Faculty of Natural Sciences and Technology
Master-Program in Physics

Modul descriptions

for the master-program in Physics

With modul descriptions of the courses in the master program Physics
from June 06, 2019

November 12, 2024

Faculty of Natural Sciences and Technology
Master-Program in Physics

Reference semester	Name of the module	Responsible lecturer	ECTS
	Mandatory Courses		
1.-2. Sem.	Experimental Physics V	Becher	8
1.-2. Sem.	Experimental/Theoretical Physics Seminar	Lecturers of the physics department	4
1. Sem.	Advanced Physics Lab IIa	Eschner	7
3. Sem.	Laboratory Project	Lecturers of the physics department	15
3. Sem.	Research Seminar	Lecturers of the physics department	15
4. Sem.	Master thesis	Lecturers of the physics department	30

	Required Electives		
1.-2. Sem.	Theoretical Physics V (e)	Santen	8 (4)
2. Sem.	Advanced Physics Lab IIb	Eschner	4

	Physics Compulsory Elective		
1.-2. Sem.	Physics Compulsory Electives	Lecturers of the physics department	15
1.-2. Sem	Advanced Optics and Photonics	Straub	5
1.-2. Sem	Build your own microscope	Lautenschläger	6
1.-2. Sem.	Computational Molecular Biophysics	Hub	5
1.-2. Sem.	Computational Physics	Rieger	5
1.-2. Sem.	Experimental Techniques in Biophysics and Surface Science 1 &2	Jacobs	2,5 (x2)
1.-2. Sem.	General Relativity	Henkel	5
1.-2. Sem.	General Relativity	Santen	3
1.-2. Sem.	Introduction to Conformal Invariance	Henkel	2
1.-2. Sem.	Introduction to Cosmology	Henkel	5
1.-2. Sem.	Introduction into Soft Condensed Matter Physics	Jacobs/Seemann	5
1.-2. Sem.	Introduction to quantum information processing	Wilhelm-Mauch	5
1.-2. Sem.	Experimental and Statistical Biological Physics (Experimental Biophysics)	Ott	5
1.-2. Sem.	Capillarity, Wetting and Dewetting	Seemann	5
1.-2. Sem.	Laser cooling and trapping of particles	Eschner	5
1.-2. Sem.	Modern Optics	Ott	5
1.-2. Sem.	Quantum and Modern Optics	Becher	5
1.-2. Sem.	Nanomechanics	Bennewitz	5
1.-2. Sem.	Nanostructure Physics II a/b	Hartmann	5
1.-2. Sem.	Nonlinear Dynamics and structure formation	Wagner	5
1.-2. Sem.	Nonlinear Optics	Straub	5
1.-2. Sem.	Optik für Fortgeschrittene – Advanced Optics	Straub	5
1.-2. Sem.	Phase Transitions	Henkel	3
1.-2. Sem.	Quantum Theory of Light	Morigi	5
1.-2. Sem.	Quantum Optics with Ultracold Atoms	Morigi	5
1.-2. Sem.	Rheology and Non Newtonian Fluid mechanics	Wagner	5
1.-2. Sem.	Stochastic Processes	Santen	5
1.-2. Sem.	Theoretical Biophysics – Advanced Concepts	Santen	5
1.-2. Sem.	Theoretical physics for quantum technologies	Wilhelm-Mauch, Morigi	5

Reference semester	Name of the module	Responsible lecturer	ECTS
Non-physics Compulsory Elective			
1.-2. Sem.	Non-physics Compulsory Elective	Examination Board Master Physics	18
1.-2. Sem	Image Processing and Computer Vision	Weickert	9
1.-2. Sem.	Programming 1	Smolka	9
1.-2. Sem.	Programming 2	Hack	9
1.-2. Sem.	Partielle Differentialgleichungen I (Partial Differential Equations I)	Fuchs	9
1.-2. Sem.	Variationsrechnung	Fuchs	9
1.-2. Sem.	Funktionalanalysis I (Functional Analysis I)	Weber	9
1.-2. Sem.	Grundlagen der Materialchemie (‚Vorlesung + Seminar' und Praktikum)	Kickelbick	3,5 und 2,5
2. Sem.	Objektorientierte Sprachen und generische Programmierung (ITG II)	Hoffmann	9
1.-2. Sem.	Language course		Max. 4

Name of the module **Experimental Physics V**					**EP V**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 and 2	**2**		**2 Semester**	**6**	**8**

Responsible lecturer	Becher
Lecturer(s)	Lecturers in experimental physics Tutors for tutorial groups
Level of the unit	mandatory
Entrance requirements	For graduate students: no formal requirements Required knowledge: fundamental knowledge at an intermediate level in optics, quantum physics and atomic physics (e.g. Experimental Physics III of the Bachelor course) as well as solid state physics (e.g. Experimental Physics IVa of the Bachelor course)
Assessment / Exams	Lectures with exercises: one graded written or oral exam for each course. Prerequisite for participation in exam: for each course successful completion of the exercises,
Course type / weekly hours	Experimental Physics Va (Physics of Atoms and Molecules) Lecture (2 hours weekly) Exercises (1 hour weekly) Experimental Physics Vb (Solid State Physics II) Lecture (2 hours weekly) Exercises (1 hour weekly)
Workload	• Attendance time lectures (2 courses x 15 weeks à 2 semester hours) = 60 hours • Attendance time exercises (2 courses x 15 weeks à 1 semester hours) = 30 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 150 hours Total: 240 hours
Grading	Grade of the written or oral examination

Learning Objectives/Competencies

- Acquisition of knowledge of advanced atomic and molecular physics
- Acquisition of knowledge of advanced solid state physics
- Acquisition of an overview of modern physics applications and problems
- Teaching of scientific methodology, in particular the ability to deal with relevant problems, i.e. to treat relevant problems quantitatively by means of mathematical formalisms and to solve them independently
- Familiarization with key experiments and experimental techniques/measurement methods
- Practice of advanced techniques of scientific work, in particular the ability to solve physical problems by applying mathematical formalisms and use of scientific literature ("Reading Class") to solve problems independently

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Content

Lecture Course Experimental Physics Va (Atomic and Molecular Physics)

- Multiple electron atoms
- Structure of the periodic table
- Nuclear spin and hyperfine structure
- Spectra of complex atoms
- Modern experimental methods in atomic physics
- Introduction to molecular physics: structure and bonding, molecular spectra

Lecture Course Experimental Physics Vb (Solid State Physics II)

- Metals
- Fermi surfaces
- Semiconductors
- Dielectric Properties
- Magnetism
- Superconductivity
- Modern experimental methods in solid state physics

Additional information

Language: English

Literature:

- B,H, Bransden, C.J. Joachain: Physics of Atoms and Molecules
- C.J. Foot: Atomic Physics
- I.V. Hertl and C.-P- Schulz, Atoms, Molecules and Optical Physics, vol,1 & vol. 2
- W. Demtröder, Atoms. Molecules and Photons

- C. Kittel, Introduction to Solid State Physics
- N. Ashcroft. Mermin, Solid State Physics
- S. Hunklinger, C. Enss, Solid State Physics

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Name of the module **Experimental Physics Seminar/Theoretical Physics Seminar**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**	**WS & SS**	**1 Semester**	**2**	**4**

Responsible lecturer	Professors of the physics department
Lecturer(s)	Lecturers in experimental or theoretical physics
Level of the unit	mandatory
Entrance requirements	No formal requirements
Assessment / Exams	Seminar presentation on a current research topic
Course type / weekly hours	Seminar (2h/week (SWS)), max. group size 15
Workload	Attendance time 30 h Preparation of the presentation, literature study 90 h Total 120 h
Grading	ungraded

Learning Objectives/Competencies

- Independent research and reading of original literature
- Ability to didactically prepare the presentation of research papers
- Presentation training

Content

- Lectures on thematically related issues in current research areas
- Consolidation of selected sub-areas from the physics courses

Additional information

Language: English, German possible

Literature:

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Name of the module **Advanced Physics Lab IIa**					**FP IIa**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**1**	**WS**	**1 Semester**	**4**	**7**

Responsible lecturer	Prof. Eschner
Lecturer(s)	1 coordinator 1 supervisor for each student team
Level of the unit	mandatory
Entrance requirements	For graduate students: none
Assessment / Exams	Initial discussion with supervisor for each experiment Execution, documentation, and analysis of the experiments Final discussion with supervisor Presentation in a common seminar at the end of the semester
Course type / weekly hours	Lab (4 hours weekly) Seminar 5 h
Workload	210 h = 40 h of lab, 5 h Seminar and 165 h private study
Grading	ungraded

Aims/Competences to be developed

- In-depth understanding of selected physical concepts and theories through experimentation.
- Comprehensive knowledge and competence in the use of modern and sophisticated experimental techniques and measurement methods.
- Performing and documenting reliable measurements.
- Using and programming computers for experiment control, data acquisition, and data analysis.
- Getting acquainted with scientific equipment used in current research.

Content

- Realization of four experiments from the fields of
  - Atomic, molecular, and optical physics
  - Solid state physics
  - Microscopy methods
  - Biophysics
  - Nuclear physics
  - Theoretical (numerical) physics
- Presentation of one of the performed experiments as part of a common seminar ("block seminar"), at the end of the semester.

Additional information

- **Language**: English
- **Literature**: will be provided by the supervisors of the experiments
- **Information**: an up-to-date list of the available experiments as well as general information is found at https://www.uni-saarland.de/fakultaet-nt/fopra.html
- **Registration**: registration with the coordinator at the beginning of the semester is required via https://www.uni-saarland.de/fakultaet-nt/fopra.html

Name of the module **Laboratory Project**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
3	**3**	**WS & SS**	**1 Semester**	**10**	**15**

Responsible lecturer	Professors of the physics department
Lecturer(s)	Lecturers in experimental or theoretical physics
Level of the unit	mandatory
Entrance requirements	Acquisition of at least 52 CPs; successful completion of the modules "Experimental Physics V" and of the area of specialization.
Assessment / Exams	Making a final report
Course type / weekly hours	Block course: 10 weeks with daily approx. 8. Hours
Workload	Processing of the research tasks and creation of the report: Total 450 h
Grading	ungraded

Learning Objectives/Competencies

- Introduction to the independent processing of scientific projects.
  Apply scientific methods required for the preparation of the Master's thesis

Content

- Familiarization with the methodology of the master thesis' research field
- Preparation for the processing of the scientific question of the master thesis

Additional information

Language: English, German possible

Name of the module **Research Seminar**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
3	**3**	**WS & SS**	**1 Semester**		**15**

Responsible lecturer	Professors of the physics department
Lecturer(s)	Lecturers in experimental or theoretical physics
Level of the unit	mandatory
Entrance requirements	Acquisition of at least 52 CPs; successful completion of the modules "Experimental Physics V" and of the area of specialization.
Assessment / Exams	Oral presentation of scientific results from the subject area of the Master's thesis.
Course type / weekly hours	Seminar (2h/week (SWS)), max. group size 15
Workload	Attendence time 30 h Preparation of the presentation, literature study 420 h Total 450 h
Grading	ungraded

Learning Objectives/Competencies

- Ability to work independently within a defined framework.
- Planning and independent execution of defined research projects
- Creation of project documentation containing the necessary information to reproduce the results obtained

Content

- Guidance for systematic literature recherche with regard to the master thesis
- Development of a project outline and schedule of the master project under the guidance of a lecturer of physics
- Instruction for the appropriate documentation of the project progress

Additional information

Language: English, German possible

Name of the module **Master thesis**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
4	**4**	**WS & SS**	**1 Semester**		**30**

Responsible lecturer	Professors of the physics department
Lecturer(s)	Lecturers in experimental or theoretical physics
Level of the unit	mandatory
Entrance requirements	According to paragraph "Admission to the Master's thesis" (Zulassung zur Master-Arbeit) in the currently valid version of the examination regulations
Assessment / Exams	• Preparation of master thesis • Scientific presentation and colloquium on the content of the master thesis
Course type / weekly hours	
Workload	Planning and implementation of the research project, Documentation of the project and writing of the Master thesis in a period of 23 weeks Total 900 h
Grading	From the assessment of the master thesis

Learning Objectives/Competencies

- Ability to carry out independent scientific work in defined areas.
- Planning and independent execution of research projects within a defined framework.
- Preparation of project documentation containing the necessary information to reproduce the results obtained.
- Written presentation of research results in scientific language

Content

- Carrying out a project on a current research topic in a research group of the physics department under the guidance of a university teacher.
- Preparation of the master thesis

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Name of the module **Theoretical Physics V**					TP V
Semester	Reference semester	Term	Duration	Weekly hours	Credits
2	**2**	**Summerterm**	**1 Semester**	**6**	**8**

Responsible lecturer	Santen
Lecturer(s)	Lecturers in theoretical physics
Level of the unit	Mandatory for students with specialization Theoretical Physics
Entrance requirements	For graduate students: none
Assessment / Exams	Written or oral examination
Course type / weekly hours	Lecture (4 hours weekly) Exercises (2 hour weekly)
Workload	150 h = 90 h of classes and 150 h private study • Attendance time lectures and seminar (15 weeks à 4 semester hours) = 60 hours • Time for preparation of seminar presentation (15 weeks à 2 semester hours) = 30 hours • Time for preparation and wrap-up of the lecture 150 hours
Grading	Grade of the written or oral examination

Aims/Competences to be developed

- Learning the methods for theoretical description and analysis of quantum mechanical many-particle systems
- Understanding of the most important physical phenomena in systems with a macroscopic number of interacting particles
- Mastery of the fundamental concepts of quantum statistics and relativistic Quantum mechanics, as well as phase transitions and non-equilibrium physics.
- Connection to current research in theoretical physics

Content

- Second quantization: bosons, fermions and field operators
- Scattering theory
- Field quantization
- Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation
- Fluctuations and response
- Basics of the path integral concept
- Advanced methods of applications

Additional information

Language: English

Literature:
- C. Cohen-Tannoudji, B. Diu, F. Laloe, Quantenmechanik 2, de Gruyter, 1998
- F. Schwabl, Quantenmechanik für Fortgeschrittene, Springer, 2005
- F. Schwabl, Statistische Mechanik, Springer, 2006
- R.P. Feynman, Statistical Mechanics, Perseus Books, 1998
- Yu V. Nazarov, J. Danon: Advanced Quantum Mechanics, Cambridge University Press
- S. J. Sakurai, Advanced Quantum Mechanics, Addison-Wesley

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Name of the module **Theoretical Physics Ve - Applications of quantum mechanics**					TP Ve
Semester	Reference semester	Term	Duration	Weekly hours	Credits
2	**2**	**Summerterm**	**1 Semester**	**4**	**4**

Responsible lecturer	Santen
Lecturer(s)	Lecturers of theoretical physics
Level of the unit	Mandatory for students with the specialization Experimental Physics
Entrance requirements	For graduate students: none
Assessment / Exams	Written or oral exam
Course type / weekly hours	Students of the specialization Experimental Physics take the course Theoretical Physics V in the first 11 weeks of the semester. During this period it is organized as a lecture with 4 SWS and exercises with 1 SWS. The exercises serve primarily to deepen the contents of the lecture.
Workload	• Attendance time lectures (11 weeks à 4 semester hours) = 44 hours • Attendance time exercises (11 weeks à 1 semester hours) = 11 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 65 hours
Grading	Grade of the written or oral examination

Aims/Competences to be developed

- Basic understanding of the methods for the theoretical description and analysis of quantum mechanical many-particle systems
- Understanding of the most important physical phenomena in systems with a macroscopic number of interacting particles
- Knowledge of the basic concepts of quantum statistics and relativistic Quantum mechanics, as well as phase transitions and non-equilibrium physics
- Connection to current research in theoretical physics

Content

- Second quantization: bosons, fermions and field operators
- Scattering theory
- Field quantization
- Relativistic quantum mechanics: Klein-Gordon equation, Dirac equation
- Fluctuations and response
- Basics of the path integral concept

Additional information

Language: English

Literature:

- C. Cohen-Tannoudji, B. Diu, F. Laloe, Quantenmechanik 2, de Gruyter, 1998
- F. Schwabl, Quantenmechanik für Fortgeschrittene, Springer, 2005
- F. Schwabl, Statistische Mechanik, Springer, 2006
- R.P. Feynman, Statistical Mechanics, Perseus Books, 1998
- Yu V. Nazarov, J. Danon: Advanced Quantum Mechanics, Cambridge University Press
- S. J. Sakurai, Advanced Quantum Mechanics, Addison-Wesley

Name of the module **Advanced Physics Lab IIb**					**FP IIb**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
2	**2**	**SS**	**1 Semester**	**2**	**4**

Responsible lecturer	Prof. Eschner
Lecturer(s)	1 coordinator 1 supervisor for each student team
Level of the unit	Mandatory for students with the specialization Experimental Physics
Entrance requirements	For graduate students: none
Assessment / Exams	Initial discussion with supervisor for each experiment Execution, documentation, and analysis of the experiments Final discussion with supervisor Presentation in a common seminar at the end of the semester
Course type / weekly hours	Lab (2 hours weekly) Seminar 5 h
Workload	120 h = 20 h of lab, 5 h Seminar and 95 h private study
Grading	ungraded

Aims/Competences to be developed

- In-depth understanding of selected physical concepts and theories through experimentation.
- Comprehensive knowledge and competence in the use of modern and sophisticated experimental techniques and measurement methods.
- Performing and documenting reliable measurements.
- Using and programming computers for experiment control, data acquisition, and data analysis.
- Getting acquainted with scientific equipment used in current research.

Content

- Realization of four experiments from the fields of
  - Atomic, molecular, and optical physics
  - Solid state physics
  - Microscopy methods
  - Biophysics
  - Nuclear physics
  - Theoretical (numerical) physics
- Presentation of one of the performed experiments as part of a common seminar ("block seminar"), at the end of the semester.

Additional information

Language: English
Literature: will be provided by the supervisors of the experiments
Information: an up-to-date list of the available experiments as well as general information is found at https://www.uni-saarland.de/fakultaet-nt/fopra.html
Registration: registration with the coordinator at the beginning of the semester is required via https://www.uni-saarland.de/fakultaet-nt/fopra.html

Name of the module **Physics Compulsory Elective**					Abk.
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**WS & SS**	**2 Semester**		**15**

Responsible lecturer	Lecturers of the physics department
Lecturer(s)	Lecturers of the physics department
Level of the unit	mandatory
Entrance requirements	For graduate students: no formal requirements
Assessment / Exams	Written or oral exam for each course
Course type / weekly hours	See description of each course that belongs to physics compulsory elective
Workload	The sum of all courses belonging to the physics compulsory elective must have a workload of at least 450 h (15 CP)
Grading	Written or oral exam. At least 5 CP must be graded

Learning Objectives/Competencies

- Overview of a current research area in physics
- Understand and be able to reproduce the essence of current research methodology in the relevant sub-field.

Content

See module descriptions for the individual courses

Additional information

Physics compulsory elective courses in experimental and theoretical physics will be offered each semester

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Name of the module **Advanced Optics and Photonics: Optical Technologies in Industry, Telecommunication and Medicine**					. **APO**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1,3	**4 terms**	**Winter term**	**1 term**	**4**	**5**

Responsible lecturer	Priv.-Doz. Dr. rer. nat. Martin Straub
Lecturer(s)	Priv.-Doz. Dr. rer. nat. Martin Straub
Level of the unit	physics compulsory elective
Entrance requirements	No formal admission requirements
Assessment / Exams	Written test or oral exam
Course type / weekly hours	3 SWS Lecture, 1 SWS Seminar
Workload	Lecture: 45 hours, preparation and learning: 45 hours Seminar: 15 hours, preparation of presentation: 45 hours
Grading	Overall mark of the examination

Learning targets / Core competencies
- In-depth knowledge of light-matter interaction, emitters and detectors, design and characteristics of modern optical systems, optical Fourier methods, optical sensors and metrology, fibre optics, high-resolution optical microscopy and lithography, micro-, nano- and integrated optics.
- Capacity to evaluate applications of optical technologies and to plan their implementation.
- Solution of problems involving calculations with complex field functions and material variables.
- Exploration and presentation of current research topics in applied optics and photonics.

Topics / Contents
- Radiometry and photometry: Physical variables and their usage in lighting engineering.
- Light-matter interaction in dielectrics, semiconductors and metals: Dispersion, absorption, scattering. Polarization: Dichroism and birefringence, liquid crystal devices.
- Emitters and detectors in various spectral ranges.
- Design and features of optical components and systems: Adaptive optics, thick and aspheric lenses, gradient-index optics, optical ray tracing, optical aberrations.
- Fourier optics and coherence theory as well as their applications in microscopy and astronomy.
- Optical sensors and metrology: 3D shapes, distance, vibrations, temperature, moisture, colour.
- Fibre optics and high-bandwidth optical telecommunication.
- High-resolution far- and near-field optical microscopy, optical superresolution.
- Mask projection and laser scanning lithography, optical 2D- and 3D-nanostructure generation
- Micro-, nano- und integrated optics, plasmonics, photonic crystals and all-optical devices

Additional information: Transparencies in English language
Working language: German, English (as desired)

Literature: [1] E. Hecht: **Optics,** 5th Global Edition, Pearson Higher Education, 2016, ISBN 978-1-292-09693-3; E. Hecht, **Optik,** 7. Auflage, Reihe De Gruyter Studium, 2018, ISBN 978-3-11-052664-6
[2] E. Hering, R. Martin: **Photonik,** Springer Verlag, 2006, ISBN 978-3-540-23438-8
[3] J. Jahns, K.-H- Brenner: **Microoptics,** Springer Verlag, 2004, ISBN 0-387-20980-8
[4] L. Novotny, B. Hecht: **Principles of Nano-Optics,** Cambridge UP., 2006, ISBN 978-0-521-83224-3

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Name of the module **Build your own microscope**					. **BYOM**
Studiensem.	Regelstudiensem.	Turnus	Dauer	SWS	ECTS-Punkte
4	**4**	**Sommersemester**	**1 Semester**	**6**	**6**

Responsible for module	Prof. Dr. Franziska Lautenschläger
Lecturer	Jun.-Prof. Dr. Laura Aradilla Zapata, Prof. Dr. Franziska Lautenschläger, Jun.-Prof. Dr. Marcel Lauterbach
Assignment to Curriculum	Mandatory elective, biophysical area for bachelor students of biophysics or elective area for master students of biophysics physics compulsory elective
Admission requirements	Optics lecture or equivalent Command of English (minimum B2, corresponds German ‚Abitur‘)
Controls / Exams	Oral Exams Condition of admission to the exam: successful elaboration of lab protocols
Courses / hours	2 hours (SWS) lecture, 4 hours (SWS) practical work During the semester
Workload (in total)	24 h lecture, 50 h practical work, 106 h Pre- and post-processing including preparation of protocols
Modulgrade	graded

Learning targets/competencies

- Basics of Optics
- Intuitive Understanding of optical microscopy
- Direct practical application of theoretical knowledge
- Building and handling of a complex device (here: optical microscope)
- Acquisition of various optical imaging methods
- Application of optical microscopy
- Preparation of scientific protocols
- Social competencies and teamwork thanks to work in small groups
- Fluency in technical English on microscopy

Contents

- Introduction to optical imaging
- Köhler Illumination
- Abbe Theory and Image Formation
- Contrast methods
- Fluoresce microscopy
- Spectra and filters

Further information: Material for lecture and practical work are given in English. The materials [1] and [2] must be printed, read and understood prior to the start of the lecture autonomously by the student.
Language: English, can be given in German on request of all students in the class.

Literature:
[1] ThorLabs Optical Microscopy Course, Course Notes (https://www.thorlabs.com/drawings/803116e8c007caa5-8D9E3D93-FF59-2143-3ED4E989CE275C6C/EDU-OMC1-CourseNotes.pdf).

[2] ThorLabs Optical Microscopy Course, Lab Notes (https://www.thorlabs.com/drawings/803116e8c007caa5-8D9E3D93-FF59-2143-3ED4E989CE275C6C/EDU-OMC1-LabNotes.pdf).

[3] C. Gerhard, Tutorium Optik, Springer Spektrum 2020.

Name of the module **Computational Molecular Biophysics**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1./2.	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Hub
Lecturer(s)	Hub
Level of the unit	physics compulsory elective
Entrance requirements	No formal prerequisites Recommended prerequisites: Basic knowledge of statistical physics, quantum mechanics, and electrostatics
Assessment / Exams	Oral exam
Course type / weekly hours	Lecture: 2 SWS Computer pratical: 2 SWS
Workload	Präsenzzeit Vorlesungen: 15 Wochen a 2 SWS 30 Stunden Präsenzzeit Computerpraktikum: 15 Wochen a 2 SWS 30 Stunden Vor- und Nachbereitung der Vorlesung und der Computerpraktika, Klausur- oder Prüfungsvorbereitung 90 Stunden ------------------ Summe 150 Stunden
Grading	Result of the oral exam

Lernziele/Kompetenzen
The students should:

- Understand the methods and concepts of computational molecular biophysics.
- Understand how physical principles, in particular statistical physics and quantum mechanics, determine the function and dynamics of proteins.
- Ability to carry out and to analyze computer simulations with the aim to understand the function of proteins.

Inhalt

- Structure, function, and intermolecular interactions of proteins
- Molecular dynamics simulations, underlying approximations, efficient algorithms, integration of equations of motion
- Electrostatics in proteins, solvent effects, protonation equilibrium
- Protein structure determination (X-ray crystallography, NMR, cryo-EM)
- Monte Carlo simulations
- Collective dynamics: principal component analysis (PCA) and normal modes
- Introduction to bioinformatics: sequence alignment, structure prediction
- Free energy calculations: free energy perturbation, thermodynamic integration, umbrella sampling
- Non-equilibrium thermodynamics: Jarzynski equation and Crooks' theorem
- Charge transfer in proteins
- Rate theory: Eyring theory, Smoluchowski equation, Kramers' theory
- Quantum chemistry: Hartree Fock method, density functional theory
- Quantum mechanical/molecular mechanical (QM/MM) simulations

Further information
Language: English
Literature: Announced during the lecture

Name of the module **Computational Physics**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1, 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Rieger
Lecturer(s)	Rieger, Santen
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Homework (programming exercises); written exam or oral examination
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	Correct solution of the programming exercise + exam grades

Aims/Competences to be developed

- Overview of fundamental concepts and modern methods and algorithms of computer physics, knowledge of the most important algorithmic principles.
- Technical competence for the computer-aided analysis of theoretical models of complex physical systems.
- Competence to critically assess numerical methods and algorithms.
- Establishing connections between theoretical concepts and results of computer simulations
- Acquisition of an experienced application of computers in theoretical-physical research
- Management of program development in natural sciences: programming, debugging, testing, optimization, data acquisition and analysis.

Content

- Numerical integration of differential equations
- Molecular dynamics simulations
- Random numbers and stochastic processes
- Monte Carlo algorithms / cluster algorithms
- Path integral and quantum Monte Carlo simulations
- Integration of the Schrödinger equation and “ab initio” methods
- Density functional methods
- Exact diagonalization of many body Hamiltonians
- Density matrix theory
- Combinatorial optimization

Additional information

Language: English

Literature:

- J.M. Thijsen, Computational Physics, Cambridge University Press (1999), Cambridge (UK)
- D. Frenkel und B. Smit, Understanding Molecular Simulation, Academic Press
- W. Krauth, Statistical Mechanics: Algorithms and Computations, Oxford Master Series in Statistical, Computational, and Theoretical Physics

Name of the module **Capillarity, Wetting and Dewetting**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 period**	**4**	**5**

Responsible lecturer	Seemann
Lecturer(s)	Seemann
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Successful completion of exercises or Seminar presentation; final written or oral examination
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	Lecture 3 hours x 15 (weeks) = 45 hours Preparation and reworking 1 hour x 15 = 15 hours Preparation of seminar lecture incl. literature search 45 hours Exam preparation 45 hours In total 150 hours
Grading	written or oral exam

Aims/Competences to be developed

- Overview of current scientific questions and applications on capillarity, wetting and dewetting.
- Knowledge of typical experimental measurement and characterization methods
- Overview of long- and short-range wetting forces, their description in the framework of the "effective interface potential" and their influence on symmetry breaking during dewetting
- Effects at the three-phase contact line
- Continuum mechanical description of the hydrodynamics of interfaces
- Knowledge of the wetting of special (topographically or chemically structured) surfaces
- Overview of applications of capillarity in the context of wet granular matter and Wetting-dependent driven fluid fronts in porous media.

Content

- Fundamentals of capillarity
- Experimental methods, contact angle, surface tension and thin film measurements, scanning force microscopy and X-ray tomography
- Effects at the three-phase contact line
- Dewetting, driving forces for dewetting
- Marangoni effect (A new perspective on drinking red wine)
- Continuum description of long-range wetting forces and spinodal dewetting
- Hydrodynamics of interfaces such as Rayleigh plateau instability and Lucas-Washburn law
- Wetting of chemically and topographically structured surfaces (e.g. Wenzel model, Cassie-Baxter model, wetting of a wedge, superhydrophobic surfaces (lotus effect))
- Wetting of random close bead packs (how does water "glue" a sand castle together)
- Quasi-static description of a fluid front penetrating a porous medium (processes which occur in oil production on the length scale of individual pores)

Additional information

Language: English

Literature:
The course will follow the outline of the textbook "Capillarity and Wetting Phenomena - Drops, Bubbles, Pearls, Waves" by Pierre-Gilles de Gennes, Francois Brochard-Wyart and David Quéré. will follow. In individual topics, it will be supplemented by recent books and journal articles such as.
- S. Herminghaus, "Wet Granular Matter - A Truly Complex Fluid" World Scientific, Series in Soft Condensed Matter Vol. 6
- O. K. C. Tsui, T. P. Russell "Polymer Thin Films" World Scientific, Series in Soft Condensed Matter Vol. 1
- J. Israelachvili "Intermolecular and Surface Forces" Academic Press
- E. Y. Bormashenko "Wetting of real Surfaces" De Gruyter
- D. Myers "Surfaces, Interfaces and Colloids - Principles and Applications" Wiley-VCH

Name of the module **Experimental Techniques in Biophysics and Surface Science 1 & 2**					**ETBS**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**2 periods**	**4**	**2 x 2,5**

Responsible lecturer	Jacobs, Müller
Lecturer(s)	Jacobs, Müller
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Written or oral exam, seminar lectures on selected topics
Course type / weekly hours	2 hours in summer term for 15 weeks (part 1) 2 hours in winter term for 15 weeks (part 2) (by arrangement also as block course possible)
Workload	Lecture 2 hours x 15 (weeks) x 2 (periods) = 60 hours Preparation and reworking 1 hour x 15 x 2 = 30 hours Preparation of seminar lecture incl. literature search 30 hours Exam preparation 30 hours In total 150 hours
Grading	Final Exam

Aims/Competences to be developed

- Overview of basic experimental techniques and strategies used in condensed matter physics (with focus on soft matter, biophysics and surface science).
- Knowledge of the working principles of selected experimental techniques, their pros and cons and their limits.
- Ability to get familiar with new experimental techniques and to estimate their fields of application. Getting an overall picture by examining different aspects when using complementary techniques.
- Ability to find the right experimental techniques to answer a particular scientific issue.
- Preparing autonomously a specific topic by literature research.
- Practical exercises in the presentation of scientific contents.

Content

Part 1 (summer term): Experimental techniques in soft matter physics and biophysics

- Characterization and description of surfaces without crystalline order.
- Introduction to sample preparation for experiments under ambient conditions.
- Preparative techniques for surface modification (e.g. silanization, thiolzation, micro contact pressure (μCP), plasma etching, plasma polymerization).
- Experimental methods for surface characterization (especially atomic force microscopy (AFM) in different operation modes: contact or tapping mode; AFM based techniques for probing elasticity, adhesion and friction; ellipsometry; plasmon resonance spectroscopy; contact angle measurement; fluorescence microscopy and other optical methods).

- Many of the presented techniques are introduced in the field of polymer films or bio films (from proteins or bacteria) and can be practiced during lab visits.

Part 2 (winter term): Experimental techniques in surface science and solid state physics

- Characterization and description of surfaces, especially with crystalline order.
- Introduction to vacuum technology (e.g. generation of vacuum, pressure measurement in different ranges of vacuum).
- Preparative techniques for *in-situ* surface modification (chemical vapor deposition (CVD; physical vapor deposition (PVD); ion beam etching).
- Experimental methods for surface characterization: real space imaging (scanning tunneling microscopy (STM), scanning electron microscopy (SEM); diffraction techniques (low energy electron diffraction (LEED), X-ray photoelectron diffraction (XPD), X-ray diffraction (XRD); spectroscopy (X-ray photoelectron spectroscopy (XPS), ultraviolet photoelectron spectroscopy (UPS), electron energy loss spectroscopy (EELS).
- Many of the presented techniques are introduced via graphene or via materials that are important for application in life sciences.

Additional information

Language: English

Literature:

Experimental and Statistical Biological Physics (Experimental Biophysics)					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Univ.-Prof. Dr. A. Ott
Lecturer(s)	Univ.-Prof. Dr. A. Ott
Level of the unit	Master Physics - physics compulsory elective Master Biophysics - mandatory
Entrance requirements	For graduate students: none
Assessment / Exams	Written or oral examination at the end of the lecture. A second examination is possible at the beginning of the following semester Participation in the seminars/tutorials is required for taking the exam.
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	Grade is from the exam

Aims/Competences to be developed

The student will learn to recognize biological systems and problems that can be approached with physical knowledge.

Acquire knowledge about the application of important current methods from physics to chosen biological problems.

Placing currently employed, important, physical, statistical and experimental techniques within their scientific and technical context regarding biological physics.

Reach good understanding of essential, major questions and difficulties currently under study in the field.

Content

- Experimental methods employed in biological physics
- Intermolecular bonds and forces
- Biological transport
- Physical aspects of the cytoskeleton and cell mechanics
- Non-Gaussian distributions in Biology
- Criticality
- Evolution
- Pattern formation in Biology
- Genetic circuits
- Massily parallel measurements
- Molecular networks
- Chosen examples

Additional information

Language: English

- Literature: Alberts “Molecular biology of the Cell”, Taylor and Francis (recent edition is better)
- Lodish “Molecular Cell Biology” Freeman (recent edition is better).
- Murray „Mathematical Biology“, Springer, 3. Edition 2007
- T. Vicsek „Fluctuations and Scaling in Biology“, Oxford Univ. Press, 1. Edition 2001
- Original journal articles – will be announced during the lecture

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Name of the module **General Relativity**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**WS**	**1 Semester**	**4**	**5**

Responsible lecturer	Henkel
Lecturer(s)	Henkel
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Oral or written exam **regular and active participation at exercises required**
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	Grade is from the exam

Aims/Competences to be developed

Introduction into foundations, concepts and calculational methods of general relativity, understanding of physical problems discussed, the problems posed and the nature of the given answers.

Content

Conceptual foundations of general relativity, general co-variance, tensor calculus, experimental tests and perspectives to current research.
A brief reviews of special relativity is included in the programme. Particular emphasis will be given to a review of experimental test of general relativity.

Additional information

Language: English

Literature: textbooks of general relativity.

L. Ryder, *General Relativity*, Cambridge University Press (2009)
Cheng, Relativity, *Gravitation and Cosmology*, 2e éd., Oxford (2010)
C.M. Will, *Theory and experiment in gravitational physics*, 2e ed, Cambridge (2018)
S. Weinberg, *Gravitation and cosmology*, Wiley (1978)
A. Barrau, J. Grain *Relativité générale*, 2 e éd., Dunod (2016)

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Name of the module **General Relativity**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1-2	**2**		**1 Semester**	**3**	**3**

Responsible lecturer	Santen
Lecturer(s)	Santen
Level of the unit	Physics Compulsory Elective
Entrance requirements	For graduate students: none Content-related prerequisites: Basic knowledge in special relativity
Assessment / Exams	Oral examination
Course type / weekly hours	Lecture (2 hours weekly) Exercises (1 hour weekly)
Workload	• Attendance time lectures (15 weeks à 2 semester hours) = 30 hours • Attendance time exercises (15 weeks à 1 semester hours) = 15 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 45 hours
Grading	Grade of the oral exam

Aims/Competences to be developed

Students should

- After successful participation, understand the physical principles of general relativity
- Be able to apply the mathematical formalism of general relativity
- Get to know applications of general relativity theory

Content

- Riemannian differential geometry, metric description of curved spaces
- Description of general relativity as a geometric theory of gravitation
- Tensorial formulation of general relativity
- Einstein's field equations
- Gravitational waves

Additional information

Language: English

Literature: Will be announced in the lecture.

Name of the module **Introduction to Conformal Invariance**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**WS**	**1 Semester**	**2**	**2**

Responsible lecturer	Prof. Dr. Malte Henkel
Lecturer(s)	Prof. Dr. Malte Henkel (UHP Nancy I)
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none recommended: knowledge of statistical mechanics and continuous phase transitions
Assessment / Exams	Final written exam
Course type / weekly hours	Lecture (2 hours weekly)
Workload	60 h = 30 h of classes and 30 h private study
Grading	Final exam

Aims/Competences to be developed

Introduction to aims of methods of conformal invariance and introduction to problems of modern research in theoretical physics.

Content

In numerous many-body systems strong collective effects are seen, especially near continuous phase transitions. These occur in physically very different situations, but all share a common mathematical structure. Especially, not only does the naturally arise scale-invariance, but in many instances this can be generalised to the larger group of conformal transformations.

This class is for students, especially at the doctoral level, who already have some experience in methods and results of statistical mechanics. Starting from a phenomenology of phase transitions, the particularly rich situation of conformally invariance phase transitions in two dimension will be analysed in detail. This should equip for applications of conformal invariance in the context of condensed-matter physics, without the requirement of previous detailed knowledge of quantum field theory.

Si souhaité, ce cours pourra être donné en français.

Additional information

Language: English (ou bien français)

Literature:
P. di Francesco, P. Mathieu et D. Sénéchal, *Conformal field theory*, Springer (Heidelberg) M. Henkel, *Conformal invariance and critical phenomena*, Springer (Heidelberg)

Name of the module **Introduction to Cosmology**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**WS**	**1 Semester**	**2**	**2**

Responsible lecturer	Prof. Dr. Malte Henkel
Lecturer(s)	Prof. Dr. Malte Henkel (UHP Nancy I)
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none recommended: knowledge of statistical mechanics and continuous phase transitions
Assessment / Exams	Final written exam
Course type / weekly hours	Lecture (2 hours weekly)
Workload	60 h = 30 h of classes and 30 h private study
Grading	Final exam

Aims/Competences to be developed

Introduction to aims of methods of conformal invariance and introduction to problems of modern research in theoretical physics.

Content

In numerous many-body systems strong collective effects are seen, especially near continuous phase transitions. These occur in physically very different situations, but all share a common mathematical structure. Especially, not only does the naturally arise scale-invariance, but in many instances this can be generalised to the larger group of conformal transformations.

This class is for students, especially at the doctoral level, who already have some experience in methods and results of statistical mechanics. Starting from a phenomenology of phase transitions, the particularly rich situation of conformally invariance phase transitions in two dimension will be analysed in detail. This should equip for applications of conformal invariance in the context of condensed-matter physics, without the requirement of previous detailed knowledge of quantum field theory.

Si souhaité, ce cours pourra être donné en français.

Additional information

Language: English (ou bien français)

Literature:
P. di Francesco, P. Mathieu et D. Sénéchal, *Conformal field theory*, Springer (Heidelberg) M. Henkel, *Conformal invariance and critical phenomena*, Springer (Heidelberg)

Name of the module **Introduction into Soft Condensed Matter Physics**					**SCMP**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1**	**4**	**5**

Responsible lecturer	Jacobs, Seemann
Lecturer(s)	Jacobs, Seemann
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Written or oral exam, seminar lectures on selected topics
Course type / weekly hours	Lecture (3 hours weekly) Tutorial (1 hour weekly)
Workload	Lecture & tutorials: 4 hours over 15 weeks = 60 hours Preparation and reworking 2 hours x 15 = 30 hours Preparation of tutorial or seminar 30 hours Exam preparation 30 hours In total 150 hours
Grading	Grading from written or oral exam

Aims/Competences to be developed

- Overview of the basic concepts of soft condensed matter
- Knowledge of key experiments and experimental techniques/measurement methods: Atomic force microscopy, ellipsometry, scattering methods, etc.
- Ability to assess an experimental situation in the soft matter field and to propose possible investigation methods
- Independent study of a narrowly defined topic based on current literature
- Practice of presentation techniques

Content

- Introduction to the predominant interactions: intermolecular (van der Waals, Coulomb) forces, short-range forces
- Examples from experiment, theory and simulation (e.g. polymers, micelles, membranes, thin films, foams)
- Theoretical models to describe chain molecules, colloids, foams, and comparison with experimental results
- Overview of experimental techniques and their applicability
- Selected problems from current research: e.g. adsorption, adhesion, instabilities, microfluidic systems
- Practical demonstrations of available techniques (e.g. AFM) & hands-on experiments (e.g. on contact angles)

Additional information

Language: English

Literature:

- I.W. Hamley "Introduction to soft matter", Wiley & Sons, ISBN 978-0-47051610-2 (easy-written overview)
- R.A.L. Jones "Introduction to the physics of soft matter", Oxford University Press, ISBN 978-0-19850589-1
- J. Israelachvili "Intermolecular forces", Academic Press, ISBN-978-0-12375181-2

For selected topics:

- P.-G. de Gennes, F. Brochard-Wyart, D. Queré „Capillarity and Wetting Phenomena: Drops,
- Bubles, Pearls, Waves“, Springer, ISBN 978-0-38700592-8
- G. Gompper, M. Schick (Herausgeber) "Soft Matter" (Bände 1 – 4), Wiley-VCH, Bd 1: ISBN 978-3-52730500-1, Bd 2: ISBN 978-3-52731369-3, Bd 3: ISBN 978-3-52731370-9, Bd 4: ISBN 978-3-52731502-4
- M. Daoud, C.Q. Williams (Herausgeber) "Soft Matter Physics", Springer, ISBN 978-3-
- 54064852-9
- M. Kleman, O.D. Lavrentovich "Soft Matter Physics – an Introduction", Springer,
- ISBN 978-0-38795267-3
- D.F. Evans, H. Wennerström "The Colloidal Domain: Where Physics, Chemistry, Biology and
- Technics Meet", Wiley-VCH, ISBN 978-0-47124247-5
- P. Tabeling "Introduction to Microfluidics", Oxford University Press, ISBN 978-0-19856864-3
- J.-L. Barrat, J.-P. Hansen "Basic Concepts for Simple and Complex Liquids", Cambridge
- University Press, ISBN 978-0-52178953-0
- N.-T. Nguyen, S.T. Wereley "Fundamentals and Applications of Microfluidics", Artech House
- Publishers, ISBN 978-1-58053972-2
- H. Bruus, "Theoretical Microfluidics", Oxford University Press, ISBN 978-0-19923509-4

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Name of the module **Introduction to quantum information processing**					QIP
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Wilhelm-Mauch
Lecturer(s)	Wilhelm-Mauch, Morigi
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Oral or written exams Requirement for participating: Succesful completion of homework assignments
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	Mark of the oral or written exam

Aims/Competences to be developed
Understanding of important quantum algorithms and important protocols of quantum information
Competence to understand errors in open quantum systems and its correction
Competence to analyse candidates for the physical realization of quantum computers
Competence zo understand original research literature in this area

Contents
Structure of quantum theory from an information perspective, entanglement, mixed states
Elementary quantum logic gates and algorithms
Quantum teleportation and communication
Open quantum systems, quantum channels, theory of quantum error correction
Elementary theory or quantum measurements
Selected candidates for the physical realization of quantum computers

Additional information

Language: English

Literature:
J. Stolze, D. Suter: Quantum Computing
P. Kaye, R. Laflamme, M. Mosca: An Introduction to Quantum Computing
G. Benentii, G. Casati, G. Strini: Principles of Quantum Computation and Information (Vol. I+II) M. Nielsen, I. Chuang: Quantum Computation and Quantum Information
M. Nakahara, T. Ohmi: Quantum Computing from Linear Algebra to Physical Realizations
N.D. Mermin: Quantum Computer Science: An Introduction

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Name of the module **Laser cooling and trapping of particles**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Jürgen Eschner
Lecturer(s)	Jürgen Eschner
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none Recommended prerequisites: Atomic Physics; Quantum Optics; Quantum Theory
Assessment / Exams	Oral or written examination
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	By the result of the examination

Aims/Competences to be developed

- Overview of the basic concepts: experimental techniques and realizations, theoretical methods and models
- Establishing the relationship between theoretical models and experimental systems and results
- Knowledge of key experiments; overview of applications
- Study and elaboration of a specific topic based on provided literature
- Practice of presentation techniques

Content

- Light-atom interaction
- Mechanical effects of light
- Paul and Penning trap
- Dipole trap
- Magnetic and magneto-optical trap
- Other trapping techniques
- Laser cooling of free particles
- Laser cooling of trapped particles
- Special cooling techniques
- Applications: Quantum optics, quantum information, precision measurements, ultracold matter

Additional information

Language: English

Literature:
- Metcalf, v.d. Straten, Laser Cooling and Trapping
- Foot, Atomic Physics
- Cohen-Tannoudji, Guery-Odelin, Advances in Atomic Physics: An Overview
- further specific literature will be provided during the course

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Name of the module Modern Optics					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Univ.-Prof. Dr. A. Ott
Lecturer(s)	Univ.-Prof. Dr. A. Ott
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	

Aims/Competences to be developed
Develop a profound understanding of the fundamentals of waveoptics.
Knowledge about important technical applications of waveoptics.
The students should be comfortable with the working principles of basically all important wave optics based optical techniques.

Content
Electromagnetic waves, interference, Fresnel formulas, Fraunhofer and Fresnel diffraction, optical imaging, Fourier optics, optical fibers, optical modes, heterodyne detection, interferometers, photon sources, Wiener-Kinchin theorem, optical spectroscopy, special optical devices and applications

Additional information

Language: English

Literature: Hecht, Optics

Name of the module **Quantum and Modern Optics**					**QMO**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Becher
Lecturer(s)	Becher
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: non formal requirements. Required knowledge: fundamental knowledge at an intermediate level in optics, quantum physics and atomic physics (e.g. Experimental Physics III of the Bachelor course).
Assessment / Exams	Seminar presentation
Course type / weekly hours	Lecture (3 hours weekly) Seminar (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study • Attendance time lectures and seminar (15 weeks à 4 semester hours) = 60 hours • Time for preparation of seminar presentation (15 weeks à 4 semester hours) = 60 hours • Time for preparation and wrap-up of the lecture, (15 weeks à 2 semester hours) = 30 hours
Grading	Grade of seminar presentation

Aims/Competences to be developed

- Acquisition of knowledge of laser physics and basic quantum optics
- Acquisition of an overview concepts, methods, models, experiments and technical applications in laser physics and quantum optics
- Teaching of scientific methodology, in particular the ability to deal with relevant problems, i.e. to treat relevant problems quantitatively by means of mathematical formalisms and to solve them independently
- Familiarization with key experiments and experimental techniques/measurement methods
- Practice of advanced techniques of scientific work, in particular to find and understand scientific literature and to present relevant scientific content

Content

- Elements of a laser, simple models
- Light-matter interaction: classical dispersion theory
- Light-matter interaction: semiclassical description and coherent effects
- Optical resonators, Gaussian beams
- Laser dynamics, mode selection, spectral properties, noise
- Overview of laser types and technical realizations
- Special properties of laser light: coherence and photon statistics
- Quantum mechanical description of the light field, experimental realization of special light states
- Modern experiments in quantum optics

Additional information

Language: English

Literature:

- O. Svelto, "Principles of Lasers", 4. ed, Springer Verlag, 1998.
- P.W. Milonni, J.H. Eberly, “Lasers”, 1. ed, Wiley Interscience, 1989.
- D. Meschede, „Optcs, Light und Lasers“, 3. ed, Wiley VCH, 2017
- H.-A. Bachor, T.C. Ralph, „A Guide to Experiments in Quantum Optics“, 2. ed, Wiley-VCH, 2004.
- R. Loudon, „The Quantum Theory of Light“, 3. ed, Oxford University Press, 2000.
- M. Fox, “Quantum Optics”, 1. Auflage, Oxford University Press, 2006.
- C.C. Gerry, P.L. Knight, “Introductory Quantum Optics”, 1. ed, Cambridge University Press, 2005.

Name of the module **Nanomechanics**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**	**SS**	**1 Semester**	**4**	**5**

Responsible lecturer	Bennewitz
Lecturer(s)	Teacher in experimental physics
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Written exam or oral exam
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	Grade of written exam or of oral exam

Aims/Competences to be developed
Overview of fundamental concepts, experimental methods, and recent results in the field of mechanical properties of structures at the nanometer scale. Connecting theoretical concepts and results with experimental results. Knowing key models and experiments and their methods. Independent study of literature for on a given topic. Presenting results of literature studies.

Content
Fundamental relations between atomic structure and mechanical properties
Molecular vibrations
Experimental methods in nanomechanics
Molecular recognition in biophysics
Physics of single polymers
Friction phenomena on atomic scale
Recent research in nanomechanics

Additional information

Language: English

Literature:
Andrew N. Cleland: Foundations of Nanomechanics, Springer-Verlag Berlin Heidelberg 2003

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Name of the module **Nanostructure Physics II**					Nano II
Semester	Reference semester	Term **Yearly**	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Hartmann
Lecturer(s)	Professors of Experimental Physics
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Oral examination
Course type / weekly hours	Lecture (3 hours weekly) Seminar (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	From oral examination

Aims/Competences to be developed

- Broad overview on nanostructure research and nanotechnology
- Deeper treatment of selected subjects: Causal relationship between size and physical properties, scaling relations, quantum mechanical fundamentals
- Forces at nanomter scale, self assambly, analytical tools, micro-nano integration
- Presentation of main fields of nanostructured media: Nanoparticles, clusters fullerenes and nanotubes, devices of information technology
- Autonomous comprehension of selected areas based on the provided literature
- Optimization of presentation skills
- Classification oft the whole area with respect to fundamental and applied importance

Content

- Definition of the area of subject
- Historical developments
- Interdisciplinary fundamentals
- Key technologies
- Properties of condensed matter on the nanoscale
- Nanostructured materials
- Nanoscale devices
- Industrial applications
- Socioeconomic and ethical conditions

Additional information

Language: English

Literature:

- U. Hartmann, Nanotechnologie (Spektrum, Heidelberg, 2006)
- E. L. Wolf, Nanophysics and Nanotechnology (Wiley-VCH, Weinheim, 2004)
- M. Di Ventra, S. Evoy, J.R. Helfin Jr. (Eds.) Introduction to Nanoscale Science and Technology (Springer, New York, 2003)

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Name of the module **Nonlinear Dynamics and structure formation**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits 5
1	**1 or 2**		**1 semester**	**4**	

Responsible lecturer	Wagner
Lecturer(s)	Wagner
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Successful completion of exercises or seminar presentation; final oral examination.
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	From the result of the oral examination

Aims/Competences to be developed

- Overview of current research issues such as self-organization in hydrodynamic and
- The ability to do a simple linear stability analysis
- To be able to determine bifurcations of model systems
- To make an elementary analysis of chaotic systems

Content

- Classification of nonlinear differential equations
- Introduction to linear stability analysis
- Presentation of experimental model systems from hydrodynamics and biology - Bifurcations
- chaos theory
- Concepts of structure formation, Ginzburg Landau equations
- Structure formation in hydrodynamic and biological model systems
- Defects and fronts

Additional information

Language: English

Literature:
- Strogatz, Nonlinear Dynamics And Chaos: With Applications To Physics, Biology, Chemistry, And Engineering, Westview Press, ISBN 978-0738204536
- Daniel Waelgraf, Spatio-Temporal Pattern Formation: With Examples from Physics, Chemistry, and Materials Science, Springer, ISBN 978-1461273110
Scott Camazine et al., Self-Organization in Biological Systems, Princeton Univers. Press, ISBN 978-0691116242

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Name of the module **Nonlinear Optics**					. **NLO**
Semester	Reference semester	Term	Duration	Weekly hours	Credits 5
2	**2**	**Summer term**	**1 term**	**4**	**5**

Responsible lecturer	Priv.-Doz. Dr. rer. nat. Martin Straub
Lecturer(s)	Priv.-Doz. Dr. rer. nat. Martin Straub
Level of the unit	physics compulsory elective
Entrance requirements	No formal admission requirements
Assessment / Exams	Written test or oral exam
Course type / weekly hours	3 SWS Lecture, 1 SWS Seminar
Workload	Lecture: 45 hours, preparation and learning: 45 hours Seminar: 15 hours, preparation of presentation: 45 hours
Grading	Overall mark of the examination

Learning targets / Core competencies
- In-depth knowledge of basics (experiments, theory) and applications of nonlinear optics
  - Comprehension of fundamental differences between linear and nonlinear optics
  - Knowledge of optical effects not existing in linear optics and their technical significance
  - Insight into the role of nonlinear optics in important fields of applications such as optical telecommunication, high-resolution optical microscopy and lithography as well as laser technology
- Familiarness with the classical, semi-classical and, in part, also the quantum-electrodynamic treatment of nonlinear-optical processes and efficient usage of these formalisms.
- Individual exploration and presentation of current nonlinear-optical research topics

Topics / Contents
Wave propagation and wave coupling in nonlinear media. Nonlinear susceptibilities, their quantum-physical representation and symmetries. Snellius law of nonlinear optics, light fields at boundaries of nonlinear media. Electro- and magneto-optical effects, second harmonic generation and higher harmonics, sum and difference frequency generation, parametric amplification and oscillation. Stimulated Raman effect, two- and multiphoton absorption. Nonlinear-optical spectroscopy: Quantum beats, saturation spectroscopy, Doppler-free two-photon absorption spectroscopy, Ramsey fringes. Four-wave-mixing, coherent anti-Stokes Raman spectroscopy, phase-conjugate mirrors. Optically induced birefringence, Kerr effects, optical bistability, self-focusing and self-phase modulation. Transient optical effects: Optical Bloch equation, transient nutation, free induction decay, photon echos, adiabatic population inversion, self-induced transparency, superfluorescence. Strong light-matter interaction. Laser isotope separation, single-molecule spectroscopy. Nonlinear optics of surfaces, in waveguides and plasmas.

Additional information: Transparencies in English language
Working language: German, English (as desired)

Literature: [1] Y. R. Shen, **The Principles of Nonlinear Optics,** Wiley, 2003. [2] R. W. Boyd, **Nonlinear Optics,** Elsevier, 2008. [3] Y. V. G. S. Murti, C. Viljayan, **Physics of Nonlinear Optics,** 2nd ed., Springer, 2021. [4]. G. New**, Introduction to Nonlinear Optics,** Cambridge University Press, 2011. [5] G. Agrawal, **Nonlinear Fiber Optics,** Elsevier, 2012. [6] M. Wegener, **Extreme Nonlinear Optics,** Springer, 2004. [7] Further topical textbooks, reviews and journal articles as required.

Faculty of Natural Sciences and Technology
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Name of the module **Optik für Fortgeschrittene – Advanced Optics**					. **AO**
Semester	Reference semester	Term	Duration	Weekly hours	Credits 5
1	**3**	**Winter term**	**1 term**	**4**	**5**

Responsible lecturer	Priv.-Doz. Dr. rer. nat. Martin Straub
Lecturer(s)	Priv.-Doz. Dr. rer. nat. Martin Straub
Level of the unit	physics compulsory elective
Entrance requirements	No formal admission requirements
Assessment / Exams	Written test or oral exam
Course type / weekly hours	3 SWS Lecture, 1 SWS Seminar
Workload	Lecture: 45 hours, preparation and learning: 45 hours Seminar: 15 hours, preparation of presentation: 45 hours
Grading	Overall mark of the examination

Learning targets / Core competencies

- In-depth knowledge of fundamentals and applications in the following areas:
  - Light-matter interaction in dielectrics, semiconductors and metals
  - Design and characteristics of modern optical systems and components
  - Fourier methods in optics
  - High-resolution optical microscopy
  - Optical lithography, optical nanostructure generation; micro-, nano- and integrated optics

Special emphasis is placed on nonlinear optics and its applications:
  - Light emission and propagation in nonlinear media
  - Nonlinear-optical spectroscopy
  - Optically induced transient and stationary change of materials
  - Nonlinear optics of surfaces, in waveguides and in plasmas
- Solution of problems involving calculations with complex field functions and material variables
- Exploration and presentation of current research topics in applied optics.

Topics / Contents

Light propagation in matter: Dispersion, absorption, scattering. Polarization: Dichroism, birefringence. Optical components and systems: Adaptive optics, thick and aspheric lenses, ray tracing, aberrations. Emitters and detectors. Fourier optics and coherence theory. Optical sensors and metrology. Lithography, holography, optical nanostructure formation. Micro-, nano- and integrated optics.

Nonlinear optics: Wave propagation in nonlinear media, nonlinear susceptibilities, electro- and magneto-optical effects, second harmonic generation, sum and difference frequency generation, parametric amplification and oscillation, stimulated Raman effect, two-photon absorption, spectroscopy, Kerr effects, self-focusing and self-phase modulation, transient optical effects, strong light-matter interaction, laser isotope separation, nonlinear optics of surfaces, in waveguides and plasmas.

Additional information: Transparencies in English language
Working language: German, English (as desired)

Literature: [1] E. Hecht, **Optics,** 5th Global Edition, Pearson Higher Education, 2016; E. Hecht, **Optik,** 7. Aufl., De Gruyter Studium, 2018. [2] Y. R. Shen, **The Principles of Nonlinear Optics,** Wiley, 2003.

Name of the module **Phase Transitions**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**WS**	**1 Semester**	**2**	**2**

Responsible lecturer	Prof. Dr. Malte Henkel
Lecturer(s)	Prof. Dr. Malte Henkel (UHP Nancy I)
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none recommended: knowledge of statistical mechanics and continuous phase transitions
Assessment / Exams	Final written exam
Course type / weekly hours	Lecture (2 hours weekly)
Workload	60 h = 30 h of classes and 30 h private study
Grading	Final exam

Aims/Competences to be developed

Introduction to aims of methods of conformal invariance and introduction to problems of modern research in theoretical physics.

Content

In numerous many-body systems strong collective effects are seen, especially near continuous phase transitions. These occur in physically very different situations, but all share a common mathematical structure. Especially, not only does the naturally arise scale-invariance, but in many instances this can be generalised to the larger group of conformal transformations.

This class is for students, especially at the doctoral level, who already have some experience in methods and results of statistical mechanics. Starting from a phenomenology of phase transitions, the particularly rich situation of conformally invariance phase transitions in two dimension will be analysed in detail. This should equip for applications of conformal invariance in the context of condensed-matter physics, without the requirement of previous detailed knowledge of quantum field theory.

Si souhaité, ce cours pourra être donné en français.

Additional information

Language: English (ou bien français)

Literature:
P. di Francesco, P. Mathieu et D. Sénéchal, *Conformal field theory*, Springer (Heidelberg) M. Henkel, *Conformal invariance and critical phenomena*, Springer (Heidelberg)

Name of the module **Quantum theory of light**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Morigi
Lecturer(s)	Lecturers in theoretical physics
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none Recommended prerequisites: basic knowledge in atomic physics, theoretical quantum physics and statistical physics
Assessment / Exams	Written or oral exam
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study • Attendance time lectures (15 weeks à 3 semester hours) = 45 hours • Attendance time exercises (15 weeks à 1 semester hours) = 15 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 90 hours
Grading	Grade of the written or oral exam

Aims/Competences to be developed

Introduction to the methods of quantum optics
Overview of the basic concepts and methods of quantum optics
Independent study of a narrowly defined topic based on given literature

Content

- The quantum mechanical electromagnetic field. The quantum vacuum.
- Atom-Photon Interaction in the electric-dipole approximation.
- Open quantum systems: the master equation for spontaneous emission.
- Cavity quantum electrodynamics: Purcell effect, Jaynes-Cummings model.
- Quantum nonlinear optics.
- Electromagnetic-Induced Transparency.
- Basic of quantum reservoir engineering.

Additional information
Language: English

Literature:

- C. Cohen-Tannoudij, et al, Photons and Atoms, Wiley Ed. (1997).
- C. Cohen-Tannoudij, et al, Atom-Photon Interactions, Wiley Ed (1998).
- P.W. Milonni, The quantum vacuum, Academic Press Ed. (1994).
- J.J. Sakurai, Advanced Quantum Mechanics, Addison-Wesley Ed. (1967).
- W. H. Luisell, Quantum Statistical Properties of Radiation, Wiley Ed. (1973).
- C.W. Gardiner, P. Zoller, Quantum noise, Springer (2004).
- M. O. Scully, M. S. Zubairy, Quantum Optics, Cambridge University Press (1977)

Name of the module **Quantum Optics with Ultracold Atoms**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Morigi
Lecturer(s)	Morigi
Level of the unit	Physics Compulsory Elective
Entrance requirements	For graduate students: none recommended: successful participation in TP III
Assessment / Exams	Written or oral exam Prerequisite for participation: completion of the exercises
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study • Attendance time lectures (15 weeks à 3 semester hours) = 45 hours • Attendance time exercises (15 weeks à 1 semester hours) = 15 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 90 hours
Grading	Grade of the written or oral exam

Aims/Competences to be developed

- Understanding of important fundamentals of quantum statistics
- Understanding of important basics of many-particle physics
- Ability to understand field theoretical description of many-particle systems
- Ability to understand original literature in the field.

Content

- Bose-Einstein statistics and condensation
- Bose-Einstein statistics and condensation
- Quantum degenerate atomic gases and Bose-Einstein condensation in interacting systems
- Field-theoretical description of weakly interacting bosons.
- Superfluidity, Bose-Einstein condensates, and quantum coherence
- Bose-Einstein condensation in optical lattices
- Outlook: Ultracold Fermi gases, Quantum simulators with ultracold atoms.

Additional information

Students in the Bachelor of Physics are asked to consult the lecturer in advance.

Language: English

Literature:

- J. Leggett, Quantum Liquids
- L. Pitaevskii, S. Stringari, Bose-Einstein Condensation
- J. Pethick andH. Smith, Bose-Einstein Condensation in Dilute Gases
- S. Sachdev, Quantum Phase Transitions
- K. Huang, Statistical Mechanics

Name of the module **Rheology and Non Newtonian Fluid mechanics**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 semester**	**4**	**5**

Responsible lecturer	Wagner
Lecturer(s)	Wagner
Level of the unit	physics compulsory elective
Entrance requirements	For graduate students: none
Assessment / Exams	Successful completion of exercises or seminar presentation; final oral examination.
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grading	From the result of the oral examination

Aims/Competences to be developed

- Overview of current research issues such as microrheology, biological flow situations, industrial manufacturing processes of plastics.
- Knowledge of the continuum mechanical description of simple flow situations
- Overview of characteristic flow phenomena of complex fluids
- Knowledge of the relationship between microscopic models and macroscopic flow behavior for different model systems.
- Overview of modern measurement methods in flow measurement technology and rheology

Content

- Continuum mechanical description for simple and complex fluids: Lagrangian and Euler formalism, deformations, stress tensor, the Navier-Stokes equation and simple solutions.
- Microscopic models of various model systems such as polymers and colloids.
- Special flow phenomena
- Measurement methods such as classical rheology, extensional rheology, microrheology, rheooptical methods, particle imaging velocimetry, laser Doppler anemeometry and scattering experiments.

Additional information

Language: English

Literature: The courses do not follow a specific textbook. Supporting literature will be announced at the beginning of the course.

The following exemplary standard works are recommended:

- E. Guyon, J.P. Hulin, L. Petit, Physical Hydrodynamics, Oxford Uiniv. Press, 2000
- Ch. W. Macosko, Rheology: Principles, Measurements, and Applications, Verlag Wiley,1.Auflage, 1994
- M. Doi, S. F. Edwards, The Theory of Polymer Dynamics, Clarendon Press, Reprint edition, 1988
- G. Marrucci, R. B. Bird, C. F. Curtiss, R. C. Armstrong, O. Hassager, Dynamics of polymeric liquids, Vol 1 & 2, John Wiley & Sons, Inc., New York, 2nd Ed., 1987
- G.G. Fuller, Optical Rheometry of Complex Fluids, Oxford University Press, 1. Auflage,1997
- .E Cates, M.R Evans, Soft and Fragile Matter, Taylor & Francis 1. Auflage, 2000

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Name of the module **Stochastic Processes**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Santen
Lecturer(s)	Rieger, Santen
Level of the unit	Physics Compulsory Elective
Entrance requirements	For graduate students: none
Assessment / Exams	Oral or written examination: Prerequisite for participation: completion of the exercises.
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study • Attendance time lectures (15 weeks à 3 semester hours) = 45 hours • Attendance time exercises (15 weeks à 1 semester hours) = 15 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 90 hours
Grading	Grade of the oral or written exam

Aims/Competences to be developed

- Ability to describe stochastic processes mathematically
- Ability to analyze stochastic processes
- Ability to independently read current publications in the field of stochastic processes

Content

- Stochastic variables and random events
- Markov processes
- Master, Langevin, and Fokker-Planck equations
- Diffusion processes, stochastic integrals
- First-Passage Times, Rare Events

Additional information

Language: English

Literature:

- Kaprivsky, Redner, Ben-Naim: A Kinetic View of Statistical Physics
- van Kampen: Stochastic Processes in Physics and Chemistry
- Gardiner: Handbook of Stochastic Methods

November 12, 2024

Theoretical Biophysics – Advanced Concepts					**TBP**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 oder 2	**2**	**Annual/Winter Semester**	**1 Semester**	**4**	**5**

Responsible Lecturer	Santen
Lecturer	Hub, Rieger, Santen
Level of the unit / mandatory or not	Master Physics - Physics Compulsory Elective Master Biophysics -Mandatory
Entrance requirements	No formal requirements
Assessment / Exams	Passing the oral or written exam Successful completion of at least 50% of the exercises
Course Type/ weekly hours	• Lecture (3 hours weekly) • Tutorial (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study
Grade	Will be determined by the performance in the oral or written exams.

Goals/Competences:

- Theoretical analysis of biological systems
- Physical approach to biological systems
- Interdisciplinary communication skills
- Independent reading of recent scientific publications

Contents

- Introduction to cellular processes
- Network motifs, robustness
- Statistical physics of polymers
- Stochastic processes
- Molecular motors
- Dynamics of Axonems
- Dynamics of the cytoskeleton
- Evolutionary Dynamics

Further Information

Literature:

- U. Alon: An Introduction to Systems Biology
- P. Nelson: Biological Physics
- J. Howard: Mechanics of Motor Proteins and the Cytoskeleton
- M. Doi, S. Edwards: The Theory of Polymer Dynamics
- C. Gardiner: Handbook of Stochastic Methods

Name of the module **Theoretical physics for quantum technologies**					
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1 or 2	**2**		**1 Semester**	**4**	**5**

Responsible lecturer	Wilhelm-Mauch, Morigi
Lecturer(s)	Wilhelm-Mauch, Morigi
Level of the unit	Physics Compulsory Elective
Entrance requirements	For graduate students: none
Assessment / Exams	Oral or written examination Prerequisite for participation: completion of the exercises. Urgent recommendation: successful participation in TP III or TP III for LaG
Course type / weekly hours	Lecture (3 hours weekly) Exercises (1 hour weekly)
Workload	150 h = 60 h of classes and 90 h private study • Attendance time lectures (15 weeks à 3 semester hours) = 45 hours • Attendance time exercises (15 weeks à 1 semester hours) = 15 hours • Time for preparation and wrap-up of the lecture, completing the exercises, exam or test preparation = 90 hours
Grading	Grade of the written or oral examination

Aims/Competences to be developed

- Understanding of important fundamentals of quantum technologies
- Understanding of important quantum algorithms and protocols
- Ability to analyze, describe, and control the dynamics of open quantum systems
- Ability to understand original literature in the field

Content

- Structure of the quantum theory from the information point of view
- Elementary quantum mechanical logic gates and algorithms
- Quantum teleportation and quantum communication
- Elementary theory of quantum measurement
- Elementary theory of open systems
- Quantum channels, elementary theory of quantum error correction.

Additional information

Students in the Bachelor of Physics are asked to consult the lecturer in advance.

Language: English

Literature:

- J. Stolze, D. Suter: Quantum Computing
- G. Benentii, G. Casati, G. Strini: Principles of Quantum Computation and Information (Vol. I+II)
- M. Nielsen, I. Chuang: Quantum Computation and Quantum Information
- N.D. Mermin: Quantum Computer Science: An Introduction
- C.W. Gardiner and P. Zoller, Quantum Noise
- V. B. Braginsky, F. Ya. Khalili, Quantum measurement

Name of the module **Non-physics Compulsory Elective**					.
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**WS & SS**	**1 Semester**		**18**

Responsible lecturer	Examination Board Master Physics
Lecturer(s)	Lecturers of the course
Level of the unit	mandatory
Entrance requirements	For graduate students: no formal requirements
Assessment / Exams	Written or oral exam for each course
Course type / weekly hours	See description of each course that belongs to non-physics compulsory elective
Workload	The sum of all courses belonging to the non-physics compulsory elective must have a workload of at least 540 h (18 CP)
Grading	Written or oral exam. At least 9 CP must be graded

Learning Objectives/Competencies

- Learning the methodology and language of related scientific disciplines.
- Preparation for work in interdisciplinary research projects.
- Apply physical methods to interdisciplinary problems.
- See module descriptions of non-physics compulsory elective courses

Content

See module descriptions for the individual courses

Additional information

Appropriate non-physics compulsory elective courses will be offered each semester.

Image Processing and Computer Vision					IPCV
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1,2	**2**	**At least every two years**	**1 Semester**	**6**	**9**

Responsible Lecturer	Prof. Dr. Joachim Weickert
Lecturer	Prof. Dr. Joachim Weickert
Level of the unit / mandatory or not	non-physics compulsory elective
Entrance requirements	Undergraduate mathematics (e.g. Mathematik für Informatiker I-III) and elementary programming knowledge in C
Assessment / Exams	• For the homework assignments one can obtain up to 24 points per week. Actively participating in the classroom assignments gives 12 more points per week, regardless of the correctness of the solutions. To qualify for both exams one needs 2/3 of all possible points. • Passing the final exam or the re-exam. • A re-exam takes place during the last two weeks before the start of lectures in the following semester.
Course Type/ weekly hours	4 h lectures + 2 h tutorial = 6 h (weekly)
Workload	90 h of classes + 180 h private study = 270 h (= 9 ECTS)
Grade	Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

Goals/Competences:

Broad introduction to mathematical methods in image processing and computer vision. The lecture qualifies students for a bachelor thesis in this field. Together with the completion of advanced or specialised lectures (9 credits at least) it is the basis for a master thesis in this field.

Contents

Inhalt
1. Basics
    1.1 Image Types and Discretisation
    1.2 Degradations in Digital Images
2. Colour Perception and Colour Spaces
3. Image Transformations
    3.1 Continuous Fourier Transform
    3.2 Discrete Fourier Transform
    3.3 Image Pyramids
    3.4 Wavelet Transform
4. Image Compression
5. Image Interpolation
6. Image Enhancement
    6.1 Point Operations
    6.2 Linear Filtering and Feature Detection
    6.3 Morphology and Median Filters
    6.3 Wavelet Shrinkage, Bilateral Filters, NL Means
    6.5 Diffusion Filtering
    6.6 Variational Methods
    6.7 Deconvolution Methods
7. Texture Analysis
8. Segmentation
    8.1 Classical Methods
    8.2 Variational Methods
9. Image Sequence Analysis
    9.1 Local Methods
    9.2 Variational Methods
10. 3-D Reconstruction
    10.1 Camera Geometry
    10.2 Stereo
    10.3 Shape-from-Shading
11. Object Recognition
    11.1 Hough Transform
    11.2 Invariants
    11.3 Eigenspace Methods

Further Information

Literature:
Will be announced before the start of the course on the course page on the Internet.

Programming 1					**Prog1**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**1**	**WS**	**1 semester**	**6**	**9**

Responsible Lecturer	Prof. Dr. Gert Smolka
Lecturer	Prof. Dr. Gert Smolka Prof. Dr.-Ing. Holger Hermanns Prof. Bernd Finkbeiner, Ph.D
Level of the unit / mandatory or not	non-physics compulsory elective
Entrance requirements	No formal requirements
Assessment / Exams	• Weekly exercises / tests • Midterm and endterm exam • Re-examination at end of semester
Course Type/ weekly hours	4 h lectures + 2 h tutorial = 6 h (weekly)
Workload	90 h of classes + 180 h private study = 270 h (= 9 ECTS)
Grade	Grade combines performance in exams and weekly exercises.

Goals/Competences:

- functional programming, higher-order and typed
- practical programming skills using an interpreter, debugging, testing
- recursive data structures and recursive algorithms (numbers, lists, trees)
- exceptions
- type abstraction and modularity
- data structures with mutable state, exceptions
- correctness proofs and runtime estimates
- structure of programming languages
- formal description of programming languages (syntax and semantics)
- implementation of programming languages (parsers, interpreters, compilers, stack machines)

Contents

see above

Further Information

Literature:
Will be announced before the start of the course on the course page on the Internet.

Programming 2					**Prog 2**
Semester	Reference semester	Term	Duration	Weekly hours	Credits
2	**6**	**SoSe**	**1 semester**	**6**	**9**

Responsible Lecturer	Prof. Dr. Sebastian Hack
Lecturer	Prof. Dr. Sebastian Hack Prof. Dr. Jörg Hoffmann
Level of the unit / mandatory or not	non-physics compulsory elective
Entrance requirements	Programming 1 and Mathematics for Computer Scientists 1 and mathematics courses in the study semester or comparable knowledge from other mathematics courses (recommended)
Assessment / Exams	Examination performances are given in two parts, which contribute equally to the final grade. To pass the entire course, each part must be passed individually. In the **practical part**, students must implement a series of programming tasks independently. These programming tasks allow students to practise language concepts and also introduce more complex algorithms and data structures. Automatic tests check the quality of the implementations. The grade of the practical part is largely determined by the test results. In the **lecture part**, students must complete written examinations and work on exercises. The exercises deepen the material of the lecture. Admission to the written examination depends on the successful completion of the exercises. In the practical part, a follow-up task can be offered.
Course Type/ weekly hours	4 h lectures + 2 h tutorial = 6 h (weekly)
Workload	90 h of classes + 180 h private study = 270 h (= 9 ECTS)
Grade	Will be determined from performance in exams, exercises and practical tasks. The exact modalities will be announced at the beginning of the module.

Goals/Competences:
This course teaches the foundations of imperative and object-oriented programming.
In more detail students learn:
* how computers execute programs and how to write programs in assembly language * to implement, debug, and test smaller C programs * to design, implement, debug, and test mid-size Java programs * the basics of object-oriented programming * a basic understanding of formal semantics, type systems, correctness, testing, and verification of imperative languages

Contents

- Programming at the machine level (assembly)
- Imperative programming
- Object-oriented programming
- Classes and objects
- Inheritance, sub-typing, and dynamic dispatch
- Formal semantics and a type system of a simple imperative language
- Type safety, undefined behavior and their implications
- Foundations of testing and verification

as well as lectures specifically designed for the individual programming tasks.

Further Information
Literature:
Will be announced before the start of the course on the course page on the Internet.

Partielle Differentialgleichungen I (Partial Differential Equations I)					PDG I
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**Mind. einmal alle 2 Jahre**	**1 Semester**	**V4 + Ü2**	**9**

Responsible Lecturer	Prof. Fuchs
Lecturer	Dozent(Inn)en der Mathematik, insbesondere mit Forschungsschwerpunkt im analytischen Bereich
Level of the unit / mandatory or not	non-physics compulsory elective
Entrance requirements	No formal requirements (Recommended: Analysis I, II + III, Linear Algebra I + II)
Assessment / Exams	Regelmäßige, aktive Teilnahme an der Vorlesung und an den begleitenden Übungen; Abschlussprüfung
Course Type/ weekly hours	Vorlesung (4 SWS), Übung (2 SWS)
Workload	60 h Kontaktzeit für die Vorlesung, 30 h Kontaktzeit in den Übungen 180 h Selbststudium (Vor- und Nachbereitung, Bearbeitung von Übungsaufgaben) – insgesamt 270 h
Grade	Durch Klausur(en) und/oder mündliche Prüfung. Der Modus wird zu Beginn der Vorlesung bekannt gegeben

Contents

- Beispiele für partielle Differentialgleichungen, Klassifikation, elementare Lösungsmethoden
- Lineare elliptische Gleichungen der Ordnung zwei: Maximumprinzipien, Existenz- und Eindeutigkeitsaussagen für verschiedene Randwertaufgaben
- Diskussion der Anfangs/Randwertaufgabe für lineare parabolische und hyperbolische Probleme
- Optional: Einführung in die Theorie nichtlinearer partieller Differentialgleichungen

Further Information
Unterrichtssprache: Deutsch, bei Bedarf auch Englisch

Literature:

J. Jost, Partielle Differentialgleichungen. Springer 1998.
D. Gilbarg, N.S. Trudinger, Elliptic partial differential equations of second order. Springer 1983.
F. John, Partial Differential Equations. Springer 1982.
A. Friedman, Partial Differential Equations of parabolic type. Prentice-Hall 1964.
L.C. Evans, Partial Differential Equations. American Mathematical Society. Graduate Studies in Mathematics, Volume 19,1991.
Weitere Angaben werden jeweils vor Beginn der Vorlesung auf der Vorlesungsseite im Internet bekannt gegeben.
Methoden: Information durch Vorlesung; Vertiefung durch Eigentätigkeit (Nacharbeit, Übungen).
Anmeldung: Bekanntgabe jeweils rechtzeitig vor Semesterbeginn durch Aushang und im Internet.

Variationsrechnung					**VR**
Studiensem.	Regelsem.	Turnus	Dauer	SWS	ECTS-Punkte
1	**2**	**unregelmäßig**	**1 Semester**	**6**	**9**

Modulverantwortliche(r)	M. Fuchs
Dozent(inn)en	Dozenten der Mathematik
Zuordnung zum Curriculum	non-physics compulsory elective
Zulassungsvoraussetzungen	Analysis I – III, Lineare Algebra I + II (empfohlen)
Leistungskontrollen / Prüfungen	Regelmäßige, aktive Teilnahme an der Vorlesung und an den begleitenden Übungen; Abschlussprüfung.
Lehrveranstaltungen / SWS	Vorlesung (4 SWS), Übung (2 SWS)
Arbeitsaufwand	60 h Kontaktzeit für die Vorlesung, 30 h Kontaktzeit in den Übungen, 180 h Selbststudium (Vor- und Nachbereitung, Bearbeitung von Übungsaufgaben) – insgesamt 270 h.
Modulnote	Durch die Klausur(en) oder mündliche Prüfung. Der Modus wird zu Beginn der Vorlesung bekannt gegeben.

Inhalt

- Beispiele für unendlichdimensionale Extremwertaufgaben: Minimalflächen, Harmonische Abbildungen zwischen Riemannschen Mannigfaltigkeiten, elastisches und plastisches Materialverhalten
- Funktionalanalytische Grundlagen: Sobolevräume und ihre Eigenschaften
- Die direkte Methode der Variationsrechnung: Unterhalbstetigkeitssätze und Existenz schwacher Minima für konvexe Probleme
- Entwicklung einer Regularitätstheorie für einfache Modelle
- Variationsprobleme aus Fluid- und Kontinuumsmechanik

Weitere Informationen

Unterrichtssprache: deutsch, bei Bedarf auch englisch

Literaturhinweise:

B. Dacorogna, Direct methods in the calculus of variations. Springer 1988
M . Giaquinta, Multiple integrals in the calculus of variations and nonlinear elliptic systems. Princeton UP 1983
M. Fuchs, Topics In The Calculus Of Variations, Vieweg Verlag 1994
M. Fuchs, G. Seregin, Variational methods for problems from plasticity theory and for generalized Newtonian fluids. Springer LNM 1749
(2000)

Weitere Angaben warden jeweils vor Beginn der Vorlesung auf der Vorlesungsseite im Internet bekannt gegeben.

Methoden: Information durch Vorlesung; Vertiefung durch Eigentätigkeit (Nacharbeit, Übung)

Anmeldung: Bekanntgabe jeweils rechtzeitig vor Semesterbeginn durch Aushang und im Internet

Funktionalanalysis I (Functional Analysis I)					FkAna1
Semester	Reference semester	Term	Duration	Weekly hours	Credits
1	**2**	**Mind. einmal alle 2 Jahre**	**1 Semester**	**V4 + Ü2**	**9**

Responsible Lecturer	Prof. Weber
Lecturer	Dozent(Inn)en der Mathematik, insbesondere mit Forschungsschwerpunkt im analytischen Bereich
Level of the unit / mandatory or not	non-physics compulsory elective
Entrance requirements	No formal requirements (Recommended: Analysis I, II + III, Linear Algebra I + II)
Assessment / Exams	Regelmäßige, aktive Teilnahme an der Vorlesung und an den begleitenden Übungen; Abschlussprüfung
Course Type/ weekly hours	Vorlesung (4 SWS), Übung (2 SWS)
Workload	60 h Kontaktzeit für die Vorlesung, 30 h Kontaktzeit in den Übungen 180 h Selbststudium (Vor- und Nachbereitung, Bearbeitung von Übungsaufgaben) – insgesamt 270 h
Grade	Durch Klausur(en) und/oder mündliche Prüfung. Der Modus wird zu Beginn der Vorlesung bekannt gegeben

Contents

- Grundlagen aus der Topologie (metrische und topologische Räume, Kompaktheit, ggf. lokalkonvexe Räume)
- Banachräume und Banachalgebren, ggf. C*-Algebren, Gelfand-Transformation, Satz von Stone-Weierstraß
- Hilberträume
- beschränkte Operatoren (auf Banach- und Hilberträumen, kompakte Operatoren)
- Satz von Hahn-Banach, Trennungssätze, Dualräume und Reflexivität
- Satz von Baire (u.a. Satz von der offenen Abbildung, Prinzip der gleichmäßigen Beschränktheit)
- Spektraltheorie von kompakten und normalen Operatoren (ggf. analytischer Funktionalkalkül)
- optional: Fredholmoperatoren
- optional: unbeschränkte Operatoren

Further Information
Unterrichtssprache: Deutsch oder Englisch

Literature:
W. Rudin: Functional Analysis, 1991.
J. Conway, A Course in Functional Analysis, 1985.
H. Heuser, Funktionalanalysis, 2006.
F. Hirzebruch, W. Scharlau, Einführung in die Funktionalanalysis, 1991.
W. Kaballo, Grundkurs Funktionalanalysis, 2011.
R. Meise, D. Vogt, Einführung in die Funktionalanalysis, 2011.
H. Schröder, Funktionalanalysis, 2000.
Weitere Angaben jeweils vor der Vorlesung auf der Vorlesungsseite im Internet.
Methoden: Information durch Vorlesung; Vertiefung durch Eigentätigkeit (Nacharbeit, Übungen).
Anmeldung: Bekanntgabe jeweils rechtzeitig vor Semesterbeginn durch Aushang

Name of the module **Grundlagen der Materialchemie**					. **MatChem I**
Studiensem.	Regelstudiensem.	Turnus	Dauer	SWS	ECTS-Punkte
6	**6**	**jährlich**	**1 Semester**	**4**	**6**

Modulverantwortliche/r	Kickelbick
Dozent/inn/en	Kickelbick, Kraus,
Zuordnung zum Curriculum	non-physics compulsory elective
Zulassungsvoraussetzungen	Modul AAI Praktikum PKG: ACI, AnII, OCIII
Leistungskontrollen / Prüfungen	Abschlussklausur zur Vorlesung (benotet), Seminarvortrag (unbenotet); Praktikum: Testat, Protokolle (unbenotet)
Lehrveranstaltungen / SWS	**MaC01** Einführung in die Materialchemie**,** 2V + 1S **PKG** Praktikum Kolloide und Grenzflachen, 3 P
Arbeitsaufwand	**MaC01** Vorlesung: 7,5 Wochen, 4 SWS 30 h Vor- und Nachbereitung, Prüfung 45 h (zus. 2,5 CP) **MaC01** Seminar: 7,5 Wochen, 2 SWS 15 h Vor- und Nachbereitung, Prüfung 15 h (zus. 1 CP) **PKG** 3 Wochen Blockpraktikum 55 h Vor-/Nachbereitung 20 h (zus. 2,5 CP) Summe: 180 h (6 CP)
Modulnote	Note der Klausur. Praktikum und Seminar unbenotet.

Lernziele/Kompetenzen

Die Studierenden erwerben Kenntnisse in Kernbereichen der Materialchemie und Materialwissenschaften:

MaC01:

- Überblick über chemische Bindungen und ihr Einfluss auf Materialeigenschaften
- Verständnis von fundamentalen chemischen Ansätzen zur Synthese von Materialien
- Vergleich verschiedener Methoden zur Charakterisierung von Materialien
- Überblick zur molekularen Materialchemie
- Verständnis der Chemie von Funktionswerkstoffen
- Eigenständiges Erarbeiten eines materialchemischen Themas und Präsentation vor dem Auditorium

PKG:

- Verständnis disperser Systeme mit Partikeln verschiedener Größenbereiche
- Synthese von Nanopartikel-Suspensionen auf unterschiedlichen Wegen
- Verständnis des kolloidalen Verhaltens von Partikeln
- Relevanz von Grenzflachen in dispersen Systemen
- Charakterisierung von Suspensionen durch optische Spektroskopie und Streuung
- Kennenlernen technischer Anwendungsbereiche disperser Partikel
- Präparation von Materialien und Schichten aus Partikeln
- Kennenlernen der elektronenmikroskopischen Untersuchung von Partikeln

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Inhalt
<u>**MaC01** *Einführung in die Materialchemie mit Seminar (3,5 CP)*</u>:

- Ionische, kovalente und metallische Bindungsbeschreibung und die Auswirkung auf Materialeigenschaften
- Prinzipien der Synthese von Materialien an ausgewählten Materialklassen (z.B. anorganische nichtmetallische Feststoffe)
- Unterschiede in der Synthese von Materialien in Abhängigkeit der Aggregatszustande
- Materialcharakterisierung von Feststoffen und Flüssigkeiten: Möglichkeiten und Grenzen: Röntgenbeugung, Röntgenstreuung, bildgebende Verfahren, NMR-, IR-, Raman-Spektroskopie, thermische Verfahren, Kopplungstechniken)
- Molekulare Materialchemie: Rolle der Gestalt von Molekülen, chemische Reaktivität, Selbstanordnungsphänomene, Kristallisation
- Chemie von ausgewählten Funktionswerkstoffen: Gläser, Hochleistungskeramiken, Membrane, optische und photonische Materialien, Oberflächenchemie von Materialien, Biomaterialien, Nanomaterialien

<u>**PKG** Praktikum Kolloide und Grenzflachen (2,5 CP)</u>:
5 Gruppen von Experimenten:

- Siliziumdioxidpartikel: Synthese, Modifikation, Charakterisierung, Herstellung eines Opals
- Goldpartikel: Synthese, Modifikation, Charakterisierung, Agglomeration
- Halbleiterpartikel: Synthese, Fluoreszenzeigenschaften, Einbau in ein Nanokomposit
- Titandioxidpartikel: Synthese, Extraktion aus Sonnencreme, Charakterisierung, Photokatalyse
- Keramische und andere Partikel: Rheologie von Schlickern, Rus, Aktivkohle

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Weitere Informationen

Unterrichtssprache: Deutsch oder Englisch (Unterlagen vielfach auf Englisch)

Literaturhinweise:
MaC01:
Vorlesung auf Powerpoint-Folien (zum Download im Internet zuganglich).
Introduction to Materials Chemistry, H.R. Allcock, Wiley
Materials Chemistry, B.D. Fahlman, Springer
Understanding Solids – The Science of Materials, R. Tilley, Wiley

PKG:
D. F. Evans and H. Wennerstrom, „The colloidal domain: where physics, chemistry, biology, and technology meet", 2nd edition, Wiley, 1999.
R. Jelinek, „Nanoparticles", 1st edition, De Gruyter, 2015.
G. Schmid: „Nanoparticles : from theory to application", 2nd edition, Wiley, 2010.
T. F. Tadros, „Interfacial Phenomena and Colloid Stability: Basic Principles", 1st edition, De Gruyter, 2015.

Anmeldung zum Praktikum per email: praktikum-kolloide@uni-saarland.de

Name of the module **Objektorientierte Sprachen und generische Programmierung ITG2 (ab WS 21/22)**					. **ITG2**
Studiensem.	Regelstudiensem	Turnus	Dauer	SWS	ECTS-Punkte
Ba 5, Ma 1	**Ba 5, Ma 1**	**WS**	**1 Sem.**	**6**	**9**

Modulverantwortliche/r	Hoffmann
Dozent/inn/en	Hoffmann, N.N.
Zuordnung zum Curriculum	Master-Physics, non-physics compulsory elective, Bachelor Physik, Wahlpflichtbereich
Zulassungsvoraussetzungen	keine
Leistungskontrollen / Prüfungen	Klausur und/oder Projektarbeiten
Lehrveranstaltungen / SWS	3V 3Ü
Arbeitsaufwand	- Präsenzzeit Vorlesungen: 15 Wochen à 3 SWS 45 h - Präsenzzeit Übung: 5 Wochen à 3 SWS 45 h - Vor- und Nachbereitung Vorlesung, Bearbeitung der Übungsaufgaben, Projekt- und Klausurvorbereitung 180 h Summe 270 h
Modulnote	benotet

Lernziele/Kompetenzen

Die Veranstaltung vermittelt fundierte theoretische und praktische Kenntnisse aus den Bereichen objektorientierte Programmiersprachen (OOP) und generische Programmierung (GP), sowie elementare Grundlagen über Software Design Pattern (SDP) und über theoretische Informatik (lexikalische und syntaktische Analyse, Datenstrukturen, Algorithmen).

Kenntnisse in OOP, GP und vor allem in SDP stellen fundamentale und außerordentlich nützliche Hilfsmittel bzgl. Algorithmen und Datenstrukturen bei der Implementierung komplexer physikalischer Probleme dar (Simulationen).

Vorkenntnisse: die Kenntnis einer Programmiersprache ist hilfreich in einer Vorlesung über objektorientierte Programmierung, ist aber keine notwendige Bedingung, da wir mit C++ bei „Null“ beginnen.

Aus dem Inhalt:

- Theorie und Praxis objektorientierter Programmiersprachen
- Generische Programmierung (Templates, Traits, Constraints, Concepts, SDP)
- Software Design Pattern: „Das richtige Klassen-Konzept für jede Problemkategorie“
- Algorithmen und Datenstrukturen: Deterministische und nicht-deterministische Programmierung, Parallelisierung und Nebenläufigkeit...
- Grundlagen der theoretischen Informatik (Grammatiken, Sprachen, Parser, Code-Generierung)
- Optionale Themen (Linux-Kernelmodule und Device-Treiber, Assembler, Informationstheorie)

Weitere Informationen

Für weitere Fragen: https://alpha.lusi.uni-sb.de/chhof

Unterrichtssprache: deutsch

Literaturhinweise:

Es existiert ein ausführliches, umfangreiches und quasikontinuierlich aktualisiertes Skript inkl. sämtlicher Materialien (Aufgaben, Lösungen, Codes, Datenblätter, Literatur, ...) als Attachments unter

https://alpha.lusi.uni-sb.de/chhof/Skript.pdf

Name of the module **Digitalelektronik und digitales Schaltungsdesign (ITG 3) (ab WS 21/22)**					. **ITG 3**
Studiensem.	Regelstudiensem.	Turnus	Dauer	SWS	ECTS-Punkte
2	**2**	**SS**	**1 Sem.**	**6**	**9**

Modulverantwortliche/r	Hoffmann
Dozent/inn/en	Hoffmann, N.N
Zuordnung zum Curriculum	Master-Physics, non-physics compulsory elective
Zulassungsvoraussetzungen	Keine formale Voraussetzungen
Leistungskontrollen / Prüfungen	Klausur und/oder Projektarbeiten
Lehrveranstaltungen / SWS	3V 3Ü
Arbeitsaufwand	- Präsenzzeit Vorlesungen:15 Wochen à 3 SWS 45 h - Präsenzzeit Übung: 15 Wochen à 3 SWS 45 h - Vor- und Nachbereitung Vorlesung, Bearbeitung der Übungsaufgaben, Klausur- oder Prüfungsvorbereitung 180 h Summe 270 h
Modulnote	Benotet

Lernziele/Kompetenzen

Lernziele: Vermittelt werden breitgefächerte und anwendungsnahe (Grund-)Kenntnisse aus den Gebieten Analog- und Digitalelektronik, sowie analoge und digitale Schaltungstechnik. Dabei steht die Entwicklung einer vollständigen 8-Bit CPU und deren Implementierung auf einem FPGA am Ende der Veranstaltung. Die dazu notwendigen Grundlagen der Automatentheorie, Digitalelektronik und Rechnerarchitektur werden erarbeitet.

Kompetenzen: Wesentliches Ziel ist die Entwicklung des physikalischen Verständnisses für elektronische und elektrotechnische Zusammenhänge und deren Übertragung auf allgemeine physikalische Systeme, sowie die Umsetzung praktischer Mess-, Steuer- und Regeltechniken mit Mitteln der Analog- bzw. Digitalelektronik.

Weitere Kompetenzen: Die Handhabung typischer Messgeräte wie Oszilloskop, Spektrum-Analyzer und Logic-Analyzer zur Analyse und Fehlersuche wird in einer Vielzahl praktischer Aufgaben eingeübt. Damit soll die Veranstaltung eine wesentliche Lücke zwischen der theoretisch-physikalischen Ausbildung und den Anforderungen der experimentellen Arbeit schließen.

Vorkenntnisse: Elementare mathematische und physikalische Kenntnissen der ersten beiden Bachelor-Semester sind hilfreich aber nicht notwendig. Insbesondere sind keine Programmierkenntnisse nötig.

Inhalt

Einige der Themen sind obligatorisch, einige optional und werden je nach Interessen und Wünschen der Teilnehmer behandelt.

- Grundlagen Analogelektronik: Lineare Systemtheorie, Laplace-Transformation und komplexe Übertragungsfunktion, lineare und nichtlineare elektronische Bauelemente und Kleinsignalanalyse (physikalisch: lineare Störungstheorie)
- Digitalelektronik: Gatter, Boolesche Logik, kombinatorische und sequentielle Schaltungstechnik
- Arbeiten mit Oszilloskop, Spektrum-Analyzer, Logic-Analyzer, etc.
- Entwicklung einer 8-Bit CPU in Verilog und Implementierung auf FPGA

Weitere Informationen

Für weitere Fragen: https://alpha.lusi.uni-sb.de/chhof

Unterrichtssprache: deutsch

Literaturhinweise:

Es existiert ein ausführliches, umfangreiches und quasikontinuierlich aktualisiertes Skript inkl. sämtlicher Materialien (Aufgaben, Lösungen, Codes, Datenblätter, Literatur, ...) als Attachments unter

https://alpha.lusi.uni-sb.de/chhof/Skript.pdf

Name of the module **Language course (Niveau minimum B1, English minimum C1)**					.
Semester	Reference semester.	Term	Duration	Weekly hours	Credits
1-6	**6**	**Each Semester**	**1 Sem.**	**2-4 & indiv.**	**Max. 4**

Responsible lecturer	Dr. Peter Tischer, Head of language center
Lecturer(s)	https://www.szsb.uni-saarland.de/personal.html
Level of the unit	Master Physics, non-physics compulsory elective (contributable at level minimum B1, for English minimum C1)
Entrance requirements	For beginner: none French, English, Spanish: Mandatory placement test Advanced courses: Proof of courses taken or conversations with the lecturer
Assessment / Exams	Final exam and class attendance (at least 80%)
Course type / weekly hours	Seminar with 2 -4 SWS, independent learning with monthly meetings and 4-week intensive courses with 4 hours of lessons per day. Group of 6 – 40 students
Workload	2 SWS: 90 h = 30 h Seminar and 60 h self-study 4 SWS: 180 h = 80 h Seminar and 100 h self-study
Grading	Ungraded

Learning Objectives/Competencies

At the appropriate level:

- Reading comprehension
- Listening comprehension
- Speaking skills
- grammar
- Writing training

Content

Depending on course

Additional information

Language of instruction: German and language taught

Literature: Depending on course

Media form: books, projector, slides, blackboard, language lab, video