisert sind, • und besitzen die Kompetenz, aktuelle Problemstellungen aus dem obengenannten Themenbereich selbständig zu bearbeiten. • Integrierter Erwerb von Schlüsselqualifikationen		
Workload: Total: 150 h 60 h lecture and exercise course (attendance) 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study) 50 h studying of course content through exercises / case studies (self-study)		
Conditions: none		
Frequency: annually	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 3	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Processing of Materials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 3
Learning Outcome: siehe Modulbeschreibung
Contents: siehe Modulbeschreibung
Literature: • M. Ohring, Materials science of thin films (Academic Press) • H. E. H. Meijer (ed.), Processing of polymers (Wiley-VCH) • K. A. Jackson, Processing of semiconductors (VCH) • M. Stuke, Materials surface processing (Elsevier) • R. W. Cahn, Processing of metals and alloys (VCH)

Examination

Processing of Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Processing of Materials

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

Contents:

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

Learning Outcomes / Competences:

The students

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

Workload:

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

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

Parts of the Module

Part of the Module: Non-Destructive Testing

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

Learning Outcome:

see module description

Contents:

see module description

Literature:

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

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

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

Module PHM-0144: Materials Physics *Materials Physics*	6 ECTS/LP

Version 1.1.0 (since WS15/16)
Person responsible for module: apl. Prof. Dr. Helmut Karl

Contents:

- Electrons in solids
- Phonons
- Properties of metals, semiconductors and insulators
- Application in optical, electronic, and optoelectronic devices
- Dielectric solids, optical properties

Learning Outcomes / Competences:

- The students know the basic terms and concepts of solid state physics like the free electron gas, electronic band structure, charge carrier statistics, phonons, doping and optical properties,
- are capable to apply derived approximations as the effective mass or the electron-hole concept to describe basic characteristics of semiconductor materials,
- have the competence to apply these concepts for the description of electric, electro-optic and thermal properties of solids and to describe their functionalities,
- understand size effects on material physical properties.
- Integrated acquirement of soft skills: Working with specialist literature, literature search and interdisciplinary thinking.

Remarks:
compulsory module

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

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

Parts of the Module

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

Learning Outcome:
see module description

Contents:

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

Literature:

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

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

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

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

Literature:

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

Assigned Courses:

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

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

Mode of Instruction: laboratory course

Language: English

Contact Hours: 2

Assigned Courses:

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

Examination

Method Course: Electronics for Physicists and Materials Scientists

written exam / length of examination: 90 minutes

Module PHM-0147: Method Course: Electron Microscopy *Method Course: Electron Microscopy*	8 ECTS/LP

Version 1.3.0 (since SoSe15)
Person responsible for module: Prof. Dr. Ferdinand Haider

Contents:

Scanning electron microscopy (SEM)

- Electron optical components
- Detectors
- EDX, EBSD

Transmission electron microscopy (TEM)

- Diffraction
- Contrast mechanisms
- High resolution EM
- Scanning TEM
- Analytical TEM
- Aberration correction

Learning Outcomes / Competences:

The students:

- get introduced to the basics of scanning electron microscopy and transmission electron microscopy, using lectures to teach the theoretical basics, which are afterwards deepened using practical courses,
- are able to operate SEM and TEM on a basic level
- are able to characterize materials using different electron microscopy techniques
- Aquire the competence to decide about a technique feasible for a certain problem.
- aquire the competence to assess EM images, also regarding artefacts
- learn to search for scientific literature and to formulate a scientific report

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

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

Conditions: Recommended: knowledge of solid-state physics, reciprocal lattice		**Credit Requirements:** regular participation, oral presentation (10 min), written report (one report per group)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

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

Contents:

SEM:

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

TEM:

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

Literature:

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

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

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Examination

Method Course: Electron Microscopy

report

Examination Prerequisites:

Method Course: Electron Microscopy

Module PHM-0149: Method Course: Methods in Biophysics *Method Course: Methods in Biophysics*		8 ECTS/LP
Version 2.0.0 (since SoSe22) Person responsible for module: Dr. Christoph Westerhausen		
Contents: Unit Membrane biophysics • Preparation of synthetic lipid membranes • Size, fluorescence and phase transition characterization of lipid membranes • Nanoparticle uptake synthetic membrane Unit microfluidic • Microfluidic systems • Fabrication of microfluidic systems • Calculation of microfluidic problems Unit live cell experiments • Cell culture • Cell couting and separation using microfluidics Unit analysis		
Learning Outcomes / Competences: The students: • know basic terms, concepts and phenomena in biophysics • acquire basic knowledge of fluidic and biophysical phenomena on small length scales and applications and technologies of microfluidic manipulation and analysis systems, • learn skills in tissue culture and immun-histochemical staining procedures, • learn skills in fluorescence microscopy, • learn skills to calculate fluidic problems on small length scales, • learn skills to handle microfluidic channel systems.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h		
Conditions: Attendance of the lecture "Biophysics and Biomaterials"		**Credit Requirements:** 1 written lab report
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Method Course: Methods in Biophysics **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 2

Part of the Module: Method Course: Methods in Biophysics (Practical Course)

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Literature:

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

Examination

Method Course: Methods in Biophysics

report

Examination Prerequisites:

Method Course: Methods in Biophysics

<table>
<tr><td colspan="2">Module PHM-0150: Method Course: Spectroscopy on Condensed Matter
Method Course: Spectroscopy on Condensed Matter</td><td>8 ECTS/LP</td></tr>
<tr><td colspan="3">Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. István Kézsmárki</td></tr>
<tr><td colspan="3">Contents:
Dielectric Spectroscopy [8]
Methods
Cryo-techniques
Measurement quantities
Relaxation processes
Dielectric phenomena
Ferroelectric Materials [7]
Mechanism of ferroelectric polarization
Hysteresis loop measurements
Dielectric spectroscopy
Glassy Matter [8]
Introduction
Glassy phenomena
Dielectric spectroscopy
Multiferroic Materials [7]
Introduction
Microscopic origins of multiferroicity
Pyrocurrent measurements
Dielectric spectroscopy</td></tr>
<tr><td colspan="3">Learning Outcomes / Competences:
The students:
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,
are trained in planning and performing complex experiments. They 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.</td></tr>
<tr><td colspan="3">Remarks:
ELECTIVE COMPULSORY MODULE</td></tr>
<tr><td colspan="3">Workload:
Total: 240 h</td></tr>
<tr><td colspan="2">Conditions:
Recommended: basic knowledge in solid state physics, basic knowledge in physics of glasses and supercooled liquids</td><td>Credit Requirements:
written report on the experiments (editing time 2 weeks)</td></tr>
<tr><td>Frequency: irregular (usu. winter semester)</td><td>Recommended Semester:
from 1.</td><td>Minimal Duration of the Module:
1 semester[s]</td></tr>
<tr><td>Contact Hours:
6</td><td>Repeat Exams Permitted:
according to the examination regulations of the study program</td><td></td></tr>
</table>

Parts of the Module

Part of the Module: Method Course: Spectroscopy on Condensed Matter
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Literature:

- N.W. Ashcroft, N.D. Mermin, Festkörperphysik (Oldenbourg)
- Ch. Kittel, Einführung in die Festkörperphysik (Oldenbourg)
- C.J.F. Böttcher, P. Bordewijk, Theory of Electric Polarization (Elsevier)
- J. R. Macdonald, Impedance Spectroscopy (Wiley)
- H. Scholze, Glas (Springer)
- S.R. Elliott, Physics of Amorphous Materials (Longman)
- R. Zallen, The Physics of Amorphous Solids (Wiley)

Assigned Courses:

Method Course: Spectroscopy on Condensed Matter (lecture)

Part of the Module: Method Course: Spectroscopy on Condensed Matter (Practical Course)
Mode of Instruction: laboratory course
Language: English
Contact Hours: 4

Assigned Courses:

Method Course: Spectroscopy on Condensed Matter (Practical Course) (internship)

Examination
Method Course: Spectroscopy on Condensed Matter
oral exam / length of examination: 45 minutes
Examination Prerequisites:
Method Course: Spectroscopy on Condensed Matter

Module PHM-0152: Method Course: Structure Determination in Solids *Method Course: Structure Determination in Solids*	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. Wolfgang Scherer

Contents:
Subject of the method course is the practical application of X-ray diffraction and solid state NMR techniques and their combined utilization to analyze structure property relationships in novel materials.

- Magic angle spinning (MAS) NMR
- Modern pulsed NMR techniques
- Utilization of chemical shift, dipolar and quadrupolar interaction to evaluate local structural motifs
- Analysis and interpretation of NMR data
- Data collection and reduction techniques for powder and single crystal X-ray diffraction experiments
- Symmetry and space group determination
- Structure determination (Patterson method, direct methods)
- Refinements of structural models (Rietveld method, difference fourier techniques)
- Combination of the complementary local and global structural information obtained from both experimental approaches

Learning Outcomes / Competences:
The students:

- acquire practical knowledge of operating a solid state NMR spectrometer,
- can - under guidance - plan, perform, and analyze modern solid state NMR experiments to analyze local strutural motifs in materials,
- gain basic practical knowledge on structural characterization methods for single crystalline and powder samples employing X-ray and neutron diffraction techniques,
- have the skill to - under guidance - perform phase analyses, structure determinations and refinements,
- can evaluate the opportunities and limits of solid state NMR and X-ray diffraction methods and know how to synergetically combine the two approaches to analyze the structure-property realationship of novel materials.

Remarks:
ELECTIVE COMPULSORY MODULE

Workload:
Total: 240 h

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

Parts of the Module

Part of the Module: Method Course: Structure Determination in Solids
Mode of Instruction: lecture
Language: English
Contact Hours: 2

Part of the Module: Method Course: Structure Determination in Solids (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.
5. C. Hammond, The Basics of Crystallography and Diffraction, Oxford University Press Inc., New York, 1994.
6. W. Clegg, A. J. Blake, R. O. Gould, P. Main, Crystal Structure Analysis, Principle and Practice, Oxford University Press Inc., New York, 2001.
7. G. Giacovazzo, Fundamentals of Crystallography, Oxford University Press Inc., New York, 1994.
8. R. A. Young, The Rietveld Method, Oxford University Press Inc., New York, 2002.
9. W. Massa, Crystal Structure Determination, Springer, Berlin, 2004.

Examination

Method Course: Structure Determination in Solids

written exam / length of examination: 90 minutes

Examination Prerequisites:

Method Course: Structure Determination in Solids

Module PHM-0153: Method Course: Magnetic and Superconducting Materials *Method Course: Magnetic and Superconducting Materials*		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Philipp Gegenwart		
Contents: Methods of growth and characterization: Sample preparation (bulk materials and thin films), e.g., • arcmelting • flux-growth • sputtering and evaporation Sample characterization, e.g., • X-ray diffraction • electron microscopy, scanning tunneling microscopy • magnetic susceptibility, electrical resistivity • specific heat		
Learning Outcomes / Competences: The students • get to know the basic methods of materials growth and characterization, such as poly- and single crystal growth, thin-film growth, X-ray diffraction, magnetic susceptibility, dc-conductivity, and specific heat measurements • are trained in planning and performing complex experiments • learn to evaluate and analyze the collected data, are taught to work on problems in experimental solid state physics, including analysis of measurement results and their interpretation in the framework of models and theories		
Workload: Total: 240 h 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 literarture (self-study)		
Conditions: Recommended: basic knowledge in solid state physics and quantum mechanics		**Credit Requirements:** presentation and written report on the experiments (editing time 3 weeks, max. 30 pages)
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Method Course: Magnetic and Superconducting Materials (lecture)

Part of the Module: Method Course: Magnetic and Superconducting Materials (Practical Course)

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Assigned Courses:

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

Examination

Method Course: Magnetic and Superconducting Materials

report

Examination Prerequisites:

Method Course: Magnetic and Superconducting Materials

Module PHM-0154: Method Course: Modern Solid State NMR Spectroscopy

8 ECTS/LP

Method Course: Modern Solid State NMR Spectroscopy

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

Contents:

Physical foundations of NMR spectroscopy

Internal interactions in NMR spectroscopy

- Chemical shift interaction
- Dipole interaction and
- Quadrupolar interaction

Magic Angle Spinning techniques

Modern applications of NMR in materials science

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

Learning Outcomes / Competences:

The students:

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

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

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

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

Parts of the Module

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

Literature:

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

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

Mode of Instruction: laboratory course

Language: English

Contact Hours: 4

Literature:

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

Examination

Method Course: Modern Solid State NMR Spectroscopy

report / work period for assignment: 2 weeks

Examination Prerequisites:

Method Course: Modern Solid State NMR Spectroscopy

Module PHM-0156: Method Course: Materials Synthesis *Method Course: Materials Synthesis*		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Wolfgang Scherer		

Contents:

Content of the practical course and the lecture are the theoretical basics, the synthesis and characterization of the following functional materials:

1. Organic polymers [4+2]
2. Zeolites and mesoporous materials [4+2]
3. Porous coordination polymers [4+2]
4. Ionic liquids [4+2]
5. Bio materials [4+2]
6. Oxides "sol-gel processing and ceramic methods" [4+2]
7. Lower dimensional structure materials [4+2]
8. Ferrofluides [2+1]

Learning Outcomes / Competences:

The students:

- gain basic practical knowledge about chemical materials synthesis and analytical methods (e.g. ICP / EA / REM-EDX), including the characterization via X-ray diffraction and spectroscopic techniques (e.g. IR / NMR) as well as physical methods (e.g. thermoelectric properties, magnetism),
- possess the ability to perform materials syntheses under instruction,
- are able to choose the appropriate characterization method for certain materials.

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

Total: 240 h

90 h studying of course content through exercises / case studies (self-study)

30 h studying of course content using literarture (self-study)

30 h studying of course content using provided materials (self-study)

90 h lecture and exercise course (attendance)

Conditions: recommended: the practical course is based on the modules Chemistry I,Chemistry II, Chemistry III and the practical course in physical chemistry		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Materials Synthesis

Mode of Instruction: lecture

Language: English

Contact Hours: 2

Literature:

- U. Schubert, N. Hüsing, Synthesis of Inorganic Materials (Wiley-VCH)
- D. W. Bruce, D. O'Hare, Inorganic Materials (John Wiley & Sons)
- J.-P. Jolivet, Metal Oxide Chemistry and Synthesis – From Solution to Solid State (John Wiley & Sons)
- W. Jones, C.N.R. Rao, Supramolecular Organization and Materials Design (Cambridge University Press)
- L.V. Interrante, M.J. Hampden Smith, Chemistry of Advanced Materials – An Overview (Wiley)
- A. R. West, Basic Solid State Chemistry (John Wiley & Sons)

Part of the Module: Method Course: Materials Synthesis (Practical Course)

Mode of Instruction: internship

Language: English

Contact Hours: 4

Examination

Method Course: Materials Synthesis

written exam / length of examination: 90 minutes

Examination Prerequisites:

Method Course: Materials Synthesis

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

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

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

Module PHM-0159: Laboratory Project *Laboratory Project*		10 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		
Contents: Experimental or theoretical work in a laboratory / research group in the Institute of Physics. Has to be conducted within 3 months.		
Learning Outcomes / Competences: The students: • know the basic terms, skills and concepts to pursuit a real research project in the existing laboratories within the research groups, • experience the day to day life in a research group from within, • prepare themselves to conduct a research project during their Masters thesis.		
Remarks: The Laboratory Project will be offered in SoSe 2020 as soon as the current situation allows. **COMPULSORY MODULE**		
Workload: Total: 300 h		
Conditions: Recommended: solid knowledge in (solid state) Physics, Chemistry and Materials Science, both experimentally and theoretically		**Credit Requirements:** 1 written report (editing time 2 weeks)
Frequency: each semester Siehe Bemerkungen	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 0 semester[s]
Contact Hours: 8	**Repeat Exams Permitted:** according to the examination regulations of the study program	

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

Examination
Laboratory Project project work **Examination Prerequisites:** Laboratory Project

Module PHM-0161: Coordination Materials

Coordination Materials

6 ECTS/LP

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

Contents:

A) Basics of coordination Chemistry

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

B) Selected classes of functional materials

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

Learning Outcomes / Competences:

The students

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

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

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

Conditions:

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

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

Parts of the Module

Part of the Module: Coordination Materials

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

Literature:

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

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

Module PHM-0163: Fiber Reinforced Composites: Processing and Materials Properties *Fiber Reinforced Composites: Processing and Materials Properties*	6 ECTS/LP

Version 1.2.0 (since SoSe15)
Person responsible for module: Dr. Judith Moosburger-Will

Contents:

- Production of fibers (e.g. glass, carbon, or ceramic fibers)
- Physical and chemical properties of fibers and their precursor materials
- Physical and chemical properties of commonly used polymeric and ceramic matrix materials
- Semi-finished products
- Composite production technologies
- Application of fiber reinforced materials

Learning Outcomes / Competences:

The students:

- know the physical and chemical properties of fibers, matrices, and fiber-reinforced materials.
- know the basics of production technologies of fibers, polymeric, ceramic matrices, and fiber-reinforced materials.
- know the application areas of composite materials.
- have the competence to explain material properties of fibers, matrices, and composites.
- have the competence to choose the right materials according to application relevant conditions.
- are able to independently acquire further knowledge of the scientific topic using various forms of information.

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

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

Conditions:

Recommended: basic knowledge in materials science, basic lectures in organic chemistry

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

Parts of the Module

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

Literature:

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

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

Assigned Courses:

Fiber Reinforced Composites: Processing and Materials Properties (lecture)

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Literature:

see lecture

Assigned Courses:

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

Examination

Fiber Reinforced Composites: Processing and Materials Properties

written exam / length of examination: 90 minutes

Examination Prerequisites:

Fiber Reinforced Composites: Processing and Materials Properties

Module PHM-0164: Characterization of Composite Materials *Characterization of Composite Materials*		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Markus Sause		
Contents: The following topics are presented: • Introduction to composite materials • Applications of composite materials • Mechanical testing • Thermophysical testing • Nondestructive testing		
Learning Outcomes / Competences: The students: • acquire knowledge in the field of materials testing and evaluation of composite materials. • are introduced to important concepts in measurement techniques, and material models applied to composites. • are able to independently acquire further information of the scientific topic using various forms of information.		
Workload: Total: 180 h 20 h studying of course content using literarture (self-study) 20 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance) 80 h studying of course content through exercises / case studies (self-study)		
Conditions: Recommended: basic knowledge in materials science, particularly in composite materials		
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Characterization of Composite Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

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

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

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

Module PHM-0166: Carbon-based functional Materials (Carboterials) *Carbon-based functional Materials (Carboterials)*		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer		

Contents:

1. Introduction to carbon allotropes and porous carbon materials [4]

2. Physical properties of fullerenes, carbon nanotubes and graphene [4]

3. Solid state NMR spectroscopy of carbon materials [4]

4. Metal carbides [4]

5. Carbon thin films and coatings [4]

6. Manufacturing and processing technology of carbon fibres [4]

7. Carbon-fibre reinforced polymer composites [4]

8. Carbon-fibre reinforced aluminium (Metal Matrix Composites, MMC) [4]

9. Energy storage in carbon materials [4]

10. Carbon-based materials for opto-electronics [4]

11. Quantum transport phenomena relating to carbon materials [4]

12. a) Manipulating heat flow with carbon-based electronic analogs: phononics in place of electronics [2]

12. b) Carbon-based spintronics [2]

13. Fabrication and processing of carbon-based nanostructures [4]

Learning Outcomes / Competences:

The students:

- know the basics of the chemistry and physics of carbon materials and their applications,
- acquire knowledge about the structural characterization, physical properties and engineering of functional materials and carbon based devices,
- learn to work with specialist literature in english.

Workload:

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

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

Parts of the Module

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

Literature:
will be announced by the lecturers

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

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

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

Contents:
Introduction

Review of thermodynamics

Chemical equilibria

Electrochemistry

Electrode kinetics

High temperature oxidation

Localized corrosion

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

Water and seawater corrosion

Corrosion monitoring

Corrosion properties of specific materials

Specific corrosion problems in certain branches

- Oil and Gas industry
- Automobile industry
- Food industry

Corrosion protection

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

Learning Outcomes / Competences:
The students:

- know the the fundamental basics, mechanics, types of corrosion processes and their electrochemical explanation
- obtain the skill to understand typical electrochemical quantification of corrosion processes.
- aquire the competence to assess corrosion phenomena from typical damage patterns

Remarks:
Scheduled every second summer semster.

Workload:
Total: 180 h
60 h lecture and exercise course (attendance)

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

Parts of the Module

Part of the Module: Oxidation and Corrosion
Mode of Instruction: lecture
Language: English
Frequency: each winter semester
Contact Hours: 3

Literature:

- Schütze: Corrosion and Environmental Degradation

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

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

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

Contents:

Introduction

Review of physical metallurgy

Steels:

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

Aluminium alloys:

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

Titanium alloys

Magnesium alloys

Superalloys

Intermetallics, high entropy alloys

Learning Outcomes / Competences:

Students

- learn about relevant classes of actual metallic alloys and their properties
- aquire the skill to derive alloy properties from physical metallurgy principles and concepts
- have the competence to choose and to explain appropriate metallic materials for special applications

Remarks:

Scheduled every second summer semster.

Workload:

Total: 180 h

60 h lecture and exercise course (attendance)

20 h studying of course content using provided materials (self-study)

20 h studying of course content using literarture (self-study)

80 h studying of course content through exercises / case studies (self-study)

Conditions: Recommended: Knowledge of physical metallurgy and physical chemistry		
Frequency: each summer semester alternating with PHM-0167	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Modern Metallic Materials **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 4
Literature: Cahn-Haasen-Kramer: Materials Science and Technology Original literature

Examination

Modern Metallic Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Modern Metallic Materials

Module PHM-0171: Method Course: Coordination Materials *Method Course: Coordination Materials*		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Dirk Volkmer Dr. Hana Bunzen		
Contents: 1. Synthesis of metal complexes: 2. Analytical characterization of metal complexes (thermal analysis, UV/vis spectroscopy, IR spectroscopy, X-ray diffraction) 3. Material composition and stability studies 4. Functional coordination materials (spin-crossover materials, oxygen-carrying materials)		
Learning Outcomes / Competences: The students will learn how to: • prepare transition metal complexes employing modern preparation techniques (e.g. microwave synthesis), inert synthesis conditions (Schlenk technique), • characterize coordination compounds by selected analytical techniques, • develop functional coordination materials based on organic / inorganic hybrid compounds, • employ X-ray diffraction methods for structural analysis.		
Remarks: **ELECTIVE COMPULSORY MODULE**		
Workload: Total: 240 h 20 h studying of course content using provided materials (self-study) 80 h studying of course content through exercises / case studies (self-study) 20 h studying of course content using literarture (self-study) 120 h lecture and exercise course (attendance)		
Conditions: none		**Credit Requirements:** written report (protocols)
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Method Course: Coordination Materials (Practical Course) **Mode of Instruction:** laboratory course **Language:** English **Contact Hours:** 4
Part of the Module: Method Course: Coordination Materials (Seminar) **Mode of Instruction:** seminar **Language:** English **Contact Hours:** 2
Literature: • Chemical databases • Primary literature

Examination

Method Course: Coordination Materials (Seminar)

seminar

Examination Prerequisites:

Method Course: Coordination Materials (Seminar)

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

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

Contents:

Synthesis and characterization of functional materials according to the topics:

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

Learning Outcomes / Competences:

The students will know how to:

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

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

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

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

Parts of the Module

Part of the Module: Method Course: Functional Silicate-analogous Materials (Practical Course)

Mode of Instruction: laboratory course
Language: English
Contact Hours: 6

Learning Outcome:

The students will know how to:

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

Contents:

Synthesis and characterization of functional materials according to the topics:

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

Examination

Method Course: Functional Silicate-analogous Materials

seminar

Examination Prerequisites:

Method Course: Functional Silicate-analogous Materials

Module PHM-0173: Method Course: Finite element modeling of multiphysics phenomena *Method Course: Finite element modeling of multiphysics phenomena*	8 ECTS/LP

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

Contents:

- Modeling and simulation of physical processes and phenomena
- Basic concepts of FEM programs
- Generation of meshes
- Optimization strategies
- Selection of solvers
- Examples from electrodynamics
- Examples from thermodynamics
- Examples from continuum mechanics
- Examples from fluid dynamics

Learning Outcomes / Competences:

- Students know established numerical procedures to model and simulate physical processes and systems
- Students acquire abilities to build numerical models based on real world challenges
- Students learn basic operational principles of FEM tools based on the program "COMSOL Multiphysics"

Remarks:
ELECTIVE COMPULSORY MODULE

This module is provided by external lecturers and lecturers from the mathematics and physics department. It is dedicated to materials scientists, physicists and engineers who intend to strengthen their background in numerical simulation using state-of-the-art FEM programs.

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

Conditions: Recommended: basic knowledge of numerical cocepts		**Credit Requirements:** 1 written report on selected topic, editing time 2 weeks
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Finite element modeling of multiphysics phenomena
Mode of Instruction: lecture
Language: English
Contact Hours: 3

Part of the Module: Method Course: Finite element modeling of multiphysics phenomena (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 3

Examination

Method Course: Finite element modeling of multiphysics phenomena

report

Examination Prerequisites:

Method Course: Finite element modeling of multiphysics phenomena

Module PHM-0174: Theoretical Concepts and Simulation

Theoretical Concepts and Simulation

6 ECTS/LP

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

Contents:

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

Learning Outcomes / Competences:

The students:

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

Remarks:

Links to software related to the course:

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

Workload:

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

Conditions: Recommended: basic knowledge of quantum mechanics, thermodynamics, and numerical methods as well as of a programming language		**Credit Requirements:** project work in small groups, including a written summary of the results (ca. 10-20 pages) as well as an oral presentation
Frequency: each summer semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Theoretical Concepts and Simulation

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

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

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Examination

Theoretical Concepts and Simulation

seminar / length of examination: 30 minutes

Examination Prerequisites:

Theoretical Concepts and Simulation

Module PHM-0180: Characterization of Materials *Characterization of Materials*		6 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: Prof. Dr. Markus Sause		
Contents: 1. X-ray diffraction [2] 2. Mechanical characterization [2] 3. Optical methods [2] 4. Electrical measurements and characterization [2] 5. NMR spectroscopy [2] 6. Spectroscopy using synchrotron radiation[2] 7. Thermal analysis [2] 8. Ion beam methods [2] 9. Charakterization of organic systems [2] 10. Electron microscopy [2]		
Learning Outcomes / Competences: Basic characterization methods will be introduced to the students in a lecture series with a workload of 4 hrs each. The students: • know the basic characterization methods of materials science, • acquire knowledge how to apply these methods, • acquire the competence to use these techniques for the analysis of structural, chemical, electronical, magnetical, and optical properties of materials.		
Remarks: **COMPULSORY MODULE** starting from summer term 2014 this compulsory lecture is replaced by "Characterization of Composite Materials"		
Workload: Total: 120 h 60 h studying of course content using provided materials (self-study) 60 h lecture and exercise course (attendance)		
Conditions: Recommended: basic knowledge in Materials Science		
Frequency: each winter semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: 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.

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 Materials

written exam / length of examination: 90 minutes

Examination Prerequisites:

Characterization of Materials

Module PHM-0182: Method Course: Thin Film Analysis with Ion Beams *Method Course: Thin Film Analysis with Ion Beams*		8 ECTS/LP
Version 1.0.0 (since SoSe15) Person responsible for module: apl. Prof. Dr. Helmut Karl		
Contents: 1. Introduction to ion beam analysis techniques and concepts 2. Rutherford backscattering spectroscopy 3. Theory of particle scattering and cross-section 4. Experimental setup 5. Dynamic secondary ion mass spectroscopy (SIMS) 6. Simulation and data evaluation of Rutherford backscattering spectrometry (RBS) experiments		
Learning Outcomes / Competences: The students: • know basic terms, skills and concepts to plan and perform analysis of thin films by ion beams, • prepare themselves for successful research during their Master thesis.		
Remarks: **ELECTIVE COMPULSORY MODULE** Experimental work in the laboratory in the Institute of Physics has to be conducted within 3 months.		
Workload: Total: 240 h 90 h lecture and exercise course (attendance) 90 h studying of course content through exercises / case studies (self-study) 30 h studying of course content using provided materials (self-study) 30 h studying of course content using literarture (self-study)		
Conditions: Recommended: solid knowledge in solid state and experimental physics		**Credit Requirements:** one written report
Frequency: annually	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Method Course: Thin Film Analysis with Ion Beams **Mode of Instruction:** lecture **Language:** English **Contact Hours:** 2
Literature: • Will be provided by supervisor.
Part of the Module: Method Course: Thin Film Analysis with Ion Beams (Practical Course) **Mode of Instruction:** internship **Language:** English **Contact Hours:** 4

Examination

Method Course: Thin Film Analysis with Ion Beams

seminar

Examination Prerequisites:

Method Course: Thin Film Analysis with Ion Beams

Module PHM-0187: Mathematics and Physics of Space-Time *Mathematik und Physik der Raum-Zeit*		8 ECTS/LP
Version 1.1.0 (since WS15/16) Person responsible for module: Prof. Dr. Gert-Ludwig Ingold Prof. Dr. Marc Nieper-Wißkirchen		

Contents:

Within this interdisciplinary module, the mathematical and physical foundations of general relativity are jointly taught by two lecturers from the institutes of mathematics and physics, respectively. The module thus provides a bridge from differential geometry all the way to the observation of gravitational effects on cosmic scales.

Among the topics to be discussed are:

- Coordinate systems
- Symmetries and covariance
- Equivalence principle
- Vector fields, differential forms and tensors
- Parallel shift
- Curvature and torsion
- Geodesics
- Consequences of curved geometry in the solar system
- Einstein field equation and energy-momentum tensor
- Einstein-Cartan geometry
- Schwarzschild solution and further exact solutions
- Gravitational waves

Learning Outcomes / Competences:

- Students know the mathematical foundations of general relativity and understand their physical consequences.
- They know the physical consequences of general relativity as well as important experimental tests of the theory.
- Students are able to independently solve typical problems of general relativity.

Integrated acquirement of soft skills:

- By working in small groups, students develop their ability to work in a team.
- They are able to argue target group oriented within an interdisciplinary context and to assess and understand arguments from another discipline.

Workload:

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

Conditions: Knowledge of theoretical physics and mathematics as they are typically acquired in a bachelor programme in physics or mathematics with physics minor.		**Credit Requirements:** The module examination needs to be passed.
Frequency: irregular (usu. winter semester)	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Geometry and Gravitation
Mode of Instruction: lecture
Language: German / English
Contact Hours: 4

Learning Outcome:

- Students know the mathematical foundations of general relativity and understand their physical consequences.
- They know the physical consequences of general relativity as well as important experimental tests of the theory.

Contents:
see module description

Literature:

- R. W. Sharpe, *Differential Geometry* (Springer-Verlag, 2000)
- R. P. Feynman, *Feynman Lectures on Gravitation* (Westview Press, 2002)
- J. Foster, J. D. Nightingale, *A short course in general relativity* (Springer-Verlag, 2010)
- S. M. Carroll, *Spacetime and Geometry: An Introduction to General Relativity* (Cummings, 2003)
- Ch. W. Misner, K. S. Thorne, J. A. Wheeler, *Gravitation* (Princeton University Press, 2017)

Assigned Courses:

Geometrie und Gravitation (lecture)
**

Part of the Module: Exercises on Geometry and Gravitation
Mode of Instruction: exercise course
Language: German / English
Contact Hours: 2

Learning Outcome:

- Students are able to independently solve typical problems of general relativity.

Integrated acquirement of soft skills:

- By working in small groups, students develop their ability to work in a team.
- They are able to argue target group oriented within an interdisciplinary context and to asess and understand arguments from another discipline.

Contents:
see module description

Literature:
see literature entry for lecture

Assigned Courses:

Übung zu Geometrie und Gravitation (exercise course)
(online/digital) *

Examination
Geometry and Gravitation
oral exam / length of examination: 30 minutes

Module PHM-0188: Seminar on Spectroscopy of Organic Semiconductors *Seminar on Spectroscopy of Organic Semiconductors*		4 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Wolfgang Brütting		
Contents: The seminar will cover selected examples from the physics of organic semiconductors and their applications in optoelectronic devices.		
Learning Outcomes / Competences: • The students know the basic concepts of organic semiconductors with respect to application in optoelectronic devices. • They acquire the skill to identify the essential points of a current research topic and present them to their fellow students. • The students are competent in treating a given problem in an autonomous way, using specialized literature. They are able to develop their own assessment, and to present and defend their opinion in the discussion with their fellow students. • Integrated acquirement of key qualifications: gaining experience in working with scientific literature in English, and improving presentation techniques as well as English speaking skills.		
Workload: Total: 120 h 90 h preparation of presentations (self-study) 30 h seminar (attendance)		
Conditions: Sound knowledge of molecular and solid state physics as well as the physics of semiconductors; recommended participation in the lecture on Organic Semiconductors		
Frequency: each semester	**Recommended Semester:** from 3.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Seminar on Spectroscopy of Organic Semiconductors
Mode of Instruction: seminar
Language: English / German
Contact Hours: 2

Learning Outcome:
see module description

Contents:
see module description

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

Assigned Courses:

Seminar on Spectroscopy of Organic Semiconductors (seminar)

Examination

Seminar on Spectroscopy of Organic Semiconductors

seminar / length of examination: 60 minutes, not graded

Module PHM-0197: Seminar on Selected Topics in Nanomagnetism *Seminar on Selected Topics in Nanomagnetism*		4 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Manfred Albrecht		
Contents: • Magnetic nanoparticles • Magnetic coupling phenomena • Magneto-transport phenomena • Magnetic sensors, permanent magnets • Experimental methods		
Learning Outcomes / Competences: • Knowledge of physical properties and applications of magnetic phenomena and material systems in selected fields • The students are competent in treating a given special topic in an autonomous way. They are able to present this topic in a structured way, to develop their own assessment, and to present and defend their opinion in the discussion with their fellow students. • Integrated acquirement of soft skills: practicing technical English, working with English specialist literature, ability to interpret experimental results		
Remarks: From time to time, the seminar will be supplemented by lectures from external experts.		
Workload: Total: 120 h 30 h seminar (attendance) 90 h preparation of presentations (self-study)		
Conditions: Basics in solid state physics and magnetism		**Credit Requirements:** presentation (60 minutes)
Frequency: each semester	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 2	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Seminar on Selected Topics in Nanomagnetism **Mode of Instruction:** seminar **Language:** English **Contact Hours:** 2
Learning Outcome: see module description
Contents: see module description

Literature:

- S. Blundell: Magnetism in Condensed Matter. Oxford Master Series in Condensed Matter Physics, Oxford, 2008
- R. C. O'Handley: Modern Magnetic Materials - Principles and Applications. Wiley-Interscience Publications, New York, 2000
- J. M. D. Coey: Magnetism and Magnetic Materials. Cambridge University Press, Cambridge, 2010
- J. Stöhr and H. C. Siegmann: Magnetism - From Fundamentals to Nanoscale Dynamics. Springer, Berlin, Heidelberg, 2006

Examination

Seminar on Selected Topics in Nanomagnetism

seminar / length of examination: 60 minutes, not graded

Module PHM-0199: Understanding Correlated Materials *Understanding Correlated Materials*		6 ECTS/LP
Version 1.0.0 (since SoSe16) Person responsible for module: Prof. Dr. Philipp Gegenwart Dr. Veronika Fritsch		
Contents: • Synthesis and characterization of correlated materials • Crystal structures and their symmetries, relation between crystallographic symmetry and physical properties • Electronic states of atoms and crystals, nature of electronic correlations • Magnetic phenomena and their origin • Low-temperature experiments on correlated materials		
Learning Outcomes / Competences: The students: • get to know the basic methods of materials growth and characterization • have acquired the theoretical knowledge to design low-temperature experiments and interpret their results • acquire the ability to treat fundamental and applied problems of correlated materials Integrated acquirement of soft skills. • Learn to work independently with literature in English language • Learn and apply presentation techniques • Learn the rules of good scientific practice		
Workload: Total: 180 h 15 h seminar (attendance) 30 h lecture (attendance) 15 h exercise course (attendance) 120 h studying of course content using provided materials (self-study)		
Conditions: basics of solid-state physics and quantum mechanics		**Credit Requirements:** oral presentation (60 min)
Frequency: every 3rd semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Understanding Correlated Materials **Mode of Instruction:** lecture **Lecturers:** Prof. Dr. Philipp Gegenwart **Language:** English **Contact Hours:** 2
Learning Outcome: see module description
Contents: see module description

Lehr-/Lernmethoden:

- Lecture
- Self study with distributed materials and literature

Literature:

- S. Blundell, Magnetism in Condensed Matter, Oxford, Oxford Univ. Press, 2003
- N. W. Ashcroft, N. D. Mermin: Festkörperphysik, Deutsch: München, Oldenbourg, 2013
- C. Kittel: Einführung in die Festkörperphysik, Deutsch: München, Oldenbourg, 2013
- J. B. Goodenough, Magnetism and the Chemical Bond, John Wiley & Sons, Inc. 1963
- W. Buckel, R. Kleiner, Superconductivity, WILEY-VCH Verlag GmbH & Co., Weinheim 2004

Part of the Module: Understanding Correlated Materials (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see module description

Contents:

see module description

Lehr-/Lernmethoden:

- Tutorial with exercises

Literature:

see module description

Part of the Module: Understanding Correlated Materials (Seminar)

Mode of Instruction: seminar

Language: English

Contact Hours: 1

Learning Outcome:

see module description

Contents:

see module description

Lehr-/Lernmethoden:

- Tutorial
- Self study with distributed materials and literature

Literature:

see module description

Examination

Understanding Correlated Materials

seminar / length of examination: 60 minutes

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

Version 1.3.0 (since SoSe22)
Person responsible for module: Dr. Christoph Westerhausen

Contents:

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

Learning Outcomes / Competences:

The students

- know basic physical properties of human cells, as building blocks of living organisms and their material properties.
- know the basic functionality of mechanical and optical methods to study living cells
- know physical descriptions of fundamental biological processes and properties of biomaterials.
- are able to express biophysical questions and define model systems to answer these questions.

The students improve the key competences:

- self-dependent working with English specialist literature.
- processing of experimental data.
- interdisciplinary thinking and working.

Workload:

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

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

Parts of the Module

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

Learning Outcome:

see module description

Contents:

see module description

Literature:

- Sackmann, Erich, and Rudolf Merkel. *Lehrbuch der Biophysik*. Wiley-VCH, 2010.
- Heimburg, Thomas. *Thermal Biophysics of Membranes*. Wiley-VCH, 2007
- Nelson, Philip. *Biological physics*. New York: WH Freeman, 2004.
- Boal, D. *Mechanics of the Cell*. Cambridge University Press, 2012
- Lecture notes

Assigned Courses:

Physics of Cells (lecture)

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

Assigned Courses:

Physics of Cells (Tutorial) (exercise course)

Examination

Physics of Cells

oral exam / length of examination: 30 minutes

Module PHM-0216: Method Course: Thermal Analysis *Method Course: Thermal Analysis*		8 ECTS/LP
Version 1.0.0 (since WS16/17) Person responsible for module: Prof. Dr. Ferdinand Haider Dr. Robert Horny		

Contents:

Methods of thermal analysis:

- Differential Scanning Calorimetry: DSC, DTA
- Thermo-gravimetric Analysis: TGA
- Dilatometry: DIL
- Dynamic-mechanical Analysis: DMA

-Rheology: RHEO

Advanced Methods:

- Modulated Differential Scanning Calorimetry: MDSC
- Evolved Gas Analysis: EGA (GCMS, FTIR)

Learning Outcomes / Competences:

The students:

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

Remarks:

Workload:

Total: 240 h

90 h lecture and exercise course (attendance)

90 h studying of course content through exercises / case studies (self-study)

30 h studying of course content using literarture (self-study)

30 h studying of course content using provided materials (self-study)

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

Parts of the Module

Part of the Module: Method Course: Thermal Analysis

Mode of Instruction: lecture

Lecturers: Prof. Dr. Ferdinand Haider

Language: English

Frequency: each winter semester

Contact Hours: 2

Literature:

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

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

Mode of Instruction: laboratory course

Language: English

Frequency: each winter semester

Contact Hours: 4

Examination

Method Course: Thermal Analysis

report

Module PHM-0217: Advanced X-ray and Neutron Diffraction Techniques *Advanced X-ray and Neutron Diffraction Techniques*	6 ECTS/LP

Version 1.0.0 (since SoSe17)
Person responsible for module: Prof. Dr. Wolfgang Scherer
PD Dr. Georg Eickerling

Contents:

Subjects of the lecture are advanced X-ray and neutron diffraction techniques:

- The failure of the standard *I*ndependent *A*tom *M*odel (IAM) in X-ray diffraction
- Beyond the standard model: The multipolar model
- How to obtain and analyze experimental charge densities
- How to derive chemical and physical properties from diffraction data
- Applications of joined X-ray and neutron diffraction experiments

Learning Outcomes / Competences:

The students:

- gain basic theoretical knowledge on the reconstruction of accurate electron density maps from X-ray and neutron diffraction data
- know the basics of the *Quantum Theory of Atoms in Molecules*
- are competent to analyze the topology of the electron density and correlate it with the physical and chemical properties of materials

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

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

Conditions:

It is recommended to complete the Module PHM-0053 Chemical Physics I.

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

Parts of the Module

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

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Literature:

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

Assigned Courses:

Advanced X-ray and Neutron Diffraction Techniques (lecture)

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

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

Examination

Advanced X-ray and Neutron Diffraction Techniques

written exam / length of examination: 90 minutes

Examination Prerequisites:

Advanced X-ray and Neutron Diffraction Techniques

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

Parts of the Module

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

Literature:

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

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

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

Module PHM-0223: Method Course: Tools for Scientific Computing

8 ECTS/LP

Method Course: Tools for Scientific Computing

Version 1.5.0 (since SoSe18)
Person responsible for module: Prof. Dr. Gert-Ludwig Ingold

Contents:

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:

- numerical libraries like NumPy and SciPy
- visualisation of numerical results
- use of a version control system like git and its application in collaborative work
- testing of code
- profiling
- documentation of programs

Learning Outcomes / Competences:

- 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.
- The students know examples of numerical libraries and are able to apply them to solve scientific problems.
- The students know methods for quality assurance like the use of unit tests and can apply them to their code. They know techniques to identify run-time problems.
- The students know a distributed version control system and are able to use it in a practical problem.
- 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.
- The students understand the relevance of the tools taught in the method course for good scientific practice.

Remarks:

The number of students will be limited to 12.

Workload:

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)

Conditions:

Knowledge of the programming language Python is expected on the level taught in the module PHM-0243 "Einführung in Prinzipien der Programmierung".

Credit Requirements:

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

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

Parts of the Module

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

Learning Outcome:

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

Contents:

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

Literature:

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

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

Learning Outcome:

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

Contents:

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

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.

Module PHM-0224: Method Course: Theoretical Concepts and Simulation *Method Course: Theoretical Concepts and Simulation*		8 ECTS/LP
Version 1.0.0 (since WS15/16) Person responsible for module: Prof. Dr. Liviu Chioncel		

Contents:

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

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

Learning Outcomes / Competences:

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

Remarks:

The number of students will be limited to 8.

Workload:

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

Conditions: Knowledge of the programming language Phython is expected on the level taught in the modul PHM-0041. Requirements to understand basic concepts in physics: Classical Mechanics (Newton, Lagrange), Electrodynamics, Thermodynamics and Quantum Mechanics.		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: each summer semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method Course: Theoretical Concepts and Simulation

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

Contents:

Concepts of classical and quantum statistical physics:

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

Literature:

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

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.

Module PHM-0225: Analog Electronics for Physicists and Materials Scientists *Analog Electronics for Physicists and Materials Scientists*		6 ECTS/LP
Version 1.2.0 (since WS15/16) Person responsible for module: Andreas Hörner		
Contents: 1. Basics in electronic and electrical engineering 2. Quadrupole theory 3. Electronic Networks 4. Semiconductor Devices 5. Implementation of transistors 6. Operational amplifiers 7. Optoelectronic Devices 8. Measurement Devices		
Learning Outcomes / Competences: The students: • know the basic terms, concepts and phenomena of electronic and electrical engineering for the use in the Lab, • have skills in easy circuit design, measuring and control technology, analog electronics, • have expertise in independent working on circuit problems. They can calculate and develop easy circuits.		
Workload: Total: 180 h 20 h studying of course content using provided materials (self-study) 20 h studying of course content using literarture (self-study) 80 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance)		
Conditions: none		
Frequency: each winter semester	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Analog Electronics for Physicists and Materials Scientists **Mode of Instruction:** lecture + exercise **Lecturers:** Andreas Hörner **Language:** English **Contact Hours:** 4 **ECTS Credits:** 6.0
Assigned Courses: **Analog Electronics for Physicists and Materials Scientists** (lecture + exercise) *(online/digital) *

Examination

Analog Electronics Analog Electronics for Physicists and Materials Scientists

written exam / length of examination: 90 minutes

Examination Prerequisites:

Analog Electronics for Physicists and Materials Scientists

Module PHM-0226: Digital Electronics for Physicists and Materials Scientists

Digital Electronics for Physicists and Materials Scientists

6 ECTS/LP

Version 1.3.0 (since WS15/16)
Person responsible for module: Andreas Hörner

Contents:

1. Boolean algebra and logic gates
2. Digital electronics and calculation of digital circuits
3. Converters (Analog – Digital, Digital – Analog)
4. Principle of digital memory and communication,
5. Microprocessors and Networks

Learning Outcomes / Competences:

The students:

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

Workload:

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

Conditions:
none

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

Parts of the Module

Part of the Module: Digital Electronics for Physicists and Materials Scientists

Mode of Instruction: lecture + exercise
Lecturers: Andreas Hörner
Language: English
Contact Hours: 4
ECTS Credits: 6.0

Examination

Digital Electronics Digital Electronics for Physicists and Materials Scientists

written exam / length of examination: 90 minutes

Module PHM-0228: Symmetry concepts and their applications in solid state physics and materials science *Symmetry concepts and their applications in solid state physics and materials science*	6 ECTS/LP
Version 1.0.0 (since WS18/19) Person responsible for module: Prof. Dr. István Kézsmárki Deisenhofer, Joachim, Dr.	

Contents:

The topical outline of the course is as follows:

- Introduction and common examples
  - o Motivating examples
  - o Polar and axial vectors and tensors
  - o Spatial and temporal symmetries and charge conjugation
  - o Symmetries of measurable quantities and fields
  - o Symmetries of physical laws (classical and quantum)
  - o Conservation laws (linear and angular momentum, energy, etc.)
  - o Symmetry of measurement configurations (reciprocity, etc.)
- Neumann principle
  - o Linear response theory and Onsager relations
  - 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)
- Symmetry allowed energy terms
  - o On the level of classical free energy: Polar, nematic and magnetic order parameters (Landau expansion)
  - o On the level of Hamiltonians: Molecular vibrations, crystal field potential, magnetic interactions
- Symmetry of physical states
  - o Spatial inversion and parity eigenstates
  - o Discrete translations and the Bloch states
- Spontaneous symmetry breaking upon phase transitions (Landau theory)
- Outlook: Symmetry guides for skyrmion-host materials, multiferroic compounds and axion insulators

Learning Outcomes / Competences:

- The students know the simple use of symmetry concepts to understand phenomena and material properties without performing detailed calculations.
- The students know 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.
- The students acquire scientific skills to search for scientific literature and to evaluate scientific content.

Workload:

Total: 180 h

60 h (attendance)

60 h exam preparation (self-study)

60 h studying of course content (self-study)

Conditions: Background in basic quantum mechanics is required.		
Frequency: nach Bedarf WS und SoSe	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: 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

Module PHM-0249: Seminar on Magnetic skyrmions in crystals and thin films *Seminar on Magnetic skyrmions in crystals and thin films*	4 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Prof. Dr. István Kézsmárki

Contents:

1.) Magnetic interactions governing the formation of spin spirals and skyrmions

- Competition between symmetric and antisymmetric exchange interactions leading to magnetic modulations (mechanism #1)
- Frustration of exchange interactions giving rise to magnetic modulations (mechanism #2)
- Competition between easy-axis magnetic anisotropy and magnetic dipole-dipole interaction leading to magnetic modulations (mechanism #3)

2.)Different classes of magnetic magnetic spirals and skyrmions

- Spin helices versus spin cycloids; Bloch- and Néel-type skyrmions versus antiskyrmions; introduction of vorticity and helicity
- Stability of the different types of skyrmion lattices depending on the crystal symmetry of the host materials (for skyrmions stabilized via mechanism #1)
- Experimental observation of magnetic skyrmions
- Real-space imaging of magnetic spirals and skyrmions using scanning probe techniques, such as magnetic force microscopy and scanning tunneling microscopy
- Real-space imaging of magnetic spirals and skyrmions using Lorentz transmission electron microscopy
- Reciprocal-space imaging of magnetic spirals and skyrmions using small angle neutron and X-ray scattering
- Signatures of magnetic spiral and skyrmion lattice states in thermodynamic and transport properties
- Spectroscopic studies on the excitations of magnetic spiral and skyrmion lattice states

3.) Possible magnetic memory applications of skyrmions

- Race-track type memories
- Hard-drive style memories

4.) Manipulation of individual skyrmions and skyrmion lattices by external stimuli

Learning Outcomes / Competences:

The students

- understand basic physical concepts behind the formation and manipulation of modulated magnetic textures, such as spin spirals and magnetic skyrmions, on the nano- to mesoscopic scale.
- learn to know the experimental methods frequently used to image/detect magnetic skyrmions
- learn to assess a scientific problem and present the subject in a concise and understandable manner

Remarks:

The seminar will consist of two parts: i) tutorial part about the basic concepts (different magnetic interactions leading to skyrmion formation and different classes of skyrmions), ii) seminar talks of students based on research articles (review articles whenever possible) describing the experimental observation of skyrmions, their manipulation and their possible applications in magnetic memories.

Workload:

Total: 120 h
90 h preparation of presentations (self-study)
30 h seminar (attendance)

Conditions:

Grundkenntnisse der Quantenmechanik

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

Parts of the Module

Part of the Module: Seminar on Magnetic skyrmions in crystals and thin films
Mode of Instruction: seminar
Lecturers: Prof. Dr. István Kézsmárki
Language: English
Contact Hours: 2
ECTS Credits: 4.0

Examination
Seminar on Magnetic skyrmions in crystals and thin films
seminar / length of examination: 60 minutes

Module PHM-0251: Theory of magnetic skyrmions *Theorie magnetischer Skyrmionen*		8 ECTS/LP
Version 1.0.0 (since WS19/20) Person responsible for module: Priv. Doz. Dr. Wolfgang Häusler		
Contents: Topologische Invarianten Topologische Anregungen in Ferromagneten in einer, in zwei und in drei Raumdimensionen Dzyaloshinsky-Moriya Wechselwirkung Energiefunktional und Euler-Lagrange-Gleichung mit Skyrmionenlösung Landau-Lifshitz-Gilbert Dynamik Skyrmionen-Erzeugung und Skyrmionen-Vernichtung Stromgetriebene Skyrmionen Skyrmionen auf Supraleitern		
Learning Outcomes / Competences: Die Studierenden kennen die Bedeutung von Topologie in der Physik Sie besitzen gründliche theoretische Kompetenzen und können sie sicher anwenden Sie kennen solitäre Lösungen nichtlinearer Differentialgleichungen und verstehen das topologische Problem einer Skyrmionenzahländerung, auch unter effektiv gedämpfter Dynamik Integrierter Erwerb von Schlüsselqualifikationen		
Workload: Total: 240 h 6 h lecture and exercise course (attendance)		
Conditions: Klassische Mechanik, Klassische Elektrodynamik/Feldtheorie, Quantenmechanik Module Theoretical Physics IV (Classical Field Theory) (PHM-0020) - recommended		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: irregular (usu. winter semester) nach Bedarf: WS oder SoSe	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** four times	

Parts of the Module
Part of the Module: Theorie magnetischer Skyrmionen **Mode of Instruction:** lecture + exercise **Lecturers:** Priv. Doz. Dr. Wolfgang Häusler **Language:** German / English **Frequency:** jährlich nach Bedarf WS oder SoSe **Contact Hours:** 4 **ECTS Credits:** 8.0
Learning Outcome: Die Studierenden kennen die Bedeutung von Topologie in der Physik Sie besitzen gründliche theoretische Kompetenzen und können sie sicher anwenden Sie kennen solitäre Lösungen nichtlinearer Differentialgleichungen und verstehen das topologische Problem einer Skyrmionenzahländerung, auch unter effektiv gedämpfter Dynamik Integrierter Erwerb von Schlüsselqualifikationen

Contents:

Topologische Invarianten

Topologische Anregungen in Ferromagneten in einer, in zwei und in drei Raumdimensionen

Dzyaloshinsky-Moriya Wechselwirkung

Energiefunktional und Euler-Lagrange-Gleichung mit Skyrmionenlösung

Landau-Lifshitz-Gilbert Dynamik

Skyrmionen-Erzeugung und Skyrmionen-Vernichtung

Stromgetriebene Skyrmionen

Skyrmionen auf Supraleitern

Literature:

Jan Seidel (Editor) "Topological Structures in Ferroic Materials - Domain Walls, Vortices and Skyrmions", Springer Series in Materials Science (2016)

Shinichiro Seki and Masahito Mochizuki "Skyrmions in Magnetic Materials", SpringerBriefs in Physics (2016)

Albert Fert, Vincent Cros and João Sampaio "Skyrmions on the track", Nat. Nanotechnol. 8, 152 (2013)

Wang Kang, Yangqi Huang, Xichao Zhang, Yan Zhou, Weisheng Zhao "Skyrmion-Electronics: An Overview and Outlook", Proceedings of the IEEE 104, 2040 (2016)

A. Bogdanov and A. Hubert "Thermodynamically stable magnetic vortex states in magnetic crystals", Journal of Magnetism and Magnetic Materials 138, 255 (1994)

Examination

PHM-0251 Theorie magnetischer Skyrmionen

oral exam / length of examination: 30 minutes

Module PHM-0252: Optical Excitations in Materials *Optical Excitations in Materials*	6 ECTS/LP

Version 1.9.0 (since SoSe20)
Person responsible for module: Prof. Dr. Joachim Deisenhofer

Contents:

1. Classical Light-Matter Interation in Solids:

- Introduction: Typical Optical Response of Metals and Semiconductors
- Classical electromagnetic wave propagation in linear optical media (Maxwell Equations, refractive index, reflection, transmission, absorption)
- Anisotropic media, birefringence, longitudinal solutions
- Classical Drude-Lorentz oscillator model
- Spectroscopic techniques: Fourier-Transform-Spectroscopy, Time-domain Spectroscopy, Ellipsometry

2. Quantum Aspects of Light-Matter interaction

- qm approach to absorption and emission: Lorentzian lineshape, Fermi's Golden Rule
- Electric-dipole and magnetic-dipole approximation
- Rabi-oscillations and the need for quantum optical approaches
- A glimpse of non-linear optics

3. Exitations in different material classes

- Optical properties of semiconductors/insulators, molecular materials, metals
- Absorption and Luminescence, excitons, luminescence centers
- Optoelectronics, detectors, light emitting devices
- Quantum confined structures: tuning of absorption and emission

Learning Outcomes / Competences:

- The students gain basic knowledge of the fundamental concepts of light-matter interaction in solids.
- The students have detailed knowledge of classical models of light-propagation and absorption and get the competence to choose adequate spectroscopic techniques for measuring the optical properties of different material classes.
- The students have a basic understanding of quantum aspects of optical processes in different materials.
- The students are able apply these concepts to understand and analyse optical properties of different materials.
- The students acquire scientific skills to search for scientific literature and to evaluate scientific content.

Workload:

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

Conditions:

Basic knowledge of classical electrodynamics, atomic and solid state physics.

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

Parts of the Module

Part of the Module: Optical Excitations in Materials

Mode of Instruction: lecture

Language: English

Contact Hours: 4

ECTS Credits: 6.0

Literature:

1. Mark Fox, Optical Properties of Solids, Oxford Master Series
2. Mark Fox, Quantum Optics: An Introduction, Oxford Master Series
3. David B. Tanner, Optical Effects in Solids, Cambridge University Press
4. Y. Toyozawa, Optical Processes in Solids, Cambridge University Press

Assigned Courses:

Optical Excitations in Materials (lecture)

Examination

Optical Excitations in Materials

written exam / length of examination: 90 minutes

Module PHM-0253: Dielectric Materials *Dielectric Materials*	6 ECTS/LP

Version 1.2.0 (since SoSe20)
Person responsible for module: PD Dr. Peter Lunkenheimer

Contents:

- Experimental techniques: quantities, broadband dielectric spectroscopy, nonlinear and polarization measurements
- Dynamic processes in dielectric materials: relaxation processes, phenomenological models
- Dielectric properties of disordered matter: liquids, glasses, plastic crystals
- Charge transport: hopping conductivity, universal dielectric response
- Ionic conductivity: conductivity mechanism, dielectric properties, advanced electrolytes for energy-storage devices
- Maxwell-Wagner relaxations: equivalent-circuits, applications (supercapacitors), colossal-dielectric-constant materials
- Electroceramics: Materials, Properties (relaxor ferroelectric, ferroelectric, antiferroelectric and multiferroic), Applications

Learning Outcomes / Competences:
Students know the fundamentals of electromagnetic wave propagation and have a sound background for a broad spectrum of dielectric phenomena. They are able to analyze materials requirements and to interpret dielectric spectra in a broad frequency range. They have the competence to select materials for different kinds of applications and to critically assess experimental results on dielectric properties.

Remarks:
Elective compulsory module

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

Conditions:
Basic knowledge of solid state physics

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

Parts of the Module

Part of the Module: Dielectric Materials
Mode of Instruction: lecture
Lecturers: PD Dr. Stephan Krohns, PD Dr. Peter Lunkenheimer
Language: English / German

Literature:

- F. Kremer and A. Schönhals (eds.), Broadband Dielectric Spectroscopy (Springer, Berlin, 2002).
- F. Kremer and A. Loidl (eds.), The scaling of relaxation processes (Springer, Cham, 2018).
- A.K. Jonscher, Dielectric Relaxations in Solids (Chelsea Dielectrics Press, London, 1983).
- C.J.F. Böttcher and P. Bordewijk, Theory of electric polarisation Vol II (Elsevier, Amsterdam, 1973).
- S.R. Elliott, Physics of Amorphous Materials (Longman, London, 1990)
- A.J.Moulson, J.M. Herbert, Electroceramics: Materials, Properties, Applications (Wiley, 2003)
- R. Waser, U. Böttger, S. Tiedke, Polar Oxides: Properties, Characterization, and Imaging (Wiley, 2005)

Examination

Dielectric Materials Dielectric Materials

presentation / length of examination: 45 minutes

Examination Prerequisites:

Dielectric Materials

Module PHM-0258: Method course: Charge doping effects in semiconductors *Method course: Charge doping effects in semiconductors*	8 ECTS/LP

Version 1.0.0 (since SoSe21)
Person responsible for module: Prof. Dr. István Kézsmárki
Dr. Lilian Prodan, Dr. Somnath Ghara

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

The following techniques will be involved:

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

Learning Outcomes / Competences:

- The students gain basic knowledge how to tailor the bulk properties of narrow-gap semiconductors via different doping techniques.
- The students have detailed knowledge in performing XRD and magnetization experiments and know how to analyze the data.
- The students acquire the comptence to plan and perform Hall effect and magnetoresistance experiments and evaluate the obtained experimental results.
- The students have the skill to distinguish between an n-type and p-type semiconductor.
- The students know how to calculate the charge, mobility, and charge carrier density of a semiconductor using information obtained from the Hall effect experiments.

Remarks:
ELECTIVE COMPULSORY MODULES

Workload:
Total: 240 h

Conditions: Recommended: basic knowledge in solid state physics and semiconductors;		**Credit Requirements:** Written report on the experiments (editing time 2 weeks)
Frequency: each semester	**Recommended Semester:**	**Minimal Duration of the Module:** semester[s]
Contact Hours: 6	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

Part of the Module: Method course: Charge doping effects in semiconductors (Practical Course)
Mode of Instruction: internship
Language: English
Contact Hours: 4

Contents:

The following techniques will be involved:

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

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

Mode of Instruction: lecture

Language: English

Contact Hours: 2

Learning Outcome:

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

Examination

Method course: Charge doping effects in semiconductors

report

Module PHM-0264: Functional and Smart Macromolecular Materials	6 ECTS/LP
Version 1.2.0 (since WS21/22) Person responsible for module: PD Dr. Klaus Ruhland	

Contents:

Electro-active polymeric materials

- Intrinsically electric conducting polymers (ICPs)
- Working principles of ICPs in selected applications
- Red/Ox-responsive ICPs
- Electrochromism
- Electroactive Actuators
- Non-electric-conducting electrically functional polymers
- Ferroelectric polymers
- Piezoelectric polymers
- Dielectric elastomers

Thermo-active polymeric materials

- Difference between invertibility and reversibility
- Pyro-electric effect vs electro-caloric effect
- High-temperature-stabile polymers
- Thermochromic polymers

Mechano-active polymeric materials

- Shape-Memory-polymers
- Self-healing polymers

Photo-active polymeric materials

- Important chromophors and switching mechanisms
- Photo-responsive polymerization initiators and catalysts

Smart polymer gels

- Thermo-responsive polymer gels (LCST/UCST)
- Electrically charged polymer gels
- pH-responsive polymer gels

Learning Outcomes / Competences:

The Students get to know which functional properties can be implemented into macromolecular marterials by action of which external stimulus.

They reach the ability to differentiate between different mechanisms to introduce smart behaviour into polymeric materials and to decide about dependences between different external stimuli.

They will be competent to design smart functional multi-resonsive macromolecular materials that serve specific application needs time- and space-dependent.

Examples for applications of this type of material design will be discussed.

Workload:

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

Conditions:	Credit Requirements:
none	passing the final examination

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

Parts of the Module

Part of the Module: Functional and Smart Macromolecular Materials

Mode of Instruction: lecture

Language: German

Contact Hours: 4

Contents:

see description of the module

Lehr-/Lernmethoden:

see description of the module

Literature:

- Smart Polymers and their Applications; M. R. Aguilar, J. S. Roman (ISBN 978-0-85709-695-1)
- Functional Monomers and Polymers; K. Takemoto, R. M. Ottenbrite, M. Kamachi (ISBN 0-8247-9991-7)
- Biomedical Applications of Electroactive Polymer Actuators; F. Carpi, E. Smela (ISBN 978-0-470-77305-5)
- Electroactive Polymer Actuators as Artificial Muscles; Y. Bar-Cohen (ISBN0-8194-5297-1)
- Smart Polymers; I. Galaev, B. Mattiasson (ISBN 978-0-8493-9161-3)
- Semiconducting and Metallic Polymers; A. J. Heeger, N. S. Sariciftci, E. B. Namdas (ISBN 978-0-19-852864-7)
- Polymers and Light; W. Schnabel (ISBN978-3-527-31866-7)
- Shape Memory Polymers; J. Hu (ISBN 978-1-90903-050-3)
- Shape Memory Maerials; D. I. Arun, P. Chakravarthy, K. R. Arockia, B.
- Santhosh (ISBN 978-0-367-57169-6)
- Polymer Materials with Smart Properties; M. Bercea (ISBN 978-1-62808-876-2)
- Self-healing Materials; K. Ghosh (ISBN 978-3-527-31829-2)
- Self-Healing Polymers; W. H. Binder (ISBN 978-3-527-33439-1)
- High Performance Polymers; J. K. Fink (ISBN 978-0-8155-1580-7)
- Functional Coatings; S. K. Ghosh (ISBN 978-3-527-31296-2)
- Handbook of Stimuli-Responsive Materials; M. W. Urban (ISBN 978-3-527-32700-3)
- Renewable Resources for Functional Polymers and Biomaterials; P. A. Williams (ISBN 978-1-84973-245-1)
- Thermochromic and Thermotropic Materials; A. Seeboth, D. Lötzsch (ISBN 978-981-4411-02-8)
- Thermochromic Phenomena in Polymers; A. Seeboth, D. Lötzsch (ISBN 978-1-84735-112-8)
- Shape-Memory Polymers for Aerospace Applications; G. P. Tandon, A. J. W. McClung, J. W. Baur (ISBN 978-1-60595-118-8)
- Polymer Mechanochemistry; R. Boulatov (ISBN 978-3-319-22824-2

Assigned Courses:

Functional and Smart Macromolecular Materials (lecture)

Examination

Functional and Smart Macromolecular Materials

written exam / length of examination: 90 minutes

Module PHM-0265: Research challenges in cell biophysics *Research challenges in cell biophysics*		6 ECTS/LP
Version 1.0.0 (since WS21/22) Person responsible for module: Prof. Dr. Christoph Alexander Weber		
Contents: • Thermodynamics of phase separation • Random phase approximation • Kinetics of phase separation • Chemical reactions in crowded environments • Chemically active emulsions Students can pick one research topic per lecture and accept a research challenge for the second half of the lecture. Research challenges will cover various questions on the Origin of life, Phase Transitions and Chemical Reactions in Living Cells.		
Learning Outcomes / Competences: The students • have basic theoretical knowledge about the physics of livings systems such as the cell or non-equilibrium assemblies with life-like features • are capable of reading leading-edge research papers relevant to solve their research challenge and know how to bridge between textbook knowledge and research questions • know how to productively discuss their research approach and progress with the project supervisor and other students forming a research team • are able to communicate their results in a final seminar talk.		
Workload: Total: 180 h 100 h studying of course content through exercises / case studies (self-study) 60 h lecture and exercise course (attendance) 20 h exam preparation (self-study)		
Conditions: Knowledge of thermodynamics and statistical mechanics as taught on the bachelor level in the corresponding theory course.		**Credit Requirements:** Bestehen der Modulprüfung
Frequency: every 3rd semester	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Research challenges in cell biophysics **Mode of Instruction:** lecture **Language:** English / German **Contact Hours:** 3
Literature: • Samuel A. Safran, *Statistical Thermodynamics of Surfaces, Interfaces and Membranes* (CRC Press, 2003) • Christoph A. Weber, David Zwicker, Frank Jülicher und Chiu Fan Lee, *Physics of active emulsions*, Rep. Prog. Phys. **82**, 064601 (2019)

Part of the Module: Übung zu Research challenges in cell biophysics
Mode of Instruction: exercise course
Language: English / German
Contact Hours: 1

Examination

Research challenges in cell biophysics
oral exam / length of examination: 30 minutes

Module PHM-0267: Fundamentals of Materials for Energy *Fundamentals of Materials for Energy*		6 ECTS/LP
Version 1.0.0 (since SoSe22) Person responsible for module: Prof. Dr. Wolfgang Brütting		
Contents: This class teaches fundamentals of conventional as well as renewable energy conversion. The following topics will be addressed: • Basics facts on energy conversion and climate change • Fossil energy • Nuclear energy • Renewable energy • Energy storage and transport		
Learning Outcomes / Competences: Students know the fundamentals of different energy technologies. They are able to assess their respective efficiency and their potential for covering current and future energy demand. They are able to deal with a specific problem using up-to-date literature and participate in the ongoing discussion about how to cover our increasing need for various forms of energy.		
Conditions: Sound background in physics, in particular solid state physics and thermodynamics.		**Credit Requirements:** Passing the exam
Frequency: annually	**Recommended Semester:**	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module
Part of the Module: Fundamentals of Materials for Energy **Mode of Instruction:** lecture **Language:** English / German **Contact Hours:** 4 **ECTS Credits:** 6.0
Literature: • D.S. Ginley, D. Cahen: Fundamentals of Materials for Energy and Environmental Sustainability (Cambridge Univ. Press) • J. Fricke, W.L. Borst: Essentials of Energy Technology (Wiley-VCH) • D.J.C. MacKay: Sustainable Energy - without the hot air (https://www.withouthotair.com/)
Assigned Courses: **Fundamentals of Materials for Energy** (lecture)

Examination
Fundamentals of Materials for Energy written exam / length of examination: 90 minutes