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.

Index by Module Groups

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

Version 3 (since WS23/24)

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

Version 4 (since WS23/24)

Module MRM-0014: Interdisciplinary seminar to the bachelor thesis *Interdisziplinäres Seminar zur Bachelorarbeit*	6 ECTS/LP

Version 1.1.1 (since WS15/16)
Person responsible for module: Prof. Dr. Andreas Rathgeber
Alle prüfungsberechtigten Dozenten des Studiengangs WING

Learning Outcomes / Competences:
This interdisciplinary seminar, which accompanies the bachelor thesis, is intended to provide the students with further skills, especially at the interface to other research areas of the MRM Institute.

Remarks:
This module is also open to exchange students, e.g., Erasmus and WeltWeit Programmes. Exchange students will present their research progress corresponding to the bachelor thesis or internship to be awarded from their home University (no degree to be awarded from the University of Augsburg) and will need a supervisor or mentor at the University of Augsburg to be able to take this Module.

Workload:
Total: 180 h

Conditions: Complementary to Bachelor Thesis. Exchange students need an Augsburg supervisor for their research and will need to find her/him independently.		**Credit Requirements:** Seminar work, oral exam or combined written-oral exam
Frequency: each semester	**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: Interdisziplinäres Seminar zur Bachelorarbeit (Seminar)
Mode of Instruction: seminar
Language: German / English
Contact Hours: 3

Contents:
The students should present the progress and the results related to their work in one or more seminar lectures accompanying the development of the bachelor thesis and discuss it with other students, doctoral students, employees, lecturers, and professors.

Lehr-/Lernmethoden:
Various

Literature:
Will be given by the supervisor depending on the topic of the seminar or the corresponding bachelor thesis.

Assigned Courses:

Interdisziplinäres Seminar zu Bachelorarbeit (seminar)

Interdisziplinäres Seminar zur Bachelorarbeit (seminar)

Interdisziplinäres Seminar zur Bachelorarbeit (seminar)

Seminar "Hybride Werkstoffsysteme" (für Bachelor) (seminar)

Examination
Interdisziplinäres Seminar zur Bachelorarbeit
seminar, seminar work, oral exam or combined written-oral exam, graded

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:** Passing the module exam
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:
see contents

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, graded

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:

see learning outcomes

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:** written exam
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:

see contents

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, graded

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
Dr. Ing. Amelie Schischke

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:** Passing the module exam
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: Mathematik I
Mode of Instruction: lecture
Lecturers: Prof. Dr. Andreas Rathgeber
Language: German
Contact Hours: 3

Lehr-/Lernmethoden:
Blackboard lecture and beamer presentation.

Literature:
Announced in lecture.

Assigned Courses:

Mathematik I - Ingenieurmathematik (lecture + exercise)

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

Parts of the Module
Part of the Module: Übung Mathematik I **Mode of Instruction:** exercise course **Language:** German **Contact Hours:** 2
Assigned Courses: **Mathematik I - Ingenieurmathematik** (lecture + exercise)

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:** Passing the module exam
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
portfolio exam, written exam, graded

Parts of the Module

Part of the Module: Übung Mathematik II
Mode of Instruction: exercise course
Language: German
Contact Hours: 4

Contents:
Repetition and consolidation of the course content with the help of exercises. Exercise sheets are offered regularly.

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:** Passing the module exam
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:
Blackboard lecture, beamer presentation, demonstration of experiments

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, graded

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. Marco Hien

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
150 h studying of course content (self-study)
90 h lecture and 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
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)

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Examination

Linear Algebra I

written exam, Portfolio / length of examination: 120 minutes, graded

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
150 h studying of course content (self-study)
90 h lecture and exercise course (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
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: 20 minutes, graded

Module MTH-1020: Analysis I	8 ECTS/LP
Version 1.2.0 (since WS18/19) Person responsible for module: Prof. Dr. Bernd Schmidt	

Contents:
Reelle Zahlen, Folgen und Reihen, Stetigkeit, Differenzierbarkeit, (Beginn der) Integration

Learning Outcomes / Competences:
Fachlich:
- Erlernen und Erkennen von sich aus den Inhalten der Lehrveranstaltung ergebenden mathematischen Konzepten, Strukturen, Techniken, Verfahren und Theorien.
- Fähigkeit zur Anwendung dieser Erkenntnisse beim selbstständigen Lösen von Problemen.

Methodisch:
- Erweiterung der Problemlösungskompetenz durch neue mathematische Strategien.
- Verbesserung der Fähigkeiten im Erfassen mathematischer Texte.
- Schärfung der Präzision in der fachsprachlichen Ausdrucksweise.
- Exemplarisches Erlernen einer logisch stringenten und syntaktisch korrekten Darstellung mathematischer Inhalte.

Sozial-personal:
- Verbesserung der innermathematischen Kommunikationsfähigkeit.
- Schulung des logischen und präzisen Denkens.
- Stärkung der Kooperations- und Teamfähigkeit.
- Erhöhung der Frustrationstoleranz und Ausdauer.

Workload:
Total: 240 h
70 h lecture and exercise course (attendance)
70 h (self-study)
100 h (self-study)

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
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)

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Examination

Analysis I

module exam, Klausur / length of examination: 120 minutes, graded

Module MTH-1030: Analysis II *Analysis II*		10 ECTS/LP
Version 2.0.0 (since SoSe20) Person responsible for module: Prof. Dr. Bernd Schmidt		
Contents: (Fortführung der) Integration, Taylorreihen, topologische Begriffe (ggf. metrische und normierte Räume), mehrdimensionale Differentialrechnung		
Learning Outcomes / Competences: Fachlich: - Erlernen und Erkennen von sich aus den Inhalten der Lehrveranstaltung ergebenden mathematischen Konzepten, Strukturen, Techniken, Verfahren und Theorien. - Fähigkeit zur Anwendung dieser Erkenntnisse beim selbstständigen Lösen von Problemen. Methodisch: - Erweiterung der Problemlösungskompetenz durch neue mathematische Strategien. - Verbesserung der Fähigkeiten im Erfassen mathematischer Texte. - Schärfung der Präzision in der fachsprachlichen Ausdrucksweise. - Exemplarisches Erlernen einer logisch stringenten und syntaktisch korrekten Darstellung mathematischer Inhalte. Sozial-personal: - Verbesserung der innermathematischen Kommunikationsfähigkeit. - Schulung des logischen und präzisen Denkens. - Stärkung der Kooperations- und Teamfähigkeit. - Erhöhung der Frustrationstoleranz und Ausdauer.		
Workload: Total: 300 h 100 h (self-study) 130 h (self-study) 70 h lecture and exercise course (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 II (lecture)

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Examination

Analysis II

oral exam / length of examination: 20 minutes, graded

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: Fachlich: - Erlernen und Erkennen von sich aus den Inhalten der Lehrveranstaltung ergebenden mathematischen Konzepten, Strukturen, Techniken, Verfahren und Theorien. - Fähigkeit zur Anwendung dieser Erkenntnisse beim selbstständigen Lösen von Problemen. Methodisch: - Erweiterung der Problemlösungskompetenz durch neue mathematische Strategien. - Verbesserung der Fähigkeiten im Erfassen mathematischer Texte. - Schärfung der Präzision in der fachsprachlichen Ausdrucksweise. - Exemplarisches Erlernen einer logisch stringenten und syntaktisch korrekten Darstellung mathematischer Inhalte. Sozial-personal: - Verbesserung der innermathematischen Kommunikationsfähigkeit. - Schulung des logischen und präzisen Denkens. - Stärkung der Kooperations- und Teamfähigkeit. - Erhöhung der Frustrationstoleranz und Ausdauer.		
Workload: Total: 270 h 100 h (self-study) 100 h (self-study) 70 h lecture and exercise course (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
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)

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Examination

Analysis III

module exam, graded

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

work period for assignment: 15 keine Einheit gewählt, graded

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, graded

Module MTH-1080: Complex Analysis
Funktionentheorie

9 ECTS/LP

Version 1.0.0 (since WS15/16)
Person responsible for module: Dr. Peter Quast

Contents:

- Komplexe Zahlen
- Holomorphe Funktionen
- Cauchyscher Integralsatz und seine Folgerungen
- isolierte Singularitäten
- Residuensatz und Residenkalkül mit Anwendung auf reelle Integrale
- Riemannsche Zahlenkugel und ihre Automorphismen
- Automorphismen der Einheitskreisscheibe und konforme Abbildungen
- Riemannscher Abbildungssatz
- Kleiner Satz von Picard
- Elliptische Funktionen
- Einführung in Riemannsche Flächen

Learning Outcomes / Competences:

Fachlich:

- Erlernen und Erkennen neuer, sich aus den Inhalten der Lehrveranstaltung ergebender, mathematischer Konzepte, Strukturen, Techniken, Verfahren und Theorien.
- Fähigkeit zur Anwendung dieser Erkenntnisse beim selbstständigen Lösen von Problemen.

Methodisch:

- Erweiterung der Problemlösungskompetenz durch neue mathematische Strategien.
- Verbesserung der Fähigkeiten im Erfassen mathematischer Texte.
- Schärfung der Präzision in der fachsprachlichen Ausdrucksweise.
- Exemplarisches Erlernen einer logisch stringenten und syntaktisch korrekten Darstellung mathematischer Inhalte.

Sozial-personal:

- Verbesserung der innermathematischen Kommunikationsfähigkeit.
- Schulung des logischen und präzisen Denkens.
- Stärkung der Kooperations- und Teamfähigkeit.

Workload:
Total: 270 h
90 h (attendance)
180 h (self-study)

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
Contact Hours: 6
ECTS Credits: 9.0

Literature:

Jähnich, K.: Funktionentheorie.

Examination

Funktionentheorie

written exam, Klausur von 120 Minuten, graded

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, graded

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 180 h (self-study) 90 h (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

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, Klausur, Dauer 120 Minuten, graded

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, graded

Test Frequency:

when a course is offered

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, graded **Test Frequency:** when a course is offered

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 3.0.0 (since WS23/24) Person responsible for module: Prof. Dr. Stefan Großkinsky			
Contents: • Ereignissysteme, Sigma-Algebren, • Zufallsvariablen, Wahrscheinlichkeitsverteilungen, • Kenngrößen und Numerische Charakteristika von Zufallsvariablen, • Konvergenzarten von Zufallsgrößen, • Grenzwertsätze der Wahrscheinlichkeitsrechnung, • Beschreibende Statistik, • Parameterschätzungen, Konfidenzbereiche, • Hypothesentests, Tests in normalverteilten Grundgesamtheiten, • lineare Regression			
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. 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: 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.

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.

Contents:

- Ereignissysteme, Sigma-Algebren,
- Zufallsvariablen, Wahrscheinlichkeitsverteilungen,
- Kenngrößen und Numerische Charakteristika von Zufallsvariablen,
- Konvergenzarten von Zufallsgrößen,
- Grenzwertsätze der Wahrscheinlichkeitsrechnung,
- Beschreibende Statistik,
- Parameterschätzungen, Konfidenzbereiche,
- Hypothesentests, Tests in normalverteilten Grundgesamtheiten,
- lineare Regression

Literature:

Wird in der Vorlesung bekannt gegeben

Assigned Courses:

Einführung in die Stochastik (Stochastik I) (lecture)

**

Examination

Einführung in die Stochastik (Stochastik I)

written exam, graded

Module MTH-1160: Probability II *Statistik (Stochastik II)*		9 ECTS/LP
Version 2.0.0 (since SoSe17) Person responsible for module: Prof. Dr. Stefan Großkinsky		
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, graded

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)
**

Examination

Grundlagen der nichtlinearen und der kombinatorischen Optimierung (Optimierung II)
written exam / length of examination: 180 minutes, graded

Test Frequency:
when a course is offered

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.

Assigned Courses:

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

Übung 2 Grundlagen der nichtlinearen und kombinatorischen Optimierung / Optimierung II (exercise course)
**

Übung 3 Grundlagen der nichtlinearen und kombinatorischen Optimierung / Optimierung II (exercise course)
**

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, graded

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: Mathematical Seminar

Mode of Instruction: seminar

Language: German / English

Contact Hours: 2

ECTS Credits: 6.0

Contents:

-

Literature:

-

Assigned Courses:

Bachelor-Seminar zur Geometrie (seminar)

**

Randomized Linear Algebra (Seminar zur Numerik) (seminar)

**

Seminar Random Matrix Theory (Blockseminar Stochastik) (seminar)

**

Seminar zur Analysis (seminar)

**

Seminar zur Optimierung: Graphentheorievermutungen mit Optimierungsbezug (seminar)

**

Seminar zur Stochastik (Bachelor) (seminar)

**

Seminar zur Stochastik (Bachelor+Master) (seminar)

**

Examination

Mathematical Seminar

module exam, -, graded

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: -
Contents: -
Lehr-/Lernmethoden: -
Literature: -
Part of the Module: Lesekurs Evolutionsgleichungen **Language:** German / English **Contact Hours:** 2 **ECTS Credits:** 9.0
Learning Outcome: -

Contents: -
Lehr-/Lernmethoden: -
Literature: -

Examination

Abschlussprüfung

portfolio exam, graded

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, graded

Module PHM-0001: Physics I (Mechanics, Thermodynamics)

Physik I (Mechanik, Thermodynamik)

8 ECTS/LP

Version 2.1.0 (since SoSe22)
Person responsible for module: Andreas Hörner

Contents:

Mechanics:

1. Kinematics and Dynamics of the Mass Points
2. Conservation Quantities in Mechanics
3. Mass Point Systems
4. Mechanics of Rigid Bodies
5. Relativistic Mechanic
6. Mechanical Oscillations and Waves
7. Mechanics of Solid Bodies, Liquids, Gases

Thermodynamics

1. Temperature, Heat and the First Law of Thermodynamics
2. Kinetic Gas Theory
3. Entropy and the Second Law of Thermodynamics

Learning Outcomes / Competences:

Technical:

- The students know the basic terms, concepts and phenomena of classical mechanics, oscillations and waves in mechanical systems and thermodynamics (thermal theory and statistical interpretation).

Methodological:

- The students have skills in simple modeling and the formulation of mathematical and physical approaches and can apply these to tasks in the areas mentioned

Social/Personal:

- The students have skills in independently working on problems from the mentioned subject areas. They are able to assess the accuracy of observation and analysis.

Integrated Acquisition of Key Qualifications:

- Analytical-methodological competence, scientific thinking, weighing up solution approaches, training in logical thinking, ability to work in a team, learning to work independently with (English-language) specialist literature

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: Physics I (Mechanics, Thermodynamics)
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 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
Physics I (Mechanics, Thermodynamics)
written exam / length of examination: 150 minutes, graded
Test Frequency:
only in the winter semester

Parts of the Module

Part of the Module: Exercise for Physik I
Mode of Instruction: exercise course
Language: German
Contact Hours: 2

Assigned Courses:

Übung zu Physik I (exercise course)
**

Module PHM-0003: Physics II (Electrodynamics, Optics) *Physik II (Elektrodynamik, Optik)*	8 ECTS/LP

Version 1.2.0 (since WS09/10)
Person responsible for module: Andreas Hörner

Contents:

Elektrodynamics

1. Electrical Interactions
2. Megnetical Interations
3. Electrical Transport
4. Matter in Static Electric and Magnetic Fields
5. Time-Dependent Electro-Magnetical Fields

Optics

1. Harmonic Waves
2. Electromagnetic Waves
3. Classical Geometric Optics

Learning Outcomes / Competences:

Technical:

- Students know the basic terms, concepts and phenomena of electrostatics and magnetism; Furthermore, the basic concepts of electrodynamics and electromagnetic waves and - derived from this - optics.

Methodological:

- The students have skills in simple modeling and the formulation of mathematical and physical approaches and can apply these to tasks in the areas mentioned

Social/Personal:

- The students have skills in independently working on problems from the mentioned subject areas. They are able to assess the accuracy of observation and analysis.

Integrated Acquisition of Key Qualifications:

- Analytical-methodological competence, scientific thinking, weighing up solution approaches, training in logical thinking, ability to work in a team, learning to work independently with (English-language) specialist literature

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:
Content of the Module Physics 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: Physics II (Electrodynamics, Optics) **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 **Physics II (Elekcrodynamics, Optics** written exam / length of examination: 150 minutes, graded **Test Frequency:** only in the summer semester

Parts of the Module
Part of the Module: Exercise for Physics 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, graded

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, graded

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. Electrostatics
2. Magnetism
3. Electrodynamics, Maxwell's equations
4. Optics
5. Evaluation of measurements

Lehr-/Lernmethoden:

Blackboard lecture and beamer presentation

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, graded

Parts of the Module

Part of the Module: Übung zu Technische Physik II

Mode of Instruction: exercise course

Language: German

Contact Hours: 1

Contents:

Repetition and consolidation of the course content with the help of exercises. Exercise sheets are offered regularly.

Module MRM-0021: Commodity Risk Management *Commodity Risk Management*	6 ECTS/LP
Version 1.3.0 (since WS15/16) Person responsible for module: Prof. Dr. Andreas Rathgeber Dr.-Ing. Jerome Geyer-Klingeberg	

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:** Passing the module exam
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

Assigned Courses:

Commodity Risk Management (lecture + exercise)

Examination
Commodity Risk Management
written exam, written exam / length of examination: 60 minutes, graded

Parts of the Module

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

Assigned Courses:

Commodity Risk Management (lecture + exercise)

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:** Passing the module exam	
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, graded

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 2.1.0 (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:** Passing the module exam
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: Bioinspired Composites **Mode of Instruction:** lecture **Lecturers:** Prof. Dr.-Ing. Dietmar Koch **Language:** English / German **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, graded

Parts of the Module

Part of the Module: Übung Bioinspired Composites

Mode of Instruction: exercise course

Language: German

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:** Passing the module exam
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, graded

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

6 ECTS/LP

Complex 3D Structures and Components from 2D Materials

Version 2.0.0 (since WS23/24)
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:** Passing the module exam
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: 2

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

Assigned Courses:

Complex 3D Structures and Components from 2D Materials (lecture)

Examination

Complex 3D Structures and Components from 2D Materials

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

Parts of the Module

Part of the Module: Complex 3D Structures from 2D Materials (Group activity)

Mode of Instruction:
Language: English
Contact Hours: 2

Assigned Courses:

Complex 3D Structures and Components from 2D Materials (lecture)

Module MRM-0143: Materials Engineering *Materials Engineering*			6 ECTS/LP
Version 1.1.0 Person responsible for module: Prof. Dr.-Ing. Nils Meyer			

Contents:

- Introduction: basics of materials science, goals of materials science for engineering
- Chemical bondings, amorphous and crystalline structures
- Material classes and their principle properties
- Metals
- Polymers
- Ceramics and glasses
- Natural materials
- Reinforced materials
- Resource management and sustainability of materials
- Processing and design of materials for engineering application

Learning Outcomes / Competences:

- The students know the basic terms and concepts of materials for engineering application.
- The students have the competence to explain material properties and describe their specific functionality.
- The students are able to choose the right materials according to application relevant conditions.
- The students are able to design components considering principle properties of materials.
- 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:** any	

Parts of the Module

Part of the Module: Materials Engineering

Mode of Instruction: lecture

Language: English

Contact Hours: 3

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

- W.D. Callister, Materials Science and Engineering (Wiley)
- D. Askeland, P. Phule, The Science and Engineering of Materials
- M.F. Ashby, D.R.H. Jones, Engineering Materials (Cambridge Univ. Press)
- G. Gottstein, Physikalische Grundlagen der Materialkunde (Springer)

Assigned Courses:

Materials Engineering (lecture + exercise)

Examination

Materials Engineering

oral exam / length of examination: 30 minutes, graded

Parts of the Module

Part of the Module: Materials Engineering

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see description of module

Contents:

see description of module

Assigned Courses:

Materials Engineering (lecture + exercise)

Module MRM-0144: Materials Simulation

Materials Simulation

6 ECTS/LP

Version 1.0.0
Person responsible for module: Prof. Dr.-Ing. Christian Weißenfels
Prof. Dr. Ferdinand Haider

Contents:

1. Introduction to atomistic models
2. Basics of molecular dynamics simulations
3. Interatomic potentials for molecular dynamics simulations
4. Applications of molecular dynamics simulations using lamps
5. Visualization of results using Ovito
6. Finite-Element-Method for bars
7. Finite Element-Method for beams
8. Concepts of homogenization for bars and beams
9. Plasticity for bars and beams

Learning Outcomes / Competences:

- The students understand the concepts and limitations of atomistic simulations for simple materials
- The students know how to apply MD simulations for simple cases
- The students aquire the competence for a appopriate choice of simulation algorithm and interatomic potentials
- The students learn to visualize results of atomistic simulations using powerfull tools like Ovito
- The students know the basic concepts of the Finite-Element-Method, homogenization and plasticity
- The students are apply this concept to bars and beams
- The students have the competence to code algorithms to solve simple engineering problems
- 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 form, capacity for teamwork.

Workload:

Total: 180 h

60 h lecture and exercise course (attendance)

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

Conditions: Elementary knowledge of programing Basic knowledge of engineering mechanics		**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: Exercise to Materials Simulation

Mode of Instruction: exercise course

Language: English

Contact Hours: 2

Learning Outcome:

See description of module

Contents:

See description of module

Assigned Courses:

Exercise to Materials Simulation (exercise course)

Parts of the Module

Part of the Module: Materials Simulation

Mode of Instruction: lecture

Language: English

Contact Hours: 2

Learning Outcome:

See description of module

Contents:

See description of module

Lehr-/Lernmethoden:

See description of module

Literature:

Books

- Daan Frenkel, Berend Smit: Understanding molecular simulation: from algorithms to applications, Academic Press, San Diego [u.a.], 2002
- M. P. Allen and D. J. Tildesley: Computer simulation of liquids, Clarendon Pr., Oxford, 1991
- K. Ohno ; K. Esfarjani ; Y. Kawazoe: Computational materials science: from ab initio to Monte Carlo methods, Springer, Berlin [u.a.], 1999
- Mark Tuckerman: Statistical Mechanics: Theory and Molecular Simulation, Oxford Graduate Texts, 2010
- D. C. Rapaport: The Art of Molecular Dynamics Simulation , Cambridge University Press 2004
- T.I. Zohdi, P. Wriggers, An Introduction to Computational Micromechanics (Springer, 2005)
- T.J.R. Hughes, The Finite Element Method (Dover, 2000)

Online-Ressources:

- MD using moldyn: http://www.courses.physics.helsinki.fi/fys/moldyn/
- A molecular dynamics primer (F. Ercolessi): https://www.cse-lab.ethz.ch/wp-content/uploads/2013/01/MD-Primer.pdf
- Script on MD: http://micro.stanford.edu/~caiwei/me346/Notes/me346-handout-01-08.pdf
- Matthieu Micoulaut: https://www.lehigh.edu/imi/teched/AtModel/Atomistic_Modeling.html

Assigned Courses:

Materials Simulation (lecture)

Examination

Materials Simulation

written exam / length of examination: 90 minutes, graded

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

Learning Outcome:
-

Contents:
-

Lehr-/Lernmethoden:
-

Literature:
-

Assigned Courses:

Seminar zur Analysis (seminar)
**

Seminar zur Analysis (seminar)

Seminar zur Analysis: Einführung in die Theorie des Optimalen Transports (Bachelor/Master) (seminar)

Examination

Seminar zur Analysis Seminar Analysis

module exam, -, graded

Module MTH-1380: Seminar in Geometry

Seminar zur Geometrie

6 ECTS/LP

Version 1.0.2 (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:	Minimal Duration of the Module:
	1. - 4.	4 semester[s]
Contact Hours:	**Repeat Exams Permitted:**	
8	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 zur Geometrie (seminar)

Master-Seminar zur Geometrie (seminar)

Master-Seminar zur Geometrie (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:

Master-Seminar zur Geometrie (seminar)

Master-Seminar zur Geometrie (seminar)

Master-Seminar zur Geometrie (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: English
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, graded

Examination

Seminar zur Topologie

oral exam / length of examination: 90 minutes, graded

Examination

Seminar zur Geometrie: Seminar Finsler-Geometrie

oral exam / length of examination: 90 minutes, graded

Examination

Seminar zur Geometrie: Seminar Topics in Symplectic Geometry

oral exam / length of examination: 90 minutes, graded

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, graded

Description:

Prüfung findet auch im Sommersemester 2023 statt.

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: Differential Topology

Language: German / English
Frequency: every 3rd semester
Workload:

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

Contact Hours: 6
ECTS Credits: 9.0

Contents:

-

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

Differential Topology

oral exam / length of examination: 30 minutes, graded

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.

Examination

Algebraische Topologie

portfolio exam, graded

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.

Examination

Stochastische Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

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: **Dynamische Systeme** (lecture)

Examination

Dynamische Systeme

oral exam / length of examination: 30 minutes, graded

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)

Examination

Numerik partieller Differentialgleichungen

oral exam / length of examination: 30 minutes, graded

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, graded

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

Oberseminar zu Inverse Problemen und partiellen Differentialgleichungen (seminar)

Examination

Vortrag

oral exam / length of examination: 90 minutes, graded

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: Mathematical software project **Language:** German / English **Frequency:** each semester **ECTS Credits:** 6.0
Contents: -
Examination **Mathematical software project** practical exam / length of examination: 1 months, graded

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 on numerical mathematics: The TOP 10 Algorithms

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

Contents:

In 2000, the editors of the journal 'computing in science and engineering' selected 10 algorithms, which according to them were most influential in the science and technology of the 20th century. This seminar provides a closer look at the algorithms and their applications. Recommended prerequisites: the lecture Numerik I (or comparable knowledge).

Literature:

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

Examination

Seminar on numerical mathematics: The TOP 10 Algorithms

module exam, -, graded

Parts of the Module

Part of the Module: Seminar on numerical mathematics: seminar

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 about a selected topic in numerical methods
(a non-exhaustive list)
Advanced solution algorithms for linear systems and Eigenvalue problems
Control theory for dynamical systems
Modelling and differential equations
Modelling and numerical analysis
No special prerequisites needed.

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:

Randomized Linear Algebra (Seminar zur Numerik) (seminar)
**

Seminar zur Numerik (seminar)

Seminar zur Numerik (Master) (seminar)

Examination

Seminar on numerical mathematics: seminar
module exam, -, graded

Parts of the Module

Part of the Module: Seminar on numerical mathematics: seminar on numerical linear algebra

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

Contents:

The seminar covers recent scientific texts in the field of numerical linear algebra. The topics can vary based on the background of the participants. Recommended prerequisites: The lecture Numerik I (or comparable knowledge)

Assigned Courses:

Randomized Linear Algebra (Seminar zur Numerik) (seminar)
**

Examination

Seminar on numerical mathematics: seminar on numerical linear algebra
module exam, -, graded

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: Stochastic Evolution Equations **Language:** German **Contact Hours:** 6 **ECTS Credits:** 9.0
Contents: -

Examination
Stochastic Evolution Equations oral exam / length of examination: 30 minutes, graded

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, graded

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)

Examination

Symplectic Geometry and Hamiltonian Dynamics

oral exam / length of examination: 30 minutes, graded

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:
-

Literature:
recent publications about machine learning (depending on the current semester)

Examination
Advanced Methods in Machine Learning
module exam, Mündliche Prüfung à 30 Minuten oder Klausur à 60 Minuten / length of examination: 60 minutes, graded
Test Frequency:
when a course is offered

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: -
Literature: recent publications about machine learning (depending on the semester)
Examination **Advanced Methods in Machine Learning II** module exam, - / length of examination: 60 minutes, graded **Test Frequency:** when a course is offered

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, graded

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-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)
6. Nano-bio-magnetism (magnetotactic bacteria, magnetoreception, malaria)

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, graded

Examination Prerequisites:

Nanostructures / Nanophysics

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, graded

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

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

Assigned Courses:

Solid State Spectroscopy with Synchrotron Radiation and Neutrons (lecture)

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

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Assigned Courses:

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

Examination

Solid State Spectroscopy with Synchrotron Radiation and Neutrons

oral exam / length of examination: 30 minutes, graded

Examination Prerequisites:

Solid State Spectroscopy with Synchrotron Radiation and Neutrons

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, graded

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

Parts of the Module

Part of the Module: Physics of Thin Films
Mode of Instruction: lecture
Language: English
Frequency: each winter semester
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, graded

Examination Prerequisites:

Physics of Thin Films

Module PHM-0058: Organic Semiconductors *Organic Semiconductors*	6 ECTS/LP

Version 1.6.0 (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: Sommersemester	**Recommended Semester:** from 2.	**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: Organic Semiconductors
Mode of Instruction: lecture
Lecturers: Prof. Dr. Wolfgang Brütting
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

Contact Hours: 2

Examination

Organic Semiconductors

written exam / length of examination: 60 minutes, graded

Examination Prerequisites:

Organic Semiconductors

Module PHM-0059: Magnetism *Magnetism*	6 ECTS/LP

Version 1.3.0 (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: 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: 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, graded

Examination Prerequisites:

Magnetism

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

Version 1.2.0 (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: 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: 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)

Assigned Courses:

Low Temperature Physics (lecture)

Part of the Module: Low Temperature Physics (Tutorial)

Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Assigned Courses:

Low Temperature Physics (Tutorial) (exercise course)

Examination

Low Temperature Physics

oral exam / length of examination: 30 minutes, graded

Examination Prerequisites:

Low Temperature Physics

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: each summer semester not in summer term 2023	**Recommended Semester:** from 2.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

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

Learning Outcome:
see module description

Contents:
see module description

Literature:

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

Examination

Superconductivity

oral exam / length of examination: 30 minutes, graded

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:
see module description

Contents:
see module description

Literature:

will be announced in the lecture

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

Mode of Instruction: exercise course

Language: English / German

Contact Hours: 2

Learning Outcome:

see module description

Examination

Complex Materials: Fundamentals and Applications

oral exam / length of examination: 30 minutes, graded

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: 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: Spintronics
Mode of Instruction: lecture
Language: English
Frequency: each summer semester
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

Frequency: each summer semester

Contact Hours: 1

Examination

Spintronics

written exam / length of examination: 90 minutes, graded

Examination Prerequisites:

Spintronics

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, graded

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: each summer semester	**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

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

Learning Outcome:
see module description

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

Module PHM-0077: Theory of Magnetism
Theorie des Magnetismus

8 ECTS/LP

Version 1.2.0 (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: English
Contact Hours: 4

Learning Outcome:
siehe Modulbeschreibung

Contents:
see module description

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: English

Contact Hours: 2

Learning Outcome:

see module description

Examination

Theory of Magnetism

oral exam / length of examination: 30 minutes, graded

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:

see module description

Contents:

see module description

Literature:

see corresponding lecture

Examination

Computational Physics and Materials Science

oral exam / length of examination: 30 minutes, graded

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, 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-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-0108: Project Work *Projektarbeit*		15 ECTS/LP
Version 1.0.1 (since WS09/10) Person responsible for module: Prof. Dr. Arno Kampf 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 lierarture (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]
	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 1.2.0 (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:	**Recommended Semester:** from 1.	**Minimal Duration of the Module:** 1 semester[s]
Contact Hours: 4	**Repeat Exams Permitted:** according to the examination regulations of the study program	

Parts of the Module

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

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

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

Part of the Module: Materials Chemistry (Tutorial)

Mode of Instruction: exercise course

Language: English

Contact Hours: 1

Learning Outcome:

see description of module

Contents:

see description of module

Literature:

see associated lecture

Examination

Materials Chemistry

written exam / length of examination: 90 minutes, graded

Test Frequency:

only in the winter semester

Examination Prerequisites:

Materials Chemistry

Description:

ab dem WiSe 2023/4 wird nur noch die Modulprüfung angeboten, jedoch keine Vorlesung mehr

from winter term 2023/4 on only the exam will be conducted, but no lecture anymore

Module PHM-0113: Advanced Solid State Materials *Advanced Solid State Materials*		6 ECTS/LP
Version 1.2.0 (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:	**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, graded

Examination Prerequisites:

Advanced Solid State 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, graded

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)

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)

Examination

Surfaces and Interfaces

written exam / length of examination: 90 minutes, graded

Examination Prerequisites:

Surfaces and Interfaces

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, graded

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, graded

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, graded

Test Frequency:

each semester

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, graded

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, graded

Examination Prerequisites:

Method Course: Methods in Biophysics

Module PHM-0150: Method Course: Spectroscopy on Condensed Matter *Method Course: Spectroscopy on Condensed Matter*	8 ECTS/LP

Version 1.0.0 (since SoSe15)
Person responsible for module: Prof. Dr. István Kézsmárki

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

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.

Remarks:

ELECTIVE COMPULSORY MODULE

Workload:

Total: 240 h

Conditions: Recommended: basic knowledge in solid state physics, basic knowledge in physics of glasses and supercooled liquids		**Credit Requirements:** written report on the experiments (editing time 2 weeks)
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: Spectroscopy on Condensed Matter
Mode of Instruction: lecture
Language: English
Frequency: irregular (usu. winter semester)
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)

Part of the Module: Method Course: Spectroscopy on Condensed Matter (Practical Course)
Mode of Instruction: laboratory course
Language: English
Frequency: irregular (usu. winter semester)
Contact Hours: 4

Examination

Method Course: Spectroscopy on Condensed Matter
oral exam / length of examination: 45 minutes, graded

Examination Prerequisites:
Method Course: Spectroscopy on Condensed Matter

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

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

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

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

Examination
Introduction to Materials presentation, graded **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, graded
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, graded

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, graded

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, graded

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, graded **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

Assigned Courses:

Oxidation and Corrosion (lecture)

Part of the Module: Oxidation and Corrosion (Tutorial)

Mode of Instruction: exercise course
Language: English
Frequency: each winter semester
Contact Hours: 1

Assigned Courses:

Oxidation and Corrosion (Tutorial) (exercise course)

Examination

Oxidation and Corrosion
written exam / length of examination: 90 minutes, graded
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, graded

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, graded

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, graded

Examination Prerequisites:

Method Course: Functional Silicate-analogous Materials

Module PHM-0174: Theoretical Concepts and Simulation *Theoretical Concepts and Simulation*			6 ECTS/LP
Version 1.1.0 (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. Concepts in atomistic materials modelling 5. Simulation of material's properties (molecular spectroscopy, magnetism)			
Learning Outcomes / Competences: The students: • know the principal concepts of 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, • are able to choose the adequate levels of description and approximations for a given problem and apply the corresponding methods, • have the expertise 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 to present the results in written and oral form, capacity for teamwork.			
Remarks: Links to exemplary software related to the course: • http://www.bloodshed.net/ • http://www.cplusplus.com/doc/tutorial/ • http://www.cygwin.com/ • http://avogadro.cc/ • http://orcaforum.kofo.mpg.de/app.php/portal			
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
Frequency: each winter semester
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)

Assigned Courses:

Theoretical Concepts and Simulation (lecture)

Part of the Module: Theoretical Concepts and Simulation (Project)
Mode of Instruction: exercise course
Language: English
Contact Hours: 1

Assigned Courses:

Theoretical Concepts and Simulation (Project) (exercise course)

Examination
Theoretical Concepts and Simulation
seminar / length of examination: 30 minutes, graded
Examination Prerequisites:
Theoretical Concepts and Simulation

Module PHM-0188: Seminar on Spectroscopy of Organic Semiconductors *Seminar on Spectroscopy of Organic Semiconductors*	4 ECTS/LP
Version 1.3.0 (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		**Credit Requirements:** Seminar presentation
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: 30 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

Assigned Courses:

Understanding Correlated Materials (lecture)

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

Assigned Courses:

Understanding Correlated Materials (Tutorial) (exercise course)

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

Assigned Courses:

Understanding Correlated Materials (Seminar) (seminar)

Examination

Understanding Correlated Materials
seminar / length of examination: 60 minutes, graded

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 Pythhon 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:** Passing the module exam
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, graded

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)

Examination

Analog Electronics Analog Electronics for Physicists and Materials Scientists

written exam / length of examination: 90 minutes, graded

Test Frequency:

only in the winter semester

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, graded **Test Frequency:** only in the summer semester

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
  - Motivating examples
  - Polar and axial vectors and tensors
  - Spatial and temporal symmetries and charge conjugation
  - Symmetries of measurable quantities and fields
  - Symmetries of physical laws (classical and quantum)
  - Conservation laws (linear and angular momentum, energy, etc.)
  - Symmetry of measurement configurations (reciprocity, etc.)
- Neumann principle
  - Linear response theory and Onsager relations
  - 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
  - On the level of classical free energy: Polar, nematic and magnetic order parameters (Landau expansion)
  - On the level of Hamiltonians: Molecular vibrations, crystal field potential, magnetic interactions
- Symmetry of physical states
  - Spatial inversion and parity eigenstates
  - 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: 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: 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, graded

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, graded

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, graded

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, graded

Module PHM-0253: Dielectric Materials *Dielectric Materials*	6 ECTS/LP

Version 2.0.0 (since SoSe23)
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
20 h studying of course content using provided materials (self-study)
20 h studying of course content using literarture (self-study)
80 h studying of course content through exercises / case studies (self-study)
60 h lecture and exercise course (attendance)

Conditions: Basic knowledge of solid state physics		Credit Requirements: Pass of module exam
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. Peter Lunkenheimer
Language: English / alle Sprachen

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, graded

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 GaV_4S_8, 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.

Assigned Courses:

Method Course: Charge doping effects in semiconductors (lecture)

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.

Assigned Courses:

Method Course: Charge doping effects in semiconductors (lecture)

Examination

Method course: Charge doping effects in semiconductors

report, graded

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, graded

Module PHM-0267: Fundamentals of Materials for Energy *Fundamentals of Materials for Energy*		6 ECTS/LP
Version 2.2.0 (since SoSe23) 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:** Seminar presentation + written handout.
Frequency: Wintersemester	**Recommended Semester:**	**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: Fundamentals of Materials for Energy
Mode of Instruction: lecture
Lecturers: Prof. Dr. Wolfgang Brütting
Language: English / German
Frequency: each winter semester
Contact Hours: 3

Literature:

- M. Stutzmann, C. Csoklich: The Physics of Renewable Energy (Springer)
- J. Fricke, W.L. Borst: Essentials of Energy Technology (Wiley-VCH)
- D.S. Ginley, D. Cahen: Fundamentals of Materials for Energy and Environmental Sustainability (Cambridge Univ. Press)
- 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

lecture + accompanying seminar / length of examination: 45 minutes, graded

Description:

30min seminar presentation + 15min discussion, together with a detailled written handout

Parts of the Module

Part of the Module: Fundamentals of Materials for Energy (Tutorial)

Mode of Instruction: exercise course

Language: English / German

Contact Hours: 2

Assigned Courses:

Fundamentals of Materials for Energy (Tutorial) (exercise course)