Module manual for
Physics
MSPhy

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RWTH AACHEN UNIVERSITY

Module manual for Physics (Master (1-Subject))

Module manual for
Physics
MSPhy

Examination Regulation Field

Module offer

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Examination Regulation Title & Version:
Physics (SPO Version / 2013)

Title	Physics
Short title	MSPhy
Version	2013
Study/Qualification Objectives	Graduates of the Master's degree program physics have acquired deepened knowledge and skills in the field of physics. They can understand, analyze and evaluate physical principles. The students exhibit high scientific qualification and autonomy and are capable of critical placement of scientific results and responsible practice. By choosing a specialization track, they possess an intensive deepened knowledge in a sub-area of physics. In an optional subsidiary subject, the students can connect the physics learned to adjacent parts of science or to applications in engineering or medicine.
Qualification Profile	
Additionnal information	

Module titel	Particle Physics I (Compulsory elective subject)
Identifier	1310597
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Basic concepts in particle physics: elementary particles, fundamental interactions and their corresponding particles, origin of mass. Quantum numbers, classification of hadrons, symmetries and conservation laws. Dirac equation, Quantum Electrodynamics, Feynman rules, Quantum Chromodynamics, electroweak interactions. Measurement concepts: accelerators, detectors, data analysis.
Learning Objectives/ Learning Outcomes	The students understand the basic concepts of particle physics. They explain the organization into particles of matter, particles for mediating interactions and the origin of mass. They know the relevant quantum numbers and are able to apply them in the classification of hadrons. They calculate the particle kinematics in different inertial systems within the framework of special relativity theory and use the Mandelstam variables. Students know how a particle accelerator and the different detector concepts work. They perform data analyses with these detectors on the computer. Students understand the Dirac equation and write down matrix elements for the interactions of quantum electrodynamics, quantum chromodynamics and weak interaction according to Feynman rules. ;Students understand how one calculates cross sections from matrix elements and the phase space and how one compares them with measured data.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	D. Perkins, Introduction to High Energy Physics K. Kleinknecht, Detektoren für Teilchenstrahlung F. Halzen, A.D. Martin, Quarks and Leptons D. Griffith, Introduction to Elementare Particles C. Berger, Elementarteilchenphysik P. Schmüser, Feynman-Graphen und Eichtheorien für Experimentalphysiker
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Martin Erdmann
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

Experimental Particle Physics
Particle Physics I (1310597)

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particle Physics I: Lecture and Exercises (131059702)	1st semester	no semester recommended	0	6
Particle Physics I: Examination (131059701)	1st semester	no semester recommended	10	0

Module titel	Particle Physics II (Compulsory elective subject)
Identifier	1310598
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Electron-positron collisions, deep-inelastic lepton-nucleon scattering, two-photon physics, photoproduction, diffractive scattering, hadron collider physics, jet physics, fragmentation, strong coupling constant, W and Z boson physics, Higgs physics, unification of the electromagnetic and weak interactions, heavy quark physics with top and bottom quarks, measurement of CP violation, CKM matrix, neutrino physics, neutrino oscillations, double beta decay, Higgs physics, Supersymmetry, searches for physics beyond the Standard Model of particle physics, relations to cosmology.
Learning Objectives/ Learning Outcomes	The students understand the principle of local gauge invariance and explain the terms of the Lagrange density of the Standard Model of particle physics. They also understand the Higgs mechanism for mass generation. Furthermore, they know the main experiments of the last 30 years and are able to name their contributions to the understanding of particle physics. These include in particular the tests of the electroweak interaction in the LEP collider, the deep inelastic lepton-nucleon scattering to study the proton structure, the physics at the Hadron Collider with W, Z, top quarks &; Higgs, and neutrino physics. In all areas, students name the specific requirements for the experiments and their realization, and perform data analyses on the computer for the experiments. Furthermore, they understand the range of validity of the Standard Model of particle physics.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	R.K. Ellis, W.J. Stirling, B.R. Webber, QCD and Collider Physics V. Barger, R. Phillips, Collider Physics R.G. Roberts, The Structure of the Proton M. Erdmann, The Partonic Structure of the Photon N. Schmitz, Neutrinophysik M. Drees, R. Godbole, P. Roy, Theory and Phenomenology of Sparticles
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Martin Erdmann
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

– Experimental Particle Physics
+ Particle Physics II (1310598)

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particle Physics II: Lecture and Execises (131059802)	2nd semester	no semester recommended	0	6
Particle Physics II: Examination (131059801)	2nd semester	no semester recommended	10	0

Module titel	Laboratory Course Particle Physics (Compulsory elective subject)
Identifier	1310599
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Preparatory course: • Brief introduction to experimental particle physics • Particle detectors • Read out electronic • Radiation and laser safety • Theoretical introduction to the experiments of the laboratory class • Data analysis • Experimental uncertainties • Scientific writing (notations, protocol, discussion) Laboratory class (selected experiments from following list): • Determination of the drift velocity of gases with a drift chamber • Life time of positrons in solid state bodies • Life time of muons • Quadrupol ion trap (Paul trap) • Saturated absorption spectroscopy • Production and decay of W bosons • Geant 4 and the spectrum of cosmic muons • Accelerator physics • Measurement of the pp->ttbar cross section and the top-quark with the CMS detector • Air shower array
Learning Objectives/ Learning Outcomes	The students can apply experimental techniques to measurement tasks in elementary particle physics. The students have a wide range of laboratory skills needed to design and safely conduct experiments including high voltages and radioactive sources. The students can develop modern experiments using a variety electronic equipment for fast analog and digital signal processing. The students know how to collect and/or process the raw data from the individual experiments. The students can interpret the measured data quantitatively, evaluate the measurement outcome and compare with the expectation. The students can analyse the precision of the measurement result by taking into account various sources of uncertainty. The students know how to document scientifically the planning of experiments, the experimentation procedures, the data taking, the evaluation of the experimental data including error and uncertainty determination and detailed discussion of the results.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Instruction manuals and literature given therein
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work

Miscellaneous	-
Module coordinator	Oliver Pooth
ECTS Credits	10
Contact time (WSH)	8
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	120,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Particle Physics: Laboratory Course (131059901)	2nd semester	no semester recommended	10	8

Module titel	Particle Physics I (Compulsory elective subject)
Identifier	1310597
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Basic concepts in particle physics: elementary particles, fundamental interactions and their corresponding particles, origin of mass. Quantum numbers, classification of hadrons, symmetries and conservation laws. Dirac equation, Quantum Electrodynamics, Feynman rules, Quantum Chromodynamics, electroweak interactions. Measurement concepts: accelerators, detectors, data analysis.
Learning Objectives/ Learning Outcomes	The students understand the basic concepts of particle physics. They explain the organization into particles of matter, particles for mediating interactions and the origin of mass. They know the relevant quantum numbers and are able to apply them in the classification of hadrons. They calculate the particle kinematics in different inertial systems within the framework of special relativity theory and use the Mandelstam variables. Students know how a particle accelerator and the different detector concepts work. They perform data analyses with these detectors on the computer. Students understand the Dirac equation and write down matrix elements for the interactions of quantum electrodynamics, quantum chromodynamics and weak interaction according to Feynman rules. ;Students understand how one calculates cross sections from matrix elements and the phase space and how one compares them with measured data.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	D. Perkins, Introduction to High Energy Physics K. Kleinknecht, Detektoren für Teilchenstrahlung F. Halzen, A.D. Martin, Quarks and Leptons D. Griffith, Introduction to Elementare Particles C. Berger, Elementarteilchenphysik P. Schmüser, Feynman-Graphen und Eichtheorien für Experimentalphysiker
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Martin Erdmann
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particle Physics I: Lecture and Exercises (131059702)	1st semester	no semester recommended	0	6
Particle Physics I: Examination (131059701)	1st semester	no semester recommended	10	0

Module titel	Quantum Field Theory of Particle Physics I (Compulsory elective subject)
Identifier	1310601
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Relativistic quantum mechanics: Klein-Gordon, Dirac and Proca equations; representations of the Poincare group; discrete symmetries C, P and T; free quantum fields. Canonical quantization: Lagrangian and Hamiltonian formalism, Noether theorem, quantization of scalar, spinor and vector fields; Gupta-Bleuler quantization of QED; perturbation theory; scattering theory; basic processes in QED. Path integral quantization: Quantum Mechanics; Lagrange and Hamilton formulation for bosons; generating functionals; fermionic path integrals; Faddeev-Popov quantization of QED. Radiative corrections: Euler-Heisenberg effective action; evaluation methods for quantum corrections; basics of renormalization; anomalous magnetic moment; Lamb shift; infrared divergences in QED.
Learning Objectives/ Learning Outcomes	The students have a working knowledge of the quantum field theory of particle physics as a foundation for performing their own research in this field. They are familiar with the framework of special relativity as applied to quantum mechanical systems at the level of single-particle states and quantum fields. They understand the derivation and limitations of perturbation theory. They know diagrammatic and path-integral methods for the modelling of particle physics processes. In particular, they can calculate cross sections for simple two-to-two processes, as well as electromagnetic properties of elementary particles, for example the anomalous magnetic moment of fermions. The students master collaborative learning, presentation of results and social peer support in small group discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory C. Itzykson, J.B. Zuber, Quantum Field Theory
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michal Czakon
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Field Theory of Particle Physics I: Lecture and Exercises (131060102)	1st semester	no semester recommended	0	6
Quantum Field Theory of Particle Physics I: Examination (131060101)	1st semester	no semester recommended	10	0

Module titel	Theory of Relativity and Cosmology (Compulsory elective subject)
Identifier	1311068
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Introduction to the theory of general relativity as a theory of gravity (mathematical foundations, foundations of differential geometry, the metric as a field, Einsteins field equations, simple effects like gravitational red shift or clocks in gravitational fields). Black holes and gravitational waves. Cosmology: homogeneous and isotropic universe; dark matter and dark energy; physics of the early universe; structure formation and inflation.
Learning Objectives/ Learning Outcomes	Understanding of gravitational interactions, the history of the universe and the ability to mathematically describe the evolution of a homogeneous universe.
(Study-Specific) Prerequisites	None
(recommended) Requirements	Module „Spezielle Relativitätstheorie/ Kosmologie“
References	Weinberg: Gravitation and Cosmology Wald: General Relativity Kolb, Turner: The Early Universe
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Lesgourgues, Julien
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theory of Relativity and Cosmology: Examination (131106801)	1st semester	no semester recommended	10	0
Theory of Relativity and Cosmology: Lecture and Exercises (131106802)	1st semester	no semester recommended	0	6

Module titel	Astroparticle Physics (Compulsory elective subject)
Identifier	1310600
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Experimental methods: satellites, air-shower detectors underground detectors Extended air showers, cascade equations, experimental observables Cosmic rays, energy spectrum composition, the knee, the ankle, the GZK cutoff Cosmic gamma radiation, production and detection results Neutrino astronomy: solar, supernova and high energy, oscillations Astrophysical sources of cosmic rays, acceleration and propagation Dark matter, experimental methods for direct and indirect detection, astrophysical models Contemporary results in the aforementioned fields
Learning Objectives/ Learning Outcomes	Experimental methods, astro physics, particle physics with cosmic radiation
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	D. Perkins: Particle Astrophysics Th. K. Gaisser: Cosmic ray and particle physics T.Stanev: High energy Cosmic rays, M. S. Longair: High Energy Astrophysics
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Christopher Wiebusch
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Astroparticle Physics: Lecture and Exercises (131060002)	2nd semester	no semester recommended	0	6
Astroparticle Physics: Examination (131060001)	2nd semester	no semester recommended	10	0

Module titel	Quantum Field Theory of Particle Physics I (Compulsory elective subject)
Identifier	1310601
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Relativistic quantum mechanics: Klein-Gordon, Dirac and Proca equations; representations of the Poincare group; discrete symmetries C, P and T; free quantum fields. Canonical quantization: Lagrangian and Hamiltonian formalism, Noether theorem, quantization of scalar, spinor and vector fields; Gupta-Bleuler quantization of QED; perturbation theory; scattering theory; basic processes in QED. Path integral quantization: Quantum Mechanics; Lagrange and Hamilton formulation for bosons; generating functionals; fermionic path integrals; Faddeev-Popov quantization of QED. Radiative corrections: Euler-Heisenberg effective action; evaluation methods for quantum corrections; basics of renormalization; anomalous magnetic moment; Lamb shift; infrared divergences in QED.
Learning Objectives/ Learning Outcomes	The students have a working knowledge of the quantum field theory of particle physics as a foundation for performing their own research in this field. They are familiar with the framework of special relativity as applied to quantum mechanical systems at the level of single-particle states and quantum fields. They understand the derivation and limitations of perturbation theory. They know diagrammatic and path-integral methods for the modelling of particle physics processes. In particular, they can calculate cross sections for simple two-to-two processes, as well as electromagnetic properties of elementary particles, for example the anomalous magnetic moment of fermions. The students master collaborative learning, presentation of results and social peer support in small group discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory C. Itzykson, J.B. Zuber, Quantum Field Theory
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michal Czakon
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Field Theory of Particle Physics I: Lecture and Exercises (131060102)	1st semester	no semester recommended	0	6
Quantum Field Theory of Particle Physics I: Examination (131060101)	1st semester	no semester recommended	10	0

Module titel	Quantum Field Theory of Particle Physics II (Compulsory elective subject)
Identifier	1310602
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Gauge theories: gauge groups and classical Lagrangians; Faddeev-Popov quantization of non-abelian gauge theories; BRST symmetry and canonical quantization; one-loop radiative corrections; running coupling and asymptotic freedom; basic processes in perturbative QCD. Spontaneous symmetry breaking: degenerate ground states in many-body physics; spontaneous symmetry breaking of global discrete symmetries; continuous symmetries and Goldstone theorem; chiral symmetry breaking; non-linear realizations of symmetry and chiral perturbation theory; Higgs mechanism; structure of the Standard Model. Anomalies: Adler-Bell-Jackiw anomaly in cut-off and dimensional regularizations; anomalies in path integrals; anomaly cancellation; phenomenological applications to neutral pion decays; U(1) problem. Introduction to physics beyond the Standard Model.
Learning Objectives/ Learning Outcomes	The students have a working knowledge of the quantum field theory of particle physics as a foundation for performing their own research in this field. They are familiar with the framework of non-abelian gauge theories both in the case of exact and spontaneously broken symmetry. They understand the problems related to quantization and renormalization of such theories. They know the physical basis of spontaneous symmetry breaking of exact and approximate symmetries, e.g. chiral symmetry. They understand the theoretical structure of the Standard Model, and can deal with anomalies. The students master collaborative learning, presentation of results and social peer support in small group discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory C. Itzykson, J.B. Zuber, Quantum Field Theory
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michal Czakon
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Field Theory of Particle Physics II: Lecture and Exercises (131060202)	2nd semester	no semester recommended	0	6
Quantum Field Theory of Particle Physics II: Examination (131060201)	2nd semester	no semester recommended	10	0

Module titel	Theory of Relativity and Cosmology (Compulsory elective subject)
Identifier	1311068
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Introduction to the theory of general relativity as a theory of gravity (mathematical foundations, foundations of differential geometry, the metric as a field, Einsteins field equations, simple effects like gravitational red shift or clocks in gravitational fields). Black holes and gravitational waves. Cosmology: homogeneous and isotropic universe; dark matter and dark energy; physics of the early universe; structure formation and inflation.
Learning Objectives/ Learning Outcomes	Understanding of gravitational interactions, the history of the universe and the ability to mathematically describe the evolution of a homogeneous universe.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Module „Spezielle Relativitätstheorie/ Kosmologie“
References	Weinberg: Gravitation and Cosmology Wald: General Relativity Kolb, Turner: The Early Universe
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Lesgourgues, Julien
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theory of Relativity and Cosmology: Examination (131106801)	1st semester	no semester recommended	10	0
Theory of Relativity and Cosmology: Lecture and Exercises (131106802)	1st semester	no semester recommended	0	6

Module titel	Condensed Matter Physics I (Compulsory elective subject)
Identifier	1311069
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	- Defects, elastic/plastic deformation - thermal conductivity, heat capacity, thermal expansion - Many body Schrödinger Equation: Exchange Interaction, Spin-Orbit-Coupling, Correlation, 2. Quantisation - Transport theory: Scattering Mechanisms - optical properties (dielectric function, .. golden rule) - Magnetism (Stoner Modell, ... Spin waves) - Superconductivity (BCS- Modell, ..., Josephson-Effects) - experimental methods
Learning Objectives/ Learning Outcomes	Lecture: The students should obtain an in-depth understanding of essential effects and concepts in solid state physics. The lectures focus on the relationship between the quantum mechanical description of microscopic processes and macroscopic measureable quantities and phenomena. Exercise: The students should apply the knowledge obtained in the lectures to solve tasks of different complexity. This includes understanding and discussing scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics I: Lecture and Exercises (131106902)	1st semester	no semester recommended	0	6
Condensed Matter Physics I: Examination (131106901)	1st semester	no semester recommended	10	0

Module titel	Condensed Matter Physics II (Compulsory elective subject)
Identifier	1310603
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	The course consists of up to four blocks of varying content. Typical block topics are: Qubits, quantum information and decoherence Modern solid state optics Modern experimental methods Functional materials Soft matter + biophysics Surface and interface physics Spintronics Interactions in in reduced dimensions Correlation effects Electrons and disorder
Learning Objectives/ Learning Outcomes	Lecture: The students will obtain an overview of modern research topics in solid state physics. To this end, each block will concentrate on one area. The students will thus be put in a position to follow selected current research fields. Tutorials: The students are to apply the knowledge obtained from the lecture by solving problems of various difficulties. Example exercises relating to recent original research literature should introduce them to current topics and reading scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Hendrik Bluhm
ECTS Credits	10
Contact time (WSH)	6

Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics II: Lecture and Exercises (131060302)	2nd semester	no semester recommended	0	6
Condensed Matter Physics II: Examination (131060301)	2nd semester	no semester recommended	10	0

Experimental Condensed Matter Physics
Laboratory Course Solid State Physics (1310604)

Module titel	Laboratory Course Solid State Physics (Compulsory elective subject)
Identifier	1310604
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Lecture: scanning probe methods, 2 dimensional electron gas, quantum hall effect, superconductivity, Josephson effect, magnetism, inelastic light scattering, light emission in solid-state, excitons, modulus of elasticity and sound propagation, measurement analysis Laboratory Course: various experiments, e.g. scanning/magnetic force microscopy, quantum transport, SQUID, photoluminescence, Raman scattering, ultrasound, laboratory experiment
Learning Objectives/ Learning Outcomes	Independent planning of the experiment, careful logging of experimental work, practical work, estimate of measurement uncertainties, elaboration of experiments with error calculation and discussion of results
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Instruction manuals and literature given therein
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Bernd Beschoten
ECTS Credits	10
Contact time (WSH)	10
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	150,0
Self-study hours (h)	150,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Condensed Matter Physics: Laboratory Course (131060401)	2nd semester	no semester recommended	10	8

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Condensed Matter Physics: Lecture	2nd semester	no semester recommended	-	2

Module titel	Condensed Matter Physics I (Compulsory elective subject)
Identifier	1311069
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	- Defects, elastic/plastic deformation - thermal conductivity, heat capacity, thermal expansion - Many body Schrödinger Equation: Exchange Interaction, Spin-Orbit-Coupling, Correlation, 2. Quantisation - Transport theory: Scattering Mechanisms - optical properties (dielectric function, .. golden rule) - Magnetism (Stoner Modell, ... Spin waves) - Superconductivity (BCS- Modell, ..., Josephson-Effects) - experimental methods
Learning Objectives/ Learning Outcomes	Lecture: The students should obtain an in-depth understanding of essential effects and concepts in solid state physics. The lectures focus on the relationship between the quantum mechanical description of microscopic processes and macroscopic measureable quantities and phenomena. Exercise: The students should apply the knowledge obtained in the lectures to solve tasks of different complexity. This includes understanding and discussing scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Nanoelectronics
Condensed Matter Physics I (1311069)

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics I: Lecture and Exercises (131106902)	1st semester	no semester recommended	0	6
Condensed Matter Physics I: Examination (131106901)	1st semester	no semester recommended	10	0

Module titel	Novel Materials and Devices for Information Technology 1 (Compulsory elective subject)
Identifier	6011259
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	State variables for memories and processing of information; fundamental principles of logic and memory devices; physical limits of scaling (thermodynamic, quantum mechanical, electromagnetic limit) # Mesoscopic transport and interconnects # Charge-based memorys (DRAM, ferroelectric memories) # Magneto electronic memories # Redox-based and phase-change-based resistive memories # New mass storage concepts (scanning probe methods) # Alternative logic concepts (spintronics, OFETs, molecular electronics) # Architectural concepts for alternative logic and memory devices
Learning Objectives/ Learning Outcomes	The students shall # Learn the fundamental principles that are used for information processing devices (logic) and information storage devices (memory) # Comprehend the potential of new materials and functions beyond conventional semiconductors # Acquire the ability of appraising the limits of scaling and # Comprehend new logic devices und memory concepts with help of concrete examples
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Präsentationsfolien, # Nanoelectronics and Informationtechnology, (Ed.) R. Waser, WILEY-VCH
Language	German/English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Rainer Waser
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Novel Materials and Devices for Information Technology 1 (601125901)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Novel Materials and Devices for Information Technology 1	1st semester	no semester recommended	-	3

Module titel	Novel Materials and Devices for Information Technology 2 (Compulsory elective subject)
Identifier	6011260
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	# Compound semiconductor materials and devices # Organic semiconductors # Optical communications # Cell-electronics coupling # Displays
Learning Objectives/ Learning Outcomes	The students # gain an understanding of the basic requirements for optical data communication systems and learn about current components and solutions # understand the fundamental properties of compound and organic semiconductors and learn the physical principles of active devices such as high electron mobility transistors, light emitting diodes and laser diodes, including technological implementations and fabrication. # aquire the basics of cell physiology as well as information transport in biological system # use basic electrical engineering knowledge to describe the modeling and coupling of cells and electronic devices. # Understand new lighting concepts taking into account human color perception
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Präsentationsfolien, # Nanoelectronics and Informationtechnology, (Ed.) R. Waser, WILEY-VCH
Language	German/English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Andrei Vescan
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Novel Materials and Devices for Information Technology 2 (601126001)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Novel Materials and Devices for Information Technology 2	2nd semester	no semester recommended	-	3

Module titel	Laboratory Course Nanoelectronics (Compulsory elective subject)
Identifier	1310605
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	Lecture: scanning probe methods, 2 dimensional electron gas, quantum hall effect, superconductivity, Josephson effect, magnetism, inelastic light scattering, light emission in solid-state, excitons, modulus of elasticity and sound propagation, measurement analysis Laboratory Course: various experiments, e.g. scanning/magnetic force microscopy, quantum transport, SQUID, photoluminescence, Raman scattering, ultrasound, laboratory experiment
Learning Objectives/ Learning Outcomes	Independent planning of the experiment, careful logging of experimental work, practical work, estimate of measurement uncertainties, elaboration of experiments with error calculation and discussion of results
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Instruction manuals and literature given therein
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Bernd Beschoten
ECTS Credits	10
Contact time (WSH)	10
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	150,0
Self-study hours (h)	150,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Nanoelectronics: Laboratory Course (131060501)	2nd semester	no semester recommended	10	8

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Nanoelectronics: Lecture	2nd semester	no semester recommended	-	2

Module titel	Condensed Matter Physics I (Compulsory elective subject)
Identifier	1311069
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	- Defects, elastic/plastic deformation - thermal conductivity, heat capacity, thermal expansion - Many body Schrödinger Equation: Exchange Interaction, Spin-Orbit-Coupling, Correlation, 2. Quantisation - Transport theory: Scattering Mechanisms - optical properties (dielectric function, .. golden rule) - Magnetism (Stoner Modell, ... Spin waves) - Superconductivity (BCS- Modell, ..., Josephson-Effects) - experimental methods
Learning Objectives/ Learning Outcomes	Lecture: The students should obtain an in-depth understanding of essential effects and concepts in solid state physics. The lectures focus on the relationship between the quantum mechanical description of microscopic processes and macroscopic measureable quantities and phenomena. Exercise: The students should apply the knowledge obtained in the lectures to solve tasks of different complexity. This includes understanding and discussing scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics I: Lecture and Exercises (131106902)	1st semester	no semester recommended	0	6
Condensed Matter Physics I: Examination (131106901)	1st semester	no semester recommended	10	0

Quantum Theory of Condensed Matter I (1310606)

Module titel	Quantum Theory of Condensed Matter I (Compulsory elective subject)
Identifier	1310606
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	• Advanced topic in quantum mechanics • Many-body theory (second quantization) • Green's functions • Linear response theory • Diagrammatic formalism (finite temperature) • Electrons and phonons • Superconductivity
Learning Objectives/ Learning Outcomes	The students can apply the theoretical concepts of Green's functions, Feynman diagrams and linear transport theory. The students have proficiency in theoretical notions for its application in various other courses. The students can analyse and evaluate the basic principles of the physics of electrons, phonons and superconductivity in solid state materials. The students can clearly distinguish the different aspects of quasiparticle concepts, screening properties, and symmetry breaking.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Fetter, Walecka: Quantum Theory of Many-Particle Systems • Mahan: Many-Particle Physics • Philipps: Advanced Solid State Physics • Bruns, Flensberg: Many-Body Quantum Theory in Condensed Matter Physics • Abrikosov, Gorkov, Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics • Wen: Quantum Field Theory of Many-Body Systems • Negele, Orland: Quantum Many Particle Systems
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Herbert Schoeller
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Quantum Technology
Quantum Theory of Condensed Matter I (1310606)

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory of Condensed Matter I: Lecture and Exercises (131060602)	1st semester	no semester recommended	0	6
Quantum Theory of Condensed Matter I: Examination (131060601)	1st semester	no semester recommended	10	0

Module titel	Theoretical Solid State Physics (Compulsory elective subject)
Identifier	1310607
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Bonding and structure of crystals, reciprocal lattice, Bloch Theorem, electronic band structures, lattice vibrations, transport properties, optical and collective excitations, superconductivity, magnetic properties of solids.
Learning Objectives/ Learning Outcomes	Understanding of the main principles and phenomena in solid state physics from the theoretical perspective.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Blügel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Solid State Physics: Lecture and Exercises (131060702)	1st semester	no semester recommended	0	6
Theoretical Solid State Physics: Examination (131060701)	1st semester	no semester recommended	10	0

Module titel	Hardware Platforms for Quantum Technology (Compulsory elective subject)
Identifier	1321355
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Quantum vs. classical physics, review of concepts of quantum mechanics, entanglement, basic ideas of quantum computing, communication and sensing, known algorithms, DiVincenzo criteria, quantum error correction, charge and spin qubits, macroscopic quantum coherence, Josephson junctions, superconducting qubits, quantum states of photons, Bloch sphere, qubit control, Rabi flopping, basic concepts of decoherence and of dephasing, pulse sequences.
Learning Objectives/ Learning Outcomes	The students will get an overview of key concepts for several quantum technologies and common hardware platforms. The exercises will train them to quantitatievely and qualitatively understand the device physics and dynamics of qubit devices.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Bluhm, Jörg Hendrik
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Hardware Platforms for Quantum Technology (132135501)	1st semester	no semester recommended	5	3

Module titel	Laboratory Course Quantum Technology (Compulsory elective subject)
Identifier	1321353
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	The students will perform QT-related experiments on their own. Possible experiments include: 1) NMR spectroscopy 2) Hong-Ou-Mandel (HOM) photon interference effect 3) Quantum transport The students will carry out the following practical experiments with help of tutors: 1) Scanning tunneling microscope 2) Spin coherence in 2D semiconductors 3) Micro- and Nano-lithography 4) Microwave readout of a SQUID 5) Electron spin qubits
Learning Objectives/ Learning Outcomes	The students will understand basic concepts of quantum technology by performing ex-periments on their own with the help of tutors. The students will independently plan the experiment, carefully log the experimental work, practical work, estimate measurement uncertainties, elaborate on the experiments with error calculation and discuss the ob-tained results.The students will be trained to write the laboratory reports, and high quality research papers. The students will be exposed to various laboratory components which will help them to design the quantum devices related to quantum technology in research laboratories or in industry.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Schreiber, Lars Reiner
ECTS Credits	5
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	75,0

Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Quantum Technology (132135301)	1st semester	no semester recommended	5	5

Module titel	Quantum Information (Compulsory elective subject)
Identifier	1310608
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Quantum Information: • States (mixtures, marginals, ensembles, bipartite states, purification) • Measurements (effects operators, POVM, measurement operators, state discrimination, state identification, instruments, information-disturbance, remote steering) • Evolutions (complete positivity, channels, state-evolution correspondence, unitary dilation, complementary channel, entropy exchange, decoupling principle, error-correction conditions, recovery channel) • Entanglement (entropy, LOCC, majorization, single-copy conversion, typicality, asymptotic conversion) Quantum Computing: • Deutsch algorithm • Classical logic gates • Single-qubit gates • Circuits and entanglement • Deutsch-Jozsa algorithm and Bernstein-Vazirani problem: examples of algorithmic speedup • Universality of classical and quantum gates • No-cloning theorem • Teleportation • Computational complexity • Grover's search algorithm • Quantum Fourier transform • Phase estimation • Order finding • Shor's large-number factoring algorithm • RSA public key cryptography • Quantum key distribution and cryptography • Error correction codes • Stabiliser formalism • Error propagation and fault-tolerance • Topological error correction codes • Hybrid quantum-classical algorithms • Digital simulation
Learning Objectives/ Learning Outcomes	The students know the fundamentals of quantum computation and the information approach to quantum theory. They have a working knowledge of their basic tools and are ready to perform their own research in this field. They are able to make predictions for open quantum systems involving mixed states, POVM measurements, non-unitary evolutions and exchange of classical information. For few-qubit systems they can derive such descriptions from projective measurement models with pure states and unitary evolutions. They are familiar with standard examples of measurements (pretty good measurement, conclusive discrimination) and channels (dephasing, depolarizing, amplitude damping) and standard protocols for entanglement processing. The students are able to construct, analyse and predict the effect of basic quantum circuits and protocols. They understand the working principles of quantum computation, communication and cryptography protocols, the physical ingredients, limitations (no-cloning) and advantages offered (e.g. computational speed-ups). Furthermore, they appreciate current challenges (errors, scalability) and approaches pursued

	(error correction, hybrid algorithms) towards the realization of near-term and future large-scale quantum information processors.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Michael A. Nielsen and Isaac L. Chuang: Quantum Computation and Quantum Information, Cambridge University Press, 2000
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	David DiVincenzo
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Information: Lecture and Exercises (131060802)	2nd semester	no semester recommended	0	6
Quantum Information: Examination (131060801)	2nd semester	no semester recommended	10	0

Module titel	Quantum Theory of Condensed Matter I (Compulsory elective subject)
Identifier	1310606
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Advanced topic in quantum mechanics • Many-body theory (second quantization) • Green's functions • Linear response theory • Diagrammatic formalism (finite temperature) • Electrons and phonons • Superconductivity
Learning Objectives/ Learning Outcomes	The students can apply the theoretical concepts of Green's functions, Feynman diagrams and linear transport theory. The students have proficiency in theoretical notions for its application in various other courses. The students can analyse and evaluate the basic principles of the physics of electrons, phonons and superconductivity in solid state materials. The students can clearly distinguish the different aspects of quasiparticle concepts, screening properties, and symmetry breaking.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Fetter, Walecka: Quantum Theory of Many-Particle Systems • Mahan: Many-Particle Physics • Philipps: Advanced Solid State Physics • Bruns, Flensberg: Many-Body Quantum Theory in Condensed Matter Physics • Abrikosov, Gorkov, Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics • Wen: Quantum Field Theory of Many-Body Systems • Negele, Orland: Quantum Many Particle Systems
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Herbert Schoeller
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Condensed Matter Theory
Quantum Theory of Condensed Matter I (1310606)

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory of Condensed Matter I: Lecture and Exercises (131060602)	1st semester	no semester recommended	0	6
Quantum Theory of Condensed Matter I: Examination (131060601)	1st semester	no semester recommended	10	0

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Condensed Matter Theory
Theoretical Solid State Physics (1310607)

Module titel	Theoretical Solid State Physics (Compulsory elective subject)
Identifier	1310607
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Bonding and structure of crystals, reciprocal lattice, Bloch Theorem, electronic band structures, lattice vibrations, transport properties, optical and collective excitations, superconductivity, magnetic properties of solids.
Learning Objectives/ Learning Outcomes	Understanding of the main principles and phenomena in solid state physics from the theoretical perspective.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Blügel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Solid State Physics: Lecture and Exercises (131060702)	1st semester	no semester recommended	0	6
Theoretical Solid State Physics: Examination (131060701)	1st semester	no semester recommended	10	0

Module titel	Quantum Theory of Condensed Matter II (Compulsory elective subject)
Identifier	1315029
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Central topic: ; Many-body theory with functional integrals Optional topics: • Fermi liquids • Instabilities (magnetism and superfluidity) • Collective excitations • Hubbard-Model • Quantum magnetism • Impurities and local correlations • Linear transport • Weak localization • Green's functions in nonequilibrium • Open quantum systems • Luttinger liquids
Learning Objectives/ Learning Outcomes	The students can apply the theoretical concepts of symmetry breaking, mean-field theory, Feynman path integrals, and Ward-identities to evaluate correlation functions. The students have proficiency in theoretical notions for its application in various other courses. The students can analyse and evaluate the basic principles of the physics of various instabilities in superconducting, magnetic, and superfluid systems. The students can analyse and evaluate the basic principles of the physics of disorder in metals and superconductors. The students can clearly distinguish the different aspects of symmetry breaking, quantum interference and quantum fluctuations.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Fetter, Walecka: Quantum Theory of Many-Particle Systems • Mahan: Many-Particle Physics • Philipps: Advanced Solid State Physics • Bruns, Flensberg: Many-Body Quantum Theory in Condensed Matter Physics • Abrikosov, Gorkov, Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics • Wen: Quantum Field Theory of Many-Body Systems • Negele, Orland: Quantum Many Particle Systems
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Herbert Schoeller

Condensed Matter Theory
Quantum Theory of Condensed Matter II (1315029)

ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory of Condensed Matter II: Examination (131502901)	2nd semester	no semester recommended	10	0
Quantum Theory of Condensed Matter II: Lecture and Exercises (131502902)	2nd semester	no semester recommended	0	6

Module titel	Computational Physics (Compulsory elective subject)
Identifier	1310610
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Computational physics encompasses a huge variety of topics. Therefore, the lecture can only cover a limited fraction of computational physics problems. Topics include: What is computational physics and what is it used for? Traditional versus non-traditional computational physics Random numbers and their applications (random number generators, random walk, cellular automata, lattice Boltzman method, event-by-event simulations) Monte Carlo method (integration, statistical error, radioactive decay, percolation, importance sampling, Ising model, Markov chains, Metropolis Monte Carlo method) Molecular dynamics method (Runge Kutta, predictor-corrector, Euler, Euler-Cromer, Verlet, leap-frog, velocity Verlet, Hamiltonian splitting, accuracy and stability ,force calculations: truncation and shift of potentials, linked list method) Diffusion equation (random walk, Brownian motion, Crank-Nicolson, product formula approach, Chebychev algorithm, matrix exponential, stability and accuracy) Computational electrodynamics (Maxwell equation, FDTD: Yee algorithm and product formula approach, ADI, multipole methods, finite element method, dissipative materials, UPML) Time-(in)dependent Schrödinger equation (Leap-frog, Crank-Nicolson, product formula, Lanczos, Davidson, linear algebra: Gauss, LU decomposition) Exact diagonalization Quantum Monte Carlo method
Learning Objectives/ Learning Outcomes	Lectures: The students will obtain an overview of various numerical methods to solve by computer a variety of problems in science. Exercises: The students will write their own computer programs for problems drawn from various areas of physics, selected such that they can be worked out in a reasonable time frame, with reasonable computational resources (PC is sufficient).
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	T. Pang, An introduction to computational physics, Cambridge Univ. Press. J. M. Thijssen, Computational physics, Cambridge Univ. Press. D. P. Landau, K. Binder, A Guide to Monte-Carlo Simulations in Statistical Physics, Cambridge Univ. Press. W. H. Press, S. A. Teukolsky, W. T. Wetterling, and B. P. Flannery, Numerical Recipes: the Art of Scientific Computing, Cambridge Univ. Press.
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation

– Condensed Matter Theory
+ Computational Physics (1310610)

Miscellaneous	-
Module coordinator	Stefan Weßel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Computational Physics: Lecture and Exercises (131061002)	2nd semester	no semester recommended	0	6
Computational Physics: Examination (131061001)	2nd semester	no semester recommended	10	0

Module titel	Quantum Information (Compulsory elective subject)
Identifier	1310608
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	Quantum Information: • States (mixtures, marginals, ensembles, bipartite states, purification) • Measurements (effects operators, POVM, measurement operators, state discrimination, state identification, instruments, information-disturbance, remote steering) • Evolutions (complete positivity, channels, state-evolution correspondence, unitary dilation, complementary channel, entropy exchange, decoupling principle, error-correction conditions, recovery channel) • Entanglement (entropy, LOCC, majorization, single-copy conversion, typicality, asymptotic conversion) Quantum Computing: • Deutsch algorithm • Classical logic gates • Single-qubit gates • Circuits and entanglement • Deutsch-Jozsa algorithm and Bernstein-Vazirani problem: examples of algorithmic speedup • Universality of classical and quantum gates • No-cloning theorem • Teleportation • Computational complexity • Grover's search algorithm • Quantum Fourier transform • Phase estimation • Order finding • Shor's large-number factoring algorithm • RSA public key cryptography • Quantum key distribution and cryptography • Error correction codes • Stabiliser formalism • Error propagation and fault-tolerance • Topological error correction codes • Hybrid quantum-classical algorithms • Digital simulation
Learning Objectives/ Learning Outcomes	The students know the fundamentals of quantum computation and the information approach to quantum theory. They have a working knowledge of their basic tools and are ready to perform their own research in this field. They are able to make predictions for open quantum systems involving mixed states, POVM measurements, non-unitary evolutions and exchange of classical information. For few-qubit systems they can derive such descriptions from projective measurement models with pure states and unitary evolutions. They are familiar with standard examples of measurements (pretty good measurement, conclusive discrimination) and channels (dephasing, depolarizing, amplitude damping) and standard protocols for entanglement processing. The students are able to construct, analyse and predict the effect of basic quantum circuits and protocols. They understand the working principles of quantum computation, communication and cryptography protocols, the physical ingredients, limitations (no-cloning) and advantages offered (e.g. computational speed-ups). Furthermore, they appreciate current challenges (errors, scalability) and approaches pursued

	(error correction, hybrid algorithms) towards the realization of near-term and future large-scale quantum information processors.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Michael A. Nielsen and Isaac L. Chuang: Quantum Computation and Quantum Information, Cambridge University Press, 2000
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	David DiVincenzo
ECTS Credits	10
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Information: Lecture and Exercises (131060802)	2nd semester	no semester recommended	0	6
Quantum Information: Examination (131060801)	2nd semester	no semester recommended	10	0

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– Condensed Matter Theory
+ Statistical Physics (1310609)

Module titel	Statistical Physics (Compulsory elective subject)
Identifier	1310609
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Foundations of the theory of phase transitions: symmetry breaking, order parameters, thermodynamic limit. Mean-field and Landau-Ginzburg theory of phase transitions and critical phenomena. Scaling and scaling relations, anomalous exponents, irrelevant, relevant and marginal couplings, dangerously irrelevant couplings, finite-size scaling. Real-space renormaliztion group, Wilson's renormalization group and field-theoretical renormalization group, epsilon-expansion, dimensional regularization, flow-equations, beta-functions, Gellmann-Low equations, corrections to scaling.
Learning Objectives/ Learning Outcomes	The students are familiar with the foundations of the theory of phase transitions and the particular relevance of the concepts of symmetry breaking, order parameters and the thermodynamic limit. They can apply phenomenological Landau-Ginzburg ;theory to derive mean-field phase diagrams for simple and also more complex interacting many-body systems. ;The students can derive and apply scaling relations among the various critical exponents and are familiar with their ;foundation within the renormalization group approach. They understand the emergence of anomalous exponents at critical points. ; The students know different renormalization group approaches to critical phenomena. They can explain the relations and differences between the real-space, Wilon's and the field-theoretical renormalization group approach. The student can perform basic calculations using these approaches in terms of Feynman diagrams and flow equations. ; Students can present solutions to specific calculations on selected topics on the subject matter in an exercise group or in a seminar talk and participate in discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• D. Forster, Hydrodynamic Fluctuations, Broken Symmetry, and Correlation Functions • L.D. Landau und E. M. Lifschitz, Hydrodynamik • G. Röpke, Statistische Mechanik für das Nichtgleichgewicht • S.H. Strogatz, Nonlinear Dynamics and Chaos • R.J. Goldston und P.H. Rutherford, Plasmaphysik • C. Domb und J.L. Lebowitz, Phase Transitions and Critical Phenomena (selected chapters)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Weßel

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Condensed Matter Theory
Statistical Physics (1310609)

ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Statistical Physics: Lecture and Exercises (131060902)	2nd semester	no semester recommended	0	6
Statistical physics (131060901)	2nd semester	no semester recommended	10	0

Module titel	Particle Physics I (Compulsory elective subject)
Identifier	1310597
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Basic concepts in particle physics: elementary particles, fundamental interactions and their corresponding particles, origin of mass. Quantum numbers, classification of hadrons, symmetries and conservation laws. Dirac equation, Quantum Electrodynamics, Feynman rules, Quantum Chromodynamics, electroweak interactions. Measurement concepts: accelerators, detectors, data analysis.
Learning Objectives/ Learning Outcomes	The students understand the basic concepts of particle physics. They explain the organization into particles of matter, particles for mediating interactions and the origin of mass. They know the relevant quantum numbers and are able to apply them in the classification of hadrons. They calculate the particle kinematics in different inertial systems within the framework of special relativity theory and use the Mandelstam variables. Students know how a particle accelerator and the different detector concepts work. They perform data analyses with these detectors on the computer. Students understand the Dirac equation and write down matrix elements for the interactions of quantum electrodynamics, quantum chromodynamics and weak interaction according to Feynman rules. ;Students understand how one calculates cross sections from matrix elements and the phase space and how one compares them with measured data.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	D. Perkins, Introduction to High Energy Physics K. Kleinknecht, Detektoren für Teilchenstrahlung F. Halzen, A.D. Martin, Quarks and Leptons D. Griffith, Introduction to Elementare Particles C. Berger, Elementarteilchenphysik P. Schmüser, Feynman-Graphen und Eichtheorien für Experimentalphysiker
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Martin Erdmann
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particle Physics I: Lecture and Exercises (131059702)	1st semester	no semester recommended	0	6
Particle Physics I: Examination (131059701)	1st semester	no semester recommended	10	0

Module titel	Particle Physics II (Compulsory elective subject)
Identifier	1310598
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Electron-positron collisions, deep-inelastic lepton-nucleon scattering, two-photon physics, photoproduction, diffractive scattering, hadron collider physics, jet physics, fragmentation, strong coupling constant, W and Z boson physics, Higgs physics, unification of the electromagnetic and weak interactions, heavy quark physics with top and bottom quarks, measurement of CP violation, CKM matrix, neutrino physics, neutrino oscillations, double beta decay, Higgs physics, Supersymmetry, searches for physics beyond the Standard Model of particle physics, relations to cosmology.
Learning Objectives/ Learning Outcomes	The students understand the principle of local gauge invariance and explain the terms of the Lagrange density of the Standard Model of particle physics. They also understand the Higgs mechanism for mass generation. Furthermore, they know the main experiments of the last 30 years and are able to name their contributions to the understanding of particle physics. These include in particular the tests of the electroweak interaction in the LEP collider, the deep inelastic lepton-nucleon scattering to study the proton structure, the physics at the Hadron Collider with W, Z, top quarks &; Higgs, and neutrino physics. In all areas, students name the specific requirements for the experiments and their realization, and perform data analyses on the computer for the experiments. Furthermore, they understand the range of validity of the Standard Model of particle physics.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	R.K. Ellis, W.J. Stirling, B.R. Webber, QCD and Collider Physics V. Barger, R. Phillips, Collider Physics R.G. Roberts, The Structure of the Proton M. Erdmann, The Partonic Structure of the Photon N. Schmitz, Neutrinophysik M. Drees, R. Godbole, P. Roy, Theory and Phenomenology of Sparticles
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Martin Erdmann
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particle Physics II: Lecture and Execises (131059802)	2nd semester	no semester recommended	0	6
Particle Physics II: Examination (131059801)	2nd semester	no semester recommended	10	0

Module titel	Laboratory Course Particle Physics (Compulsory elective subject)
Identifier	1310599
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Preparatory course: • Brief introduction to experimental particle physics • Particle detectors • Read out electronic • Radiation and laser safety • Theoretical introduction to the experiments of the laboratory class • Data analysis • Experimental uncertainties • Scientific writing (notations, protocol, discussion) Laboratory class (selected experiments from following list): • Determination of the drift velocity of gases with a drift chamber • Life time of positrons in solid state bodies • Life time of muons • Quadrupol ion trap (Paul trap) • Saturated absorption spectroscopy • Production and decay of W bosons • Geant 4 and the spectrum of cosmic muons • Accelerator physics • Measurement of the pp->ttbar cross section and the top-quark with the CMS detector • Air shower array
Learning Objectives/ Learning Outcomes	The students can apply experimental techniques to measurement tasks in elementary particle physics. The students have a wide range of laboratory skills needed to design and safely conduct experiments including high voltages and radioactive sources. The students can develop modern experiments using a variety electronic equipment for fast analog and digital signal processing. The students know how to collect and/or process the raw data from the individual experiments. The students can interpret the measured data quantitatively, evaluate the measurement outcome and compare with the expectation. The students can analyse the precision of the measurement result by taking into account various sources of uncertainty. The students know how to document scientifically the planning of experiments, the experimentation procedures, the data taking, the evaluation of the experimental data including error and uncertainty determination and detailed discussion of the results.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Instruction manuals and literature given therein
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work

Miscellaneous	-
Module coordinator	Oliver Pooth
ECTS Credits	10
Contact time (WSH)	8
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	120,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Particle Physics: Laboratory Course (131059901)	2nd semester	no semester recommended	10	8

Module titel	Particle Physics I (Compulsory elective subject)
Identifier	1310597
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Basic concepts in particle physics: elementary particles, fundamental interactions and their corresponding particles, origin of mass. Quantum numbers, classification of hadrons, symmetries and conservation laws. Dirac equation, Quantum Electrodynamics, Feynman rules, Quantum Chromodynamics, electroweak interactions. Measurement concepts: accelerators, detectors, data analysis.
Learning Objectives/ Learning Outcomes	The students understand the basic concepts of particle physics. They explain the organization into particles of matter, particles for mediating interactions and the origin of mass. They know the relevant quantum numbers and are able to apply them in the classification of hadrons. They calculate the particle kinematics in different inertial systems within the framework of special relativity theory and use the Mandelstam variables. Students know how a particle accelerator and the different detector concepts work. They perform data analyses with these detectors on the computer. Students understand the Dirac equation and write down matrix elements for the interactions of quantum electrodynamics, quantum chromodynamics and weak interaction according to Feynman rules. ;Students understand how one calculates cross sections from matrix elements and the phase space and how one compares them with measured data.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	D. Perkins, Introduction to High Energy Physics K. Kleinknecht, Detektoren für Teilchenstrahlung F. Halzen, A.D. Martin, Quarks and Leptons D. Griffith, Introduction to Elementare Particles C. Berger, Elementarteilchenphysik P. Schmüser, Feynman-Graphen und Eichtheorien für Experimentalphysiker
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Martin Erdmann
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

Particle Physics I (1310597)

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particle Physics I: Lecture and Exercises (131059702)	1st semester	no semester recommended	0	6
Particle Physics I: Examination (131059701)	1st semester	no semester recommended	10	0

Module titel	Quantum Field Theory of Particle Physics I (Compulsory elective subject)
Identifier	1310601
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Relativistic quantum mechanics: Klein-Gordon, Dirac and Proca equations; representations of the Poincare group; discrete symmetries C, P and T; free quantum fields. Canonical quantization: Lagrangian and Hamiltonian formalism, Noether theorem, quantization of scalar, spinor and vector fields; Gupta-Bleuler quantization of QED; perturbation theory; scattering theory; basic processes in QED. Path integral quantization: Quantum Mechanics; Lagrange and Hamilton formulation for bosons; generating functionals; fermionic path integrals; Faddeev-Popov quantization of QED. Radiative corrections: Euler-Heisenberg effective action; evaluation methods for quantum corrections; basics of renormalization; anomalous magnetic moment; Lamb shift; infrared divergences in QED.
Learning Objectives/ Learning Outcomes	The students have a working knowledge of the quantum field theory of particle physics as a foundation for performing their own research in this field. They are familiar with the framework of special relativity as applied to quantum mechanical systems at the level of single-particle states and quantum fields. They understand the derivation and limitations of perturbation theory. They know diagrammatic and path-integral methods for the modelling of particle physics processes. In particular, they can calculate cross sections for simple two-to-two processes, as well as electromagnetic properties of elementary particles, for example the anomalous magnetic moment of fermions. The students master collaborative learning, presentation of results and social peer support in small group discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory C. Itzykson, J.B. Zuber, Quantum Field Theory
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michal Czakon
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Field Theory of Particle Physics I: Lecture and Exercises (131060102)	1st semester	no semester recommended	0	6
Quantum Field Theory of Particle Physics I: Examination (131060101)	1st semester	no semester recommended	10	0

Module titel	Theory of Relativity and Cosmology (Compulsory elective subject)
Identifier	1311068
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Introduction to the theory of general relativity as a theory of gravity (mathematical foundations, foundations of differential geometry, the metric as a field, Einsteins field equations, simple effects like gravitational red shift or clocks in gravitational fields). Black holes and gravitational waves. Cosmology: homogeneous and isotropic universe; dark matter and dark energy; physics of the early universe; structure formation and inflation.
Learning Objectives/ Learning Outcomes	Understanding of gravitational interactions, the history of the universe and the ability to mathematically describe the evolution of a homogeneous universe.
(Study-Specific) Prerequisites	None
(recommended) Requirements	Module „Spezielle Relativitätstheorie/ Kosmologie“
References	Weinberg: Gravitation and Cosmology Wald: General Relativity Kolb, Turner: The Early Universe
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Lesgourgues, Julien
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theory of Relativity and Cosmology: Examination (131106801)	1st semester	no semester recommended	10	0
Theory of Relativity and Cosmology: Lecture and Exercises (131106802)	1st semester	no semester recommended	0	6

Module titel	Astroparticle Physics (Compulsory elective subject)
Identifier	1310600
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Experimental methods: satellites, air-shower detectors underground detectors Extended air showers, cascade equations, experimental observables Cosmic rays, energy spectrum composition, the knee, the ankle, the GZK cutoff Cosmic gamma radiation, production and detection results Neutrino astronomy: solar, supernova and high energy, oscillations Astrophysical sources of cosmic rays, acceleration and propagation Dark matter, experimental methods for direct and indirect detection, astrophysical models Contemporary results in the aforementioned fields
Learning Objectives/ Learning Outcomes	Experimental methods, astro physics, particle physics with cosmic radiation
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	D. Perkins: Particle Astrophysics Th. K. Gaisser: Cosmic ray and particle physics T.Stanev: High energy Cosmic rays, M. S. Longair: High Energy Astrophysics
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Christopher Wiebusch
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Astroparticle Physics: Lecture and Exercises (131060002)	2nd semester	no semester recommended	0	6
Astroparticle Physics: Examination (131060001)	2nd semester	no semester recommended	10	0

Module titel	Quantum Field Theory of Particle Physics I (Compulsory elective subject)
Identifier	1310601
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Relativistic quantum mechanics: Klein-Gordon, Dirac and Proca equations; representations of the Poincare group; discrete symmetries C, P and T; free quantum fields. Canonical quantization: Lagrangian and Hamiltonian formalism, Noether theorem, quantization of scalar, spinor and vector fields; Gupta-Bleuler quantization of QED; perturbation theory; scattering theory; basic processes in QED. Path integral quantization: Quantum Mechanics; Lagrange and Hamilton formulation for bosons; generating functionals; fermionic path integrals; Faddeev-Popov quantization of QED. Radiative corrections: Euler-Heisenberg effective action; evaluation methods for quantum corrections; basics of renormalization; anomalous magnetic moment; Lamb shift; infrared divergences in QED.
Learning Objectives/ Learning Outcomes	The students have a working knowledge of the quantum field theory of particle physics as a foundation for performing their own research in this field. They are familiar with the framework of special relativity as applied to quantum mechanical systems at the level of single-particle states and quantum fields. They understand the derivation and limitations of perturbation theory. They know diagrammatic and path-integral methods for the modelling of particle physics processes. In particular, they can calculate cross sections for simple two-to-two processes, as well as electromagnetic properties of elementary particles, for example the anomalous magnetic moment of fermions. The students master collaborative learning, presentation of results and social peer support in small group discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory C. Itzykson, J.B. Zuber, Quantum Field Theory
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michal Czakon
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Field Theory of Particle Physics I: Lecture and Exercises (131060102)	1st semester	no semester recommended	0	6
Quantum Field Theory of Particle Physics I: Examination (131060101)	1st semester	no semester recommended	10	0

Module titel	Quantum Field Theory of Particle Physics II (Compulsory elective subject)
Identifier	1310602
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Gauge theories: gauge groups and classical Lagrangians; Faddeev-Popov quantization of non-abelian gauge theories; BRST symmetry and canonical quantization; one-loop radiative corrections; running coupling and asymptotic freedom; basic processes in perturbative QCD. Spontaneous symmetry breaking: degenerate ground states in many-body physics; spontaneous symmetry breaking of global discrete symmetries; continuous symmetries and Goldstone theorem; chiral symmetry breaking; non-linear realizations of symmetry and chiral perturbation theory; Higgs mechanism; structure of the Standard Model. Anomalies: Adler-Bell-Jackiw anomaly in cut-off and dimensional regularizations; anomalies in path integrals; anomaly cancellation; phenomenological applications to neutral pion decays; U(1) problem. Introduction to physics beyond the Standard Model.
Learning Objectives/ Learning Outcomes	The students have a working knowledge of the quantum field theory of particle physics as a foundation for performing their own research in this field. They are familiar with the framework of non-abelian gauge theories both in the case of exact and spontaneously broken symmetry. They understand the problems related to quantization and renormalization of such theories. They know the physical basis of spontaneous symmetry breaking of exact and approximate symmetries, e.g. chiral symmetry. They understand the theoretical structure of the Standard Model, and can deal with anomalies. The students master collaborative learning, presentation of results and social peer support in small group discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	M.E. Peskin, D.V. Schroeder, An Introduction to Quantum Field Theory C. Itzykson, J.B. Zuber, Quantum Field Theory
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michal Czakon
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Field Theory of Particle Physics II: Lecture and Exercises (131060202)	2nd semester	no semester recommended	0	6
Quantum Field Theory of Particle Physics II: Examination (131060201)	2nd semester	no semester recommended	10	0

Module titel	Theory of Relativity and Cosmology (Compulsory elective subject)
Identifier	1311068
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Introduction to the theory of general relativity as a theory of gravity (mathematical foundations, foundations of differential geometry, the metric as a field, Einsteins field equations, simple effects like gravitational red shift or clocks in gravitational fields). Black holes and gravitational waves. Cosmology: homogeneous and isotropic universe; dark matter and dark energy; physics of the early universe; structure formation and inflation.
Learning Objectives/ Learning Outcomes	Understanding of gravitational interactions, the history of the universe and the ability to mathematically describe the evolution of a homogeneous universe.
(Study-Specific) Prerequisites	None
(recommended) Requirements	Module „Spezielle Relativitätstheorie/ Kosmologie“
References	Weinberg: Gravitation and Cosmology Wald: General Relativity Kolb, Turner: The Early Universe
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Lesgourgues, Julien
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theory of Relativity and Cosmology: Examination (131106801)	1st semester	no semester recommended	10	0
Theory of Relativity and Cosmology: Lecture and Exercises (131106802)	1st semester	no semester recommended	0	6

Module titel	Condensed Matter Physics I (Compulsory elective subject)
Identifier	1311069
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	- Defects, elastic/plastic deformation - thermal conductivity, heat capacity, thermal expansion - Many body Schrödinger Equation: Exchange Interaction, Spin-Orbit-Coupling, Correlation, 2. Quantisation - Transport theory: Scattering Mechanisms - optical properties (dielectric function, .. golden rule) - Magnetism (Stoner Modell, ... Spin waves) - Superconductivity (BCS- Modell, ..., Josephson-Effects) - experimental methods
Learning Objectives/ Learning Outcomes	Lecture: The students should obtain an in-depth understanding of essential effects and concepts in solid state physics. The lectures focus on the relationship between the quantum mechanical description of microscopic processes and macroscopic measureable quantities and phenomena. Exercise: The students should apply the knowledge obtained in the lectures to solve tasks of different complexity. This includes understanding and discussing scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics I: Lecture and Exercises (131106902)	1st semester	no semester recommended	0	6
Condensed Matter Physics I: Examination (131106901)	1st semester	no semester recommended	10	0

Module titel	Condensed Matter Physics II (Compulsory elective subject)
Identifier	1310603
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	The course consists of up to four blocks of varying content. Typical block topics are: Qubits, quantum information and decoherence Modern solid state optics Modern experimental methods Functional materials Soft matter + biophysics Surface and interface physics Spintronics Interactions in in reduced dimensions Correlation effects Electrons and disorder
Learning Objectives/ Learning Outcomes	Lecture: The students will obtain an overview of modern research topics in solid state physics. To this end, each block will concentrate on one area. The students will thus be put in a position to follow selected current research fields. Tutorials: The students are to apply the knowledge obtained from the lecture by solving problems of various difficulties. Example exercises relating to recent original research literature should introduce them to current topics and reading scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Hendrik Bluhm
ECTS Credits	10
Contact time (WSH)	6

Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics II: Lecture and Exercises (131060302)	2nd semester	no semester recommended	0	6
Condensed Matter Physics II: Examination (131060301)	2nd semester	no semester recommended	10	0

Module titel	Laboratory Course Solid State Physics (Compulsory elective subject)
Identifier	1310604
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Lecture: scanning probe methods, 2 dimensional electron gas, quantum hall effect, superconductivity, Josephson effect, magnetism, inelastic light scattering, light emission in solid-state, excitons, modulus of elasticity and sound propagation, measurement analysis Laboratory Course: various experiments, e.g. scanning/magnetic force microscopy, quantum transport, SQUID, photoluminescence, Raman scattering, ultrasound, laboratory experiment
Learning Objectives/ Learning Outcomes	Independent planning of the experiment, careful logging of experimental work, practical work, estimate of measurement uncertainties, elaboration of experiments with error calculation and discussion of results
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Instruction manuals and literature given therein
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Bernd Beschoten
ECTS Credits	10
Contact time (WSH)	10
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	150,0
Self-study hours (h)	150,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Condensed Matter Physics: Laboratory Course (131060401)	2nd semester	no semester recommended	10	8

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Condensed Matter Physics: Lecture	2nd semester	no semester recommended	-	2

Module titel	Condensed Matter Physics I (Compulsory elective subject)
Identifier	1311069
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	- Defects, elastic/plastic deformation - thermal conductivity, heat capacity, thermal expansion - Many body Schrödinger Equation: Exchange Interaction, Spin-Orbit-Coupling, Correlation, 2. Quantisation - Transport theory: Scattering Mechanisms - optical properties (dielectric function, .. golden rule) - Magnetism (Stoner Modell, ... Spin waves) - Superconductivity (BCS- Modell, ..., Josephson-Effects) - experimental methods
Learning Objectives/ Learning Outcomes	Lecture: The students should obtain an in-depth understanding of essential effects and concepts in solid state physics. The lectures focus on the relationship between the quantum mechanical description of microscopic processes and macroscopic measureable quantities and phenomena. Exercise: The students should apply the knowledge obtained in the lectures to solve tasks of different complexity. This includes understanding and discussing scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics I: Lecture and Exercises (131106902)	1st semester	no semester recommended	0	6
Condensed Matter Physics I: Examination (131106901)	1st semester	no semester recommended	10	0

Module titel	Novel Materials and Devices for Information Technology 1 (Compulsory elective subject)
Identifier	6011259
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	State variables for memories and processing of information; fundamental principles of logic and memory devices; physical limits of scaling (thermodynamic, quantum mechanical, electromagnetic limit) # Mesoscopic transport and interconnects # Charge-based memorys (DRAM, ferroelectric memories) # Magneto electronic memories # Redox-based and phase-change-based resistive memories # New mass storage concepts (scanning probe methods) # Alternative logic concepts (spintronics, OFETs, molecular electronics) # Architectural concepts for alternative logic and memory devices
Learning Objectives/ Learning Outcomes	The students shall # Learn the fundamental principles that are used for information processing devices (logic) and information storage devices (memory) # Comprehend the potential of new materials and functions beyond conventional semiconductors # Acquire the ability of appraising the limits of scaling and # Comprehend new logic devices und memory concepts with help of concrete examples
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Präsentationsfolien, # Nanoelectronics and Informationtechnology, (Ed.) R. Waser, WILEY-VCH
Language	German/English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Rainer Waser
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Novel Materials and Devices for Information Technology 1 (601125901)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Novel Materials and Devices for Information Technology 1	1st semester	no semester recommended	-	3

Module titel	Novel Materials and Devices for Information Technology 2 (Compulsory elective subject)
Identifier	6011260
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	# Compound semiconductor materials and devices # Organic semiconductors # Optical communications # Cell-electronics coupling # Displays
Learning Objectives/ Learning Outcomes	The students # gain an understanding of the basic requirements for optical data communication systems and learn about current components and solutions # understand the fundamental properties of compound and organic semiconductors and learn the physical principles of active devices such as high electron mobility transistors, light emitting diodes and laser diodes, including technological implementations and fabrication. # aquire the basics of cell physiology as well as information transport in biological system # use basic electrical engineering knowledge to describe the modeling and coupling of cells and electronic devices. # Understand new lighting concepts taking into account human color perception
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Präsentationsfolien, # Nanoelectronics and Informationtechnology, (Ed.) R. Waser, WILEY-VCH
Language	German/English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Andrei Vescan
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Novel Materials and Devices for Information Technology 2 (601126001)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Novel Materials and Devices for Information Technology 2	2nd semester	no semester recommended	-	3

Module titel	Laboratory Course Nanoelectronics (Compulsory elective subject)
Identifier	1310605
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	Lecture: scanning probe methods, 2 dimensional electron gas, quantum hall effect, superconductivity, Josephson effect, magnetism, inelastic light scattering, light emission in solid-state, excitons, modulus of elasticity and sound propagation, measurement analysis Laboratory Course: various experiments, e.g. scanning/magnetic force microscopy, quantum transport, SQUID, photoluminescence, Raman scattering, ultrasound, laboratory experiment
Learning Objectives/ Learning Outcomes	Independent planning of the experiment, careful logging of experimental work, practical work, estimate of measurement uncertainties, elaboration of experiments with error calculation and discussion of results
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Instruction manuals and literature given therein
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Bernd Beschoten
ECTS Credits	10
Contact time (WSH)	10
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	150,0
Self-study hours (h)	150,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Nanoelectronics: Laboratory Course (131060501)	2nd semester	no semester recommended	10	8

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Nanoelectronics: Lecture	2nd semester	no semester recommended	-	2

Module titel	Condensed Matter Physics I (Compulsory elective subject)
Identifier	1311069
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	- Defects, elastic/plastic deformation - thermal conductivity, heat capacity, thermal expansion - Many body Schrödinger Equation: Exchange Interaction, Spin-Orbit-Coupling, Correlation, 2. Quantisation - Transport theory: Scattering Mechanisms - optical properties (dielectric function, .. golden rule) - Magnetism (Stoner Modell, ... Spin waves) - Superconductivity (BCS- Modell, ..., Josephson-Effects) - experimental methods
Learning Objectives/ Learning Outcomes	Lecture: The students should obtain an in-depth understanding of essential effects and concepts in solid state physics. The lectures focus on the relationship between the quantum mechanical description of microscopic processes and macroscopic measureable quantities and phenomena. Exercise: The students should apply the knowledge obtained in the lectures to solve tasks of different complexity. This includes understanding and discussing scientific articles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	H. Ibach, H. Lüth: Festkörperphysik (Springer) C. Kittel: Einführung in die Festkörperphysik (Oldenbourg) N. Ashcroft, D. Mermin: Festkörperphysik (Oldenbourg) J. Hook, H. Hall: Solid State Physics (Wiley)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Condensed Matter Physics I: Lecture and Exercises (131106902)	1st semester	no semester recommended	0	6
Condensed Matter Physics I: Examination (131106901)	1st semester	no semester recommended	10	0

Module titel	Quantum Theory of Condensed Matter I (Compulsory elective subject)
Identifier	1310606
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	• Advanced topic in quantum mechanics • Many-body theory (second quantization) • Green's functions • Linear response theory • Diagrammatic formalism (finite temperature) • Electrons and phonons • Superconductivity
Learning Objectives/ Learning Outcomes	The students can apply the theoretical concepts of Green's functions, Feynman diagrams and linear transport theory. The students have proficiency in theoretical notions for its application in various other courses. The students can analyse and evaluate the basic principles of the physics of electrons, phonons and superconductivity in solid state materials. The students can clearly distinguish the different aspects of quasiparticle concepts, screening properties, and symmetry breaking.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Fetter, Walecka: Quantum Theory of Many-Particle Systems • Mahan: Many-Particle Physics • Philipps: Advanced Solid State Physics • Bruns, Flensberg: Many-Body Quantum Theory in Condensed Matter Physics • Abrikosov, Gorkov, Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics • Wen: Quantum Field Theory of Many-Body Systems • Negele, Orland: Quantum Many Particle Systems
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Herbert Schoeller
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory of Condensed Matter I: Lecture and Exercises (131060602)	1st semester	no semester recommended	0	6
Quantum Theory of Condensed Matter I: Examination (131060601)	1st semester	no semester recommended	10	0

Module titel	Theoretical Solid State Physics (Compulsory elective subject)
Identifier	1310607
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Bonding and structure of crystals, reciprocal lattice, Bloch Theorem, electronic band structures, lattice vibrations, transport properties, optical and collective excitations, superconductivity, magnetic properties of solids.
Learning Objectives/ Learning Outcomes	Understanding of the main principles and phenomena in solid state physics from the theoretical perspective.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Blügel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Solid State Physics: Lecture and Exercises (131060702)	1st semester	no semester recommended	0	6
Theoretical Solid State Physics: Examination (131060701)	1st semester	no semester recommended	10	0

Module titel	Hardware Platforms for Quantum Technology (Compulsory elective subject)
Identifier	1321355
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Quantum vs. classical physics, review of concepts of quantum mechanics, entanglement, basic ideas of quantum computing, communication and sensing, known algorithms, DiVincenzo criteria, quantum error correction, charge and spin qubits, macroscopic quantum coherence, Josephson junctions, superconducting qubits, quantum states of photons, Bloch sphere, qubit control, Rabi flopping, basic concepts of decoherence and of dephasing, pulse sequences.
Learning Objectives/ Learning Outcomes	The students will get an overview of key concepts for several quantum technologies and common hardware platforms. The exercises will train them to quantitatievely and qualitatively understand the device physics and dynamics of qubit devices.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Bluhm, Jörg Hendrik
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Hardware Platforms for Quantum Technology (132135501)	1st semester	no semester recommended	5	3

Laboratory Course Quantum Technology (1321353)

Module titel	Laboratory Course Quantum Technology (Compulsory elective subject)
Identifier	1321353
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	The students will perform QT-related experiments on their own. Possible experiments include: 1) NMR spectroscopy 2) Hong-Ou-Mandel (HOM) photon interference effect 3) Quantum transport The students will carry out the following practical experiments with help of tutors: 1) Scanning tunneling microscope 2) Spin coherence in 2D semiconductors 3) Micro- and Nano-lithography 4) Microwave readout of a SQUID 5) Electron spin qubits
Learning Objectives/ Learning Outcomes	The students will understand basic concepts of quantum technology by performing ex-periments on their own with the help of tutors. The students will independently plan the experiment, carefully log the experimental work, practical work, estimate measurement uncertainties, elaborate on the experiments with error calculation and discuss the ob-tained results.The students will be trained to write the laboratory reports, and high quality research papers. The students will be exposed to various laboratory components which will help them to design the quantum devices related to quantum technology in research laboratories or in industry.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Schreiber, Lars Reiner
ECTS Credits	5
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	75,0

Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Quantum Technology (132135301)	1st semester	no semester recommended	5	5

Module titel	Quantum Information (Compulsory elective subject)
Identifier	1310608
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Quantum Information: • States (mixtures, marginals, ensembles, bipartite states, purification) • Measurements (effects operators, POVM, measurement operators, state discrimination, state identification, instruments, information-disturbance, remote steering) • Evolutions (complete positivity, channels, state-evolution correspondence, unitary dilation, complementary channel, entropy exchange, decoupling principle, error-correction conditions, recovery channel) • Entanglement (entropy, LOCC, majorization, single-copy conversion, typicality, asymptotic conversion) Quantum Computing: • Deutsch algorithm • Classical logic gates • Single-qubit gates • Circuits and entanglement • Deutsch-Jozsa algorithm and Bernstein-Vazirani problem: examples of algorithmic speedup • Universality of classical and quantum gates • No-cloning theorem • Teleportation • Computational complexity • Grover's search algorithm • Quantum Fourier transform • Phase estimation • Order finding • Shor's large-number factoring algorithm • RSA public key cryptography • Quantum key distribution and cryptography • Error correction codes • Stabiliser formalism • Error propagation and fault-tolerance • Topological error correction codes • Hybrid quantum-classical algorithms • Digital simulation
Learning Objectives/ Learning Outcomes	The students know the fundamentals of quantum computation and the information approach to quantum theory. They have a working knowledge of their basic tools and are ready to perform their own research in this field. They are able to make predictions for open quantum systems involving mixed states, POVM measurements, non-unitary evolutions and exchange of classical information. For few-qubit systems they can derive such descriptions from projective measurement models with pure states and unitary evolutions. They are familiar with standard examples of measurements (pretty good measurement, conclusive discrimination) and channels (dephasing, depolarizing, amplitude damping) and standard protocols for entanglement processing. The students are able to construct, analyse and predict the effect of basic quantum circuits and protocols. They understand the working principles of quantum computation, communication and cryptography protocols, the physical ingredients, limitations (no-cloning) and advantages offered (e.g. computational speed-ups). Furthermore, they appreciate current challenges (errors, scalability) and approaches pursued

	(error correction, hybrid algorithms) towards the realization of near-term and future large-scale quantum information processors.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Michael A. Nielsen and Isaac L. Chuang: Quantum Computation and Quantum Information, Cambridge University Press, 2000
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	David DiVincenzo
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Information: Lecture and Exercises (131060802)	2nd semester	no semester recommended	0	6
Quantum Information: Examination (131060801)	2nd semester	no semester recommended	10	0

Module titel	Quantum Theory of Condensed Matter I (Compulsory elective subject)
Identifier	1310606
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Advanced topic in quantum mechanics • Many-body theory (second quantization) • Green's functions • Linear response theory • Diagrammatic formalism (finite temperature) • Electrons and phonons • Superconductivity
Learning Objectives/ Learning Outcomes	The students can apply the theoretical concepts of Green's functions, Feynman diagrams and linear transport theory. The students have proficiency in theoretical notions for its application in various other courses. The students can analyse and evaluate the basic principles of the physics of electrons, phonons and superconductivity in solid state materials. The students can clearly distinguish the different aspects of quasiparticle concepts, screening properties, and symmetry breaking.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Fetter, Walecka: Quantum Theory of Many-Particle Systems • Mahan: Many-Particle Physics • Philipps: Advanced Solid State Physics • Bruns, Flensberg: Many-Body Quantum Theory in Condensed Matter Physics • Abrikosov, Gorkov, Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics • Wen: Quantum Field Theory of Many-Body Systems • Negele, Orland: Quantum Many Particle Systems
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Herbert Schoeller
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory of Condensed Matter I: Lecture and Exercises (131060602)	1st semester	no semester recommended	0	6
Quantum Theory of Condensed Matter I: Examination (131060601)	1st semester	no semester recommended	10	0

Module titel	Theoretical Solid State Physics (Compulsory elective subject)
Identifier	1310607
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Bonding and structure of crystals, reciprocal lattice, Bloch Theorem, electronic band structures, lattice vibrations, transport properties, optical and collective excitations, superconductivity, magnetic properties of solids.
Learning Objectives/ Learning Outcomes	Understanding of the main principles and phenomena in solid state physics from the theoretical perspective.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Blügel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Solid State Physics: Lecture and Exercises (131060702)	1st semester	no semester recommended	0	6
Theoretical Solid State Physics: Examination (131060701)	1st semester	no semester recommended	10	0

Module titel	Quantum Theory of Condensed Matter II (Compulsory elective subject)
Identifier	1315029
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Central topic: ; Many-body theory with functional integrals Optional topics: • Fermi liquids • Instabilities (magnetism and superfluidity) • Collective excitations • Hubbard-Model • Quantum magnetism • Impurities and local correlations • Linear transport • Weak localization • Green's functions in nonequilibrium • Open quantum systems • Luttinger liquids
Learning Objectives/ Learning Outcomes	The students can apply the theoretical concepts of symmetry breaking, mean-field theory, Feynman path integrals, and Ward-identities to evaluate correlation functions. The students have proficiency in theoretical notions for its application in various other courses. The students can analyse and evaluate the basic principles of the physics of various instabilities in superconducting, magnetic, and superfluid systems. The students can analyse and evaluate the basic principles of the physics of disorder in metals and superconductors. The students can clearly distinguish the different aspects of symmetry breaking, quantum interference and quantum fluctuations.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Fetter, Walecka: Quantum Theory of Many-Particle Systems • Mahan: Many-Particle Physics • Philipps: Advanced Solid State Physics • Bruns, Flensberg: Many-Body Quantum Theory in Condensed Matter Physics • Abrikosov, Gorkov, Dzyaloshinski: Methods of Quantum Field Theory in Statistical Physics • Wen: Quantum Field Theory of Many-Body Systems • Negele, Orland: Quantum Many Particle Systems
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Herbert Schoeller

ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory of Condensed Matter II: Examination (131502901)	2nd semester	no semester recommended	10	0
Quantum Theory of Condensed Matter II: Lecture and Exercises (131502902)	2nd semester	no semester recommended	0	6

Module titel	Computational Physics (Compulsory elective subject)
Identifier	1310610
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Computational physics encompasses a huge variety of topics. Therefore, the lecture can only cover a limited fraction of computational physics problems. Topics include: What is computational physics and what is it used for? Traditional versus non-traditional computational physics Random numbers and their applications (random number generators, random walk, cellular automata, lattice Boltzman method, event-by-event simulations) Monte Carlo method (integration, statistical error, radioactive decay, percolation, importance sampling, Ising model, Markov chains, Metropolis Monte Carlo method) Molecular dynamics method (Runge Kutta, predictor-corrector, Euler, Euler-Cromer, Verlet, leap-frog, velocity Verlet, Hamiltonian splitting, accuracy and stability ,force calculations: truncation and shift of potentials, linked list method) Diffusion equation (random walk, Brownian motion, Crank-Nicolson, product formula approach, Chebychev algorithm, matrix exponential, stability and accuracy) Computational electrodynamics (Maxwell equation, FDTD: Yee algorithm and product formula approach, ADI, multipole methods, finite element method, dissipative materials, UPML) Time-(in)dependent Schrödinger equation (Leap-frog, Crank-Nicolson, product formula, Lanczos, Davidson, linear algebra: Gauss, LU decomposition) Exact diagonalization Quantum Monte Carlo method
Learning Objectives/ Learning Outcomes	Lectures: The students will obtain an overview of various numerical methods to solve by computer a variety of problems in science. Exercises: The students will write their own computer programs for problems drawn from various areas of physics, selected such that they can be worked out in a reasonable time frame, with reasonable computational resources (PC is sufficient).
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	T. Pang, An introduction to computational physics, Cambridge Univ. Press. J. M. Thijssen, Computational physics, Cambridge Univ. Press. D. P. Landau, K. Binder, A Guide to Monte-Carlo Simulations in Statistical Physics, Cambridge Univ. Press. W. H. Press, S. A. Teukolsky, W. T. Wetterling, and B. P. Flannery, Numerical Recipes: the Art of Scientific Computing, Cambridge Univ. Press.
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation

Miscellaneous	-
Module coordinator	Stefan Weßel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Computational Physics: Lecture and Exercises (131061002)	2nd semester	no semester recommended	0	6
Computational Physics: Examination (131061001)	2nd semester	no semester recommended	10	0

Module titel	Quantum Information (Compulsory elective subject)
Identifier	1310608
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	Quantum Information: • States (mixtures, marginals, ensembles, bipartite states, purification) • Measurements (effects operators, POVM, measurement operators, state discrimination, state identification, instruments, information-disturbance, remote steering) • Evolutions (complete positivity, channels, state-evolution correspondence, unitary dilation, complementary channel, entropy exchange, decoupling principle, error-correction conditions, recovery channel) • Entanglement (entropy, LOCC, majorization, single-copy conversion, typicality, asymptotic conversion) Quantum Computing: • Deutsch algorithm • Classical logic gates • Single-qubit gates • Circuits and entanglement • Deutsch-Jozsa algorithm and Bernstein-Vazirani problem: examples of algorithmic speedup • Universality of classical and quantum gates • No-cloning theorem • Teleportation • Computational complexity • Grover's search algorithm • Quantum Fourier transform • Phase estimation • Order finding • Shor's large-number factoring algorithm • RSA public key cryptography • Quantum key distribution and cryptography • Error correction codes • Stabiliser formalism • Error propagation and fault-tolerance • Topological error correction codes • Hybrid quantum-classical algorithms • Digital simulation
Learning Objectives/ Learning Outcomes	The students know the fundamentals of quantum computation and the information approach to quantum theory. They have a working knowledge of their basic tools and are ready to perform their own research in this field. They are able to make predictions for open quantum systems involving mixed states, POVM measurements, non-unitary evolutions and exchange of classical information. For few-qubit systems they can derive such descriptions from projective measurement models with pure states and unitary evolutions. They are familiar with standard examples of measurements (pretty good measurement, conclusive discrimination) and channels (dephasing, depolarizing, amplitude damping) and standard protocols for entanglement processing. The students are able to construct, analyse and predict the effect of basic quantum circuits and protocols. They understand the working principles of quantum computation, communication and cryptography protocols, the physical ingredients, limitations (no-cloning) and advantages offered (e.g. computational speed-ups). Furthermore, they appreciate current challenges (errors, scalability) and approaches pursued

	(error correction, hybrid algorithms) towards the realization of near-term and future large-scale quantum information processors.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Michael A. Nielsen and Isaac L. Chuang: Quantum Computation and Quantum Information, Cambridge University Press, 2000
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	David DiVincenzo
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Information: Lecture and Exercises (131060802)	2nd semester	no semester recommended	0	6
Quantum Information: Examination (131060801)	2nd semester	no semester recommended	10	0

Module titel	Statistical Physics (Compulsory elective subject)
Identifier	1310609
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Master
Content	Foundations of the theory of phase transitions: symmetry breaking, order parameters, thermodynamic limit. Mean-field and Landau-Ginzburg theory of phase transitions and critical phenomena. Scaling and scaling relations, anomalous exponents, irrelevant, relevant and marginal couplings, dangerously irrelevant couplings, finite-size scaling. Real-space renormaliztion group, Wilson's renormalization group and field-theoretical renormalization group, epsilon-expansion, dimensional regularization, flow-equations, beta-functions, Gellmann-Low equations, corrections to scaling.
Learning Objectives/ Learning Outcomes	The students are familiar with the foundations of the theory of phase transitions and the particular relevance of the concepts of symmetry breaking, order parameters and the thermodynamic limit. They can apply phenomenological Landau-Ginzburg ;theory to derive mean-field phase diagrams for simple and also more complex interacting many-body systems. ;The students can derive and apply scaling relations among the various critical exponents and are familiar with their ;foundation within the renormalization group approach. They understand the emergence of anomalous exponents at critical points. ; The students know different renormalization group approaches to critical phenomena. They can explain the relations and differences between the real-space, Wilon's and the field-theoretical renormalization group approach. The student can perform basic calculations using these approaches in terms of Feynman diagrams and flow equations. ; Students can present solutions to specific calculations on selected topics on the subject matter in an exercise group or in a seminar talk and participate in discussions.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• D. Forster, Hydrodynamic Fluctuations, Broken Symmetry, and Correlation Functions • L.D. Landau und E. M. Lifschitz, Hydrodynamik • G. Röpke, Statistische Mechanik für das Nichtgleichgewicht • S.H. Strogatz, Nonlinear Dynamics and Chaos • R.J. Goldston und P.H. Rutherford, Plasmaphysik • C. Domb und J.L. Lebowitz, Phase Transitions and Critical Phenomena (selected chapters)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Weßel

ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Statistical Physics: Lecture and Exercises (131060902)	2nd semester	no semester recommended	0	6
Statistical physics (131060901)	2nd semester	no semester recommended	10	0

Industrial Placement (1314127)

Module titel	Industrial Placement (Compulsory elective subject)
Identifier	1314127
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Bachelor/Master
Content	Industrial placement
Learning Objectives/ Learning Outcomes	• The students have an insight into the working environment of a physicist. • The students become acquainted with the organization and the work processes of a company.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	-
Language	German
Examination Terms	The internship has a duration of at least four weeks (full-time). The student must organize the internship himself/herself. The assessment is a written report or oral presentation about the internship. The student must find a lecturer at RWTH Aachen University who will assess the presentation or the internship. The module is ungraded.
Miscellaneous	-
Module coordinator	-
ECTS Credits	10
Contact time (WSH)	0
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	,0
Self-study hours (h)	300,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Industrial Placement (131412701)	5th semester	no semester recommended	10	0

Deep Learning in Physics Research (1311076)

Module titel	Deep Learning in Physics Research (Compulsory elective subject)
Identifier	1311076
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	Introduction to machine learning with deep neural networks. Introduction to the TensorFlow library for deep learning. Application of TensorFlow to image recognition and to specific problems in solid state, particle and astroparticle physics.
Learning Objectives/ Learning Outcomes	The students understand the basics of machine learning with deep neural networks. They are familiar with modern architectural concepts for neural networks. The students perform data analysis with various neural networks in different physics fields. The course enables students to develop and train their own neural networks, to evaluate their quality and to understand how the networks work.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	-
Language	English
Examination Terms	The module examination is passed through successful completion of written homework or successful participation in practical exercises. The module is ungraded.
Miscellaneous	-
Module coordinator	Klemradt, Uwe Erdmann, Hans Martin
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Deep Learning in Physics Research (Lecture and Exercises) (131107602)	2nd semester	no semester recommended	0	3
Deep Learning in Physics Research (Examination) (131107601)	2nd semester	no semester recommended	5	0

Research Internship (1314123)

Module titel	Research Internship (Compulsory elective subject)
Identifier	1314123
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Bachelor/Master
Content	Research internship
Learning Objectives/ Learning Outcomes	• The students have an insight into the current research. • ;The students become acquainted with the typical work processes of a research group.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	-
Language	German
Examination Terms	The internship has a duration of at least four weeks (full-time). The student must organize the internship himself/herself. The assessment is a written report or oral presentation about the internship. The student must find a lecturer at RWTH Aachen University who will assess the presentation or the internship. The module is ungraded.
Miscellaneous	-
Module coordinator	-
ECTS Credits	10
Contact time (WSH)	0
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	,0
Self-study hours (h)	300,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Research Internship (131412301)	1st semester	no semester recommended	10	0

Theory of Deep Learning (1326810)

Module titel	Theory of Deep Learning (Compulsory elective subject)
Identifier	1326810
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	Introduction • Linear Algebra • Probability and information theory • Machine learning basics ; Deep learning • Feedforward networks • Regularisation and optimisation • Convolutional, recurrent and recursive networks Deep learning research • Autoencoders, Generative adversarial networks, normalising flows • Representation learning • Reinforcement learning • Field theory of neural networks ;
Learning Objectives/ Learning Outcomes	The course provides an introduction to the theoretical foundations of deep learning. It covers mathematical and conceptual background, including the relevant concepts in linear algebra, probability theory and information theory, and machine learning. It analyses modern deep learning techniques such as deep feedforward networks, regularization, optimization algorithms, convolutional networks, and practical methodology. Finally, the courses addresses modern deep learning research in particle and astroparticle physics, including methods such as autoencoders, graph neural networks, normalising flows etc.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Christopher M. Bishop, ;Pattern Recognition and Machine Learning; ;Ian Goodfellow and Yoshua Bengio and Aaron Courville: Deep Learning
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michael Krämer
ECTS Credits	10
Contact time (WSH)	6

Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theory of Deep Learning (132681001)	2nd semester	no semester recommended	10	6

Module titel	Accelerator Physics Seminar (Compulsory elective subject)
Identifier	1311233
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2014
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Grading of the presentation including write-up
Miscellaneous	-
Module coordinator	Andreas Lehrach
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course on Astroparticle Physics (131123301)	2nd semester	no semester recommended	5	2

Module titel	Experimental Techniques in Particle Physics (Compulsory elective subject)
Identifier	1310611
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Lecture: Radiactive Sources, acceleration of particles, cosmogenic radiation, interaction of charged particles with matter, absorption of photons in matter, visual detectors, semiconductor detectors, gas ionization detectors, scintillators and photo detectors, particle identification, calorimetry GEANT course: MC Simulation, geometry, materials, particles, processes, physics list, tracking, electric field, magnetic field. FPGA course: digital electronics, FPGA, Xilinx, hardware description language (Verilog), boolean logic, glue-logic, clocking, data-transmission, state-machine, data storage, FiFo, counter, Time to Digital Converter, Flash ADC readout, blocking and non-blocking assignment, jitter, glitch
Learning Objectives/ Learning Outcomes	Students are able to - understand how particles interact with matter - transfer this knowledge to the design of particle detectors - model particle detectors within a software framework - track particles through a detector simulation - understand how detector signals are digitized - program special digital electronics devices (FPGAs)
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Alexander Schmidt
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0

Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Experimental Techniques in Particle Physics: Lecture and Exercises (131061102)	1st semester	no semester recommended	0	6
Experimental Techniques in Particle Physics (131061101)	1st semester	no semester recommended	10	0

Module titel	Gauge Theories in Particle Physics (Compulsory elective subject)
Identifier	1319145
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	- Introduction to quantum field theory - Tree-level applications: cross-section calculations - Loops and renormalization - Effective field theories - Gauge symmetries - Quantum chromodynamics - Spontaneous symmetry breaking - Electroweak theory - Testing the Standard Model at the LHC
Learning Objectives/ Learning Outcomes	The course provides an accessible introduction to gauge theories and the Standard Model of particle physics. The emphasis is on the main concepts of quantum field theory and of the strong and electroweak theories in particular. A detailed exposition of practical calculations for testing the Standard Model at the Large Hadron Collider LHC will be pro-vided. The course will focus on the theoretical aspects of the Standard Model and com-plement the module "Particle Physics I".
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michael Krämer
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Gauge Theories in Particle Physics (Examination) (131914501)	1st semester	no semester recommended	10	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Gauge Theories in Particle Physics (Lecture/Exercises)	1st semester	no semester recommended	-	6

Module titel	Introduction to Accelerator Physics (Compulsory elective subject)
Identifier	1311073
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	- Introduction - Common types of accelerators - Accelerator components - Linear beam dynamics in circular accelerators - Nonlinear beam dynamics and collective effects - Beam cooling and luminosity - Spin dynamics
Learning Objectives/ Learning Outcomes	The aim of this lecture is to give a comprehensive introduction to particle accelerator physics and technology. It includes the presentation of the most common types of accelerators and accelerator components and the theoretical description of beam and spin motion in circular accelerators.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Andreas Lehrach
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

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Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to Accelerator Physics: Lecture and Exercises (131107302)	1st semester	no semester recommended	0	3
Introduction to Accelerator Physics: Examination (131107301)	1st semester	no semester recommended	5	0

Module titel	Low-energy Neutrino Physics (Compulsory elective subject)
Identifier	1311075
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	- Introduction to neutrino physics - Experimental techniques in neutrino physics - Solar neutrinos: what can we learn about the Sun and about neutrinos themselves - Geo-neutrinos: a new tool to study the deep Earth - (Anti)Neutrinos from artificial sources in the search of sterile neutrino - Overview of the past, existing and future experiments
Learning Objectives/ Learning Outcomes	Students will get an overview about the state of the art of low-energy neutrino physics: from its position within the framework of modern physics, through open questions it is addressing, as well as examples of intricate details of modern experiments, towards up-to-date results and future perspectives of this exciting field.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Achim Stahl
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Low-energy Neutrino Physics: Lecture and Exercises (131107502)	2nd semester	no semester recommended	0	3
Low-energy Neutrino Physics: Examination (131107501)	2nd semester	no semester recommended	5	0

Module titel	New Results from Particle and Astroparticle Physics (Seminar) (Compulsory elective subject)
Identifier	1311070
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Varying topics from Particle and Astroparticle Physics
Learning Objectives/ Learning Outcomes	The students acquire in-depth knowledge about the subject of their seminar topic. They are able to extract the required information from the literature. The students know how to prepare an oral presentation as well as a short scientific write-up on their topic. They can communicate their topic to their peers and are able to critically review the presentations of the others.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Lutz Feld
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
New Results from Particle and Astroparticle Physics (Seminar) (131107001)	1st semester	no semester recommended	10	2

Module titel	Physics at the LHC with the CMS experiment (Compulsory elective subject)
Identifier	1311072
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Topics: • The LHC and HL/LHC project • The CMS experiment and its subdetector systems • Reconstruction algorithms and data analysis • Basics of proton-proton collider physics • Top quarks physics • Tau lepton physics • Higgs boson physics • Physics beyond the Standard Model. The student presents a topic to the peers, based on a few recent CMS publications
Learning Objectives/ Learning Outcomes	The students are introduced to the LHC project and the CMS experiment beyond the normal details learned in a regular particle physics introductory course. The students are provided with an overview of the key concepts related to reconstruction algorithms and data analysis techniques used by a large high energy physics collaboration. The students understand the context within the CMS experiment. The students have a basic understanding of the main physics topics the LHC/CMS projects are working on, namely Standard Model physics with all quarks, all leptons, the Higgs boson and searches for physics beyond the Standard Model. The students can communicate the results of the scientific work of the LHC and CMS projects by an oral presentation to their peers.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Oliver Pooth
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0

Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Physics at the LHC with the CMS experiment: Lecture and Exercises (131107202)	1st semester	no semester recommended	0	3
Physics at the LHC with the CMS experiment: Examination (131107201)	1st semester	no semester recommended	5	0

Module titel	Quark Flavour Physics (Compulsory elective subject)
Identifier	1320696
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	The lecture gives an introduction to quark flavour physics, including B-physics, charm physics and kaon physics. Specific topics include -Overview of past, current and future flavour physics experiments -Flavour physics in and beyond the Standard Model -CP-violation and mixing -Rare decays and flavour changing neutral currents -Precision searches for Physics beyond the Standard Model using flavour
Learning Objectives/ Learning Outcomes	The students will get an overview of Flavour physics including both experimental and phenomenological aspects.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Langenbruch, Christoph
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quark Flavour Physics (132069601)	2nd semester	no semester recommended	5	3

Module titel	Seminar on Statistics and Data Analysis (Compulsory elective subject)
Identifier	1319146
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	• Markov Chains • Singular Value Decomposition • Event Weighting • Discrete Fourier Transformation • Auto Correlation Functions
Learning Objectives/ Learning Outcomes	Students will be able to study a specific topic in statistics from literature and present it to their co-students.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Jörg Pretz
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar on Statistics and Data Analysis (Seminar) (131914601)	3rd semester	no semester recommended	5	3

Module titel	Statistics and Data Analysis (Compulsory elective subject)
Identifier	1311071
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Description of Data • Random Variables and Distributions • Errors (Uncertainties) • Parameter Estimation • Confidence Intervals • Test of Hypotheses • Multivariate Methods
Learning Objectives/ Learning Outcomes	Students will have an overview over various statistical methods. The goal is to familiarize the students with the tools necessary for typical data analyses, especially in particle physics. Students are able to apply statistical methods to their research projects and to critically interpret a statistical analyses.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	• Glen Cowan: "Statistical Data Analysis", Oxford Press, ISBN-13: 978-0198501558. • R.J. Barlow: "Statistics: A Guide to the Use of Statistical Methods in the Physical Sciences", John Wiley, ISBN-13: 978-0471922957. • Frederick James, Statistical Methods in Experimental Physics, World Scientific • Volker Blobel, E. Lohrmann: "Statistische und Numerische Methoden der Datenanalyse", Teubner, ISBN-13: 978-3519032434. • Particle Data Group: Review of Particle Physics
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Jörg Pretz
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0

Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Statistics and Data Analysis: Lecture and Exercises (131107102)	1st semester	no semester recommended	0	4
Statistics and Data Analysis: Examination (131107101)	1st semester	no semester recommended	5	0

Module titel	Advanced Cosmology (Compulsory elective subject)
Identifier	1320716
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	In this course of advanced cosmology, we will proceed with the description of the standard cosmological model, started in the first semester course “Relativity and Cosmology”. Using general relativity together with particle physics and thermodynamics, we will review the thermal history of the Universe. We will describe the decoupling of dark matter, neutrinos and photons, as well as the formation of the first nuclei and atoms. We will then study the evolution of linear density fluctuations in the Universe. We will see how they are likely to appear as a consequence of quantum effects during inflation, and how they evolve until now according to the laws of relativistic hydrodynamics. We will study in particular the physics of CMB anisotropies, and explain why the analysis of CMB maps provides a precise measurement of the abundance of the various ingredients that constitute our Universe.
Learning Objectives/ Learning Outcomes	The content of this course will be useful for students willing to do research in several areas: high-energy particle physics, astroparticle physics, or cosmology. Unlike in the winter semester course, the student will be able to appreciate on which solid foundations our understanding of the history and composition of the universe relies.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Lesgourgues, Julien
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced Cosmology (132071601)	2nd semester	no semester recommended	10	6

Module titel	Laboratory Course Astroparticle Physics (Compulsory elective subject)
Identifier	1311077
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Christopher Wiebusch
ECTS Credits	5
Contact time (WSH)	5
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	75,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Astroparticle Physics (131107701)	2nd semester	no semester recommended	5	5

Module titel	Neutron Stars, Black Holes and Ultra-high Energy Cosmic Rays (Compulsory elective subject)
Identifier	1320644
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	• Stellar hydrostatic equilibrium • Endpoints of stellar evolution: white dwarfs, neutron stars, black holes • Pulsars: Gold-Pacini model, pulsar phenomenology, pulsar magneto-spheres • Accretion: Eddington accretion, Bondi accretion, accretion disks • Black holes: Schwarzschild metric, Kerr metric, Boyer-Lindquist metric • Magnetospheres of BHs: Blandford-Znajek mechanism, Blandford-Paine mechanism • Phenomenology of active galaxies • Acceleration mechanisms: shock acceleration, stochastic acceleration, recon-nection • Ultra-high energy cosmic rays: source candidates, transport • Ultra-high energy neutrinos: source candidates, multi-messenger constraints • Gravitational waves: primor-dial and astrophysical sources
Learning Objectives/ Learning Outcomes	The students are familiar with the processes resulting in core collapse supernovae. They can evaluate the validity of the magnetohydrodynamics (MHD) approach in various astrophysical environments. The students are familiar with the various pulsar models, from Gold-Pacini to the self-consistent pulsar magnetosphere. The students can develop the motion of massive and massless particles in the Schwarzschild space time and can evaluate similarities and differences between the Schwarzschild and Kerr space times. They are familiar with the basics of accretion onto black holes and develop some notions of black hole magnetospheres. The students know the observational characteristics of ultra-high energy cosmic rays and can evaluate the viability of different astrophysical source candidates.
(Study-Specific) Prerequisites	Keine Voraussetzung für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Philipp Mertsch
ECTS Credits	5
Contact time (WSH)	3

Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Neutron Stars, Black Holes and Ultra-high Energy Cosmic Rays (132064401)	2nd semester	no semester recommended	5	3

Module titel	Theoretical Concepts in High-Energy Astrophysics (Compulsory elective subject)
Identifier	1315977
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	• Plasmas • Charged particles in external magnetic fields • Statistical mechanics of plasmas (test-wave, test-particle approaches) • Fluid equations • MHD (magneto-hydrodynamics) equations • MHD waves • Cold plasma waves • Fokker-Planck equation • Transport equation • Transport coefficients • Shocks • Evolution of supernova remnants • Diffusive shock acceleration • Radiation processes (Compton scattering, bremsstrahlung, cyclotron, synchrotron, inverse-Compton scattering)
Learning Objectives/ Learning Outcomes	The students can evaluate the conditions of various astrophysical plasmas and identify the ; approaches appropriate for their analytical investigation. They can derive the magnetohydrodynamics (MHD) equations in non-relativistic settings from basic fluid mechanics and electrodynamics. They can derive and interpret the dispersion relations of Alfven, fast and slow modes by linearising the MHD equations. The students can apply the quasi-linear approach to the scattering of charged particles in turbulent magnetic fields. The students are familiar with hydrodynamic shocks and can evaluate when diffusive shock acceleration can be efficient. The students can apply various radiation processes relevant to non-thermal particles.
(Study-Specific) Prerequisites	None
(recommended) Requirements	-
References	References to text books and review articles will be provided during the course.
Language	English
Examination Terms	Zulassung zur Modulprüfung: Schriftliche Hausaufgaben, praktische Übungen oder ein Referat. Modulprüfung: Klausurarbeit, mündliche Prüfung oder Referat
Miscellaneous	-
Module coordinator	Philipp Mertsch
ECTS Credits	5
Contact time (WSH)	3

Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Concepts in High-Energy Astrophysics: Lecture and Exercises (131597702)	1st semester	no semester recommended	0	3
Theoretical Concepts in High-Energy Astrophysics: Examination (131597701)	1st semester	no semester recommended	5	0

Module titel	Cosmological Perturbations (Compulsory elective subject)
Identifier	1322709
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	The course deals with the evolution of cosmological perturbations from the early radiation dominated Universe to our current Universe dominated by dark energy. We will discuss how the primordial perturbations seeded from cosmic inflation shape the cosmic microwave background and how we can use this information to determine the composition of our Universe to high precision. We will further study how massive structures such as galaxies and clusters can arise from the tiny initial perturbations.
Learning Objectives/ Learning Outcomes	The students understand the physics of cosmological perturbations
(Study-Specific) Prerequisites	-
(recommended) Requirements	No prerequisite for admission to the module.
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. The mode of examination is announced by the beginning of the semester.
Miscellaneous	-
Module coordinator	Julien Lesgourgues
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Cosmological Perturbations (132270901)	2nd semester	no semester recommended	5	3

Module titel	Astrophysics with Charged Cosmic Rays - The AMS-02 Experiment on the ISS (Compulsory elective subject)
Identifier	1323418
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	We will discuss the physics results of the Alpha Magnetic Spectrometer (AMS-02) Experiment on the International Space Station. AMS-02 has recently published several important papers in Physics Review Letters. After an introduction to the construction and operation of the AMS-02 Experiment we will review these papers. Students will present 30 minute summaries and then we will discuss the impact of the results on our understanding of high energy processes in the universe. Several important results of AMS-02 require an independent confirmation with a new instrument in Space. We will compare the AMS-02 results with the possible sensitivity, resolution and acceptance of the next generation magnetic spectrometer in Space AMS-100.
Learning Objectives/ Learning Outcomes	The students are provided with an overview of the key concepts related to the construction, operation and calibration of particle detectors in Space. The students can analyze the precision of the published scientific results and discuss various sources of uncertainty. The students master the theoretical methods and establish a connection between theory, problem-solving and applications in astroparticle physics. The students can apply computer based analysis techniques to published data sets from the Alpha Magnetic Spectrometer on the International Space Station. The students can develop computer programs for the numerical analysis of typical published data sets from the Alpha Magnetic Spectrometer on the International Space Station. The students can develop simulations for the measurements of charged cosmic rays in Space. The students can communicate the published scientific results by an oral presentation. The students demonstrate critical and innovative thinking by displaying competence in oral and visual communication.
(Study-Specific) Prerequisites	keine
(recommended) Requirements	keine
References	-
Language	English
Examination Terms	Oral presentation (50%) and written homework (50%)
Miscellaneous	-
Module coordinator	Schael, Stefan
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0

Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Astrophysics with Charged Cosmic Rays - The AMS-02 Experiment on the ISS (132341801)	1st semester	no semester recommended	5	4

Module titel	Gauge Theories in Particle Physics (Compulsory elective subject)
Identifier	1319145
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	- Introduction to quantum field theory - Tree-level applications: cross-section calculations - Loops and renormalization - Effective field theories - Gauge symmetries - Quantum chromodynamics - Spontaneous symmetry breaking - Electroweak theory - Testing the Standard Model at the LHC
Learning Objectives/ Learning Outcomes	The course provides an accessible introduction to gauge theories and the Standard Model of particle physics. The emphasis is on the main concepts of quantum field theory and of the strong and electroweak theories in particular. A detailed exposition of practical calculations for testing the Standard Model at the Large Hadron Collider LHC will be pro-vided. The course will focus on the theoretical aspects of the Standard Model and com-plement the module "Particle Physics I".
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michael Krämer
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Gauge Theories in Particle Physics (Examination) (131914501)	1st semester	no semester recommended	10	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Gauge Theories in Particle Physics (Lecture/Exercises)	1st semester	no semester recommended	-	6

Module titel	Advanced quantum field theory (Compulsory elective subject)
Identifier	1311083
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2016
Valid until	-
Module level	Master
Content	Advanced topics in quantum field theory, including in particular QCD at colliders, the operator product expansion, factorization and resummation, anomalies, the effective potential and non-perturbative methods.
Learning Objectives/ Learning Outcomes	Understanding of the course content
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Michael Krämer
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced quantum field theory: Lecture and Exercises (131108302)	3rd semester	no semester recommended	0	6
Advanced quantum field theory: Examination (131108301)	3rd semester	no semester recommended	10	0

Module titel	Dark Matter (Compulsory elective subject)
Identifier	1316959
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	This lecture series aims to give a comprehensive overview of current research into particle dark matter. We will begin by critically reviewing the astrophysical and cosmological evidence for dark matter and discuss the properties of dark matter that can be inferred from these observations. The main part of the lecture series will then be dedicated to presenting the major theories proposed to explain these observations in terms of new fundamental particles and how these proposals relate to open problems in particle physics. Particular emphasis will be placed on weakly interacting massive particles and axions, and we will study in detail the cosmology and phenomenology of both. In the final part of the lecture series, we will consider alternative ideas such as sterile neutrinos, asymmetric dark matter and self-interacting dark matter.
Learning Objectives/ Learning Outcomes	The students understand the wide range of requirements that viable models of particle dark matter must satisfy and are familiar with the most promising proposals. They have an intuition for which constraints will be most relevant for a given model and which experimental and observational strategies are most promising to make a discovery. They apply dimensional analysis to estimate the magnitude of an effect and interpret experimental data to infer the implications for a given model. The students know how to calculate the relic abundance of dark matter particles for a number of different mechanisms and how to estimate constraints on the parameter space of dark matter models from direct and indirect searches. They are familiar with the various connections between the dark matter problem and other open problems of the Standard Model of particle physics. The students critically examine proposed models, formulate relevant questions and innovative ideas and discuss them with their peers. They understand the scientific method and how to formulate and test hypotheses in order to identify the underlying laws of nature.
(Study-Specific) Prerequisites	None
(recommended) Requirements	Keine
References	-
Language	English
Examination Terms	Zulassung zur Modulprüfung: Schriftliche Hausaufgaben, praktische Übungen oder ein Referat. Modulprüfung: Klausurarbeit, mündliche Prüfung oder Referat
Miscellaneous	-
Module coordinator	Felix Kahlhöfer
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0

Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Dark Matter: Lecture and Exercises (131695902)	2nd semester	no semester recommended	0	3
Dark Matter: Examination (131695901)	2nd semester	no semester recommended	5	0

Module titel	Particles, Fields, and Strings (Seminar) (Compulsory elective subject)
Identifier	1311080
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Michael Krämer
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Particles, Fields, and Strings (Seminar) (131108001)	2nd semester	no semester recommended	10	2

Module titel	Atomically Resolved Microscopy and Spectroscopy with Electrons (Compulsory elective subject)
Identifier	1310614
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Joachim Mayer
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Atomically Resolved Microscopy and Spectroscopy with Electrons: Lecture and Exercises (131061402)	2nd semester	no semester recommended	0	3
Atomically Resolved Microscopy and Spectroscopy with Electrons: Examination (131061401)	2nd semester	no semester recommended	5	0

Module titel	Diffraction: Neutron Methods (Compulsory elective subject)
Identifier	5321599
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Scattering theory; interaction neutrons with matter; different experimental neutron scattering methods. Two-week course. First week: lectures in Jülich; second week: hands-on experiments at the FRM II neutron research reactor in Garching.
Learning Objectives/ Learning Outcomes	The course enables students to apply neutron scattering for the characterization of synthetic and biological materials. Students will learn the theoretical foundations and conduct experiments at neutron instruments to become acquainted with the method.
(Study-Specific) Prerequisites	-
(recommended) Requirements	There are no special requirements for the admission to the Laboratory Course. At-tendance in the practical course ‘Neutron Scattering’ is compulsory. Permissible times of absence will be stated by the instructor at the beginning of the course.
References	-
Language	English
Examination Terms	The module grade results from the grade of the exam.
Miscellaneous	-
Module coordinator	-
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Neutron Scattering (532159901)	4th semester	3rd semester	6	3

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Neutron Scattering	no semester recommended	no semester recommended	-	-

Module titel	Experimental Magnetic Resonance Tomography (Compulsory elective subject)
Identifier	9010792
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Dr. rer. medic. Marion GrandeModellierungsteamverantwortlicher: Vanessa Ziemons M. A.Modulverantworlicher: Universitätsprofessor Dr. phil. (GB) Nadim Joni Shah
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Experimental Magnetic Resonance Tomography (901079201)	1st semester	no semester recommended	5	3

Module titel	Experimental Methods in Modern Solid State Physics (Compulsory elective subject)
Identifier	1311085
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	-
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Uwe Klemradt, Thomas Taubner
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Experimental Methods in Modern Solid State Physics (131108501)	1st semester	no semester recommended	10	2

Module titel	From Physics Principles to the Product (Compulsory elective subject)
Identifier	1310616
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Matthias Wuttig
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
From Physics Principles to the Product: Lecture and Exercises (131061602)	2nd semester	no semester recommended	0	3
From Physics Principles to the Product: Examination (131061601)	2nd semester	no semester recommended	5	0

Module titel	High Frequency Experiments and Methods (Compulsory elective subject)
Identifier	1311088
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	- Coaxial cables and waveguides - Passive components (attenuators, mixers, couplers, circulators etc.) - Amplifiers - Diagnostic and measurement instruments (oscilloscopes, time domain reflectometry, vector networ analyzer) - Low temperature considerations There will also be occasional discussions of specific experiments that these techniques are used for, such as: - RF readout of single electron transistors and quantum point contacts - Parametric sub-quantum limit amplification - Circuit quantum electrodynamics with superconducting cavities - Dispersive microwave readout for sensors and qubits - Qubit control - Classical and quantum noise
Learning Objectives/ Learning Outcomes	This course aims to provide practical working knowledge of high frequency techniques, components and instruments used in modern experiments. The presentation will be tailored to the needs of typical experimental work. Course activities also include demonstrations and hands on experiments with high frequency components and equipment.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Hendrik Bluhm
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0

High Frequency Experiments and Methods (1311088)

Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
High Frequency Experiments and Methods: Lecture and Exercises (131108802)	1st semester	no semester recommended	0	3
High Frequency Experiments and Methods: Examination (131108801)	1st semester	no semester recommended	5	0

Module titel	Introduction to soft matter physics (Compulsory elective subject)
Identifier	1311133
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	1) Polymers, 2) Polymer gels 3) Liquid crystals and 4) Colloids
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics dealing with the physical properties and application of a soft matter. Theoretical concepts of related phenomena will be introduced and also discussed in the context of experimental data. The learned research topics will especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	1) M. Doi "Soft matter physics" (Oxford University Press, 2013) 2) R. Jones "Soft condensed matter" (Oxford University Press, 2002)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Dmitry Chigrin
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to soft matter physics: Lecture and Exercises (131113302)	1st semester	no semester recommended	0	3
Introduction to soft matter physics: Examination (131113301)	1st semester	no semester recommended	5	0

Module titel	Material Analysis by Synchrotron Radiation and Neutrons (Compulsory elective subject)
Identifier	1310612
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Brief repetition of diffraction on crystalline matter and elementary analysis of scattering experiments / Introduction to the Dynamical Theory of Diffraction / Diffraction on real crystals: mosaicity, domains, … / Scattering on amorphous matter / Interaction of X-ray radiation and neutrons with matter, including inelastic scattering / Grazing incidence / Absorption spectroscopy / Selected additional topics
Learning Objectives/ Learning Outcomes	Students will become acquainted with diffraction and scattering methods used to investigate structure and dynamics of crystalline and non-crystalline matter, using modern neutron and synchrotron x-ray sources. They will acquire an overview of experimental solutions for important questions in material analysis using scattering and selected complementary approaches.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Manuel Angst
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Material Analysis by Synchrotron Radiation and Neutrons: Lecture and Exercises (131061202)	2nd semester	no semester recommended	0	3
Material Analysis by Synchrotron Radiation and Neutrons: Examination (131061201)	2nd semester	no semester recommended	5	0

Module titel	Nano-Optics I (Compulsory elective subject)
Identifier	1311087
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Optical properties of nanostructures: • Surface plasmons (Derivation from Maxwell equations, dispersion relation, excitation of surface waves, applications in (bio)sensing, interconnects on chips, collimation of laser diodes, etc.) • Optical Properties of Nanoparticles (Localized plasmon resonances, scattering and absorption cross-sections, Mie &;; Rayleigh Scattering, Optical antennas &; their applications in sensing, microscopy etc. • Enhanced spectroscopies: Surface-enhanced Raman Scattering (SERS), Surface-enhanced Infrared Absorption (SEIRA), enhanced and quenched Fluorescence • Metamaterials: negative index of refraction, fabrication &;; measurements, coupling effects in MM, 3D and active MM, Cloaking, Superlensing
Learning Objectives/ Learning Outcomes	Students are acquainted with selected research topics dealing with the optical properties and application of nanostructures. The students understand the physical principles of nano-optical structures, can present them, discuss them and critically evaluate the potential applications of nano-optical structures. This knowledge shall prepare the students for the future of nanotechnology. The learned research topics especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Thomas Taubner
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nano-Optics I: Lecture and Exercises (131108702)	1st semester	no semester recommended	0	3
Nano-Optics I: Examination (131108701)	1st semester	no semester recommended	5	0

Module titel	Nano-Optics II (Compulsory elective subject)
Identifier	1315030
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Optical Microscopy below the diffraction limit: • Fundamentals of microscopy and introduction to near-fields (Diffraction Limit of conventional microscopes, evanescent fields, Fields of a dipole, far-field superresolution microscopes) • Near-field optical microscopy (principle, history, scanning probe microscopies, aperture probes, fields of circular aperture, transmission cutoff) • Apertureless Near- field optical microscopy (apertureless probes, dipole-dipole coupling, detection schemes, artefacts) • Applications of near-field optical microscopy (infrared near-field spectroscopy of: polymers &;; proteins, phonons in polar dielectrics, conduction properties)
Learning Objectives/ Learning Outcomes	Students are acquainted with optical concepts and techniques that are capable of imaging individual nanostructures. The students understand the basic physics behind these optical techniques and can apply them in the context of scanning probe microscopy. With this overview over experimental methods, the students are able to precisely pick the suited method for the investigation of problems related to nanostructures and their optical characterization. The learned research topics especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Thomas Taubner
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nano-Optics II: Lecture and Exercises (131503002)	2nd semester	no semester recommended	0	3
Nano-Optics II: Examination (131503001)	2nd semester	no semester recommended	5	0

Module titel	Nonequilibrium Thermodynamics (Compulsory elective subject)
Identifier	1319143
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	In the equilibrium thermodynamics one deals with processes taking place at infinitely slow rate through a sequence of equilibrium states. In the nonequilibrium thermodynam-ics rapid changes both in time and space are allowed, leading to dramatic consequences in possible system evolution. Different theoretical approaches to describe far-from-equilibrium systems will be presented. Applications to physical, chemical and biological systems will be discussed.
Learning Objectives/ Learning Outcomes	The aim of the class is to give an introduction in the nonequilibrium thermodynamics, that is the thermodynamics in the far-from-equilibrium situation.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Dmitry Chigrin
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nonequilibrium Thermodynamics (Examination) (131914301)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nonequilibrium Thermodynamics (Lecture/Exercises)	1st semester	no semester recommended	-	3

Module titel	Optical Methods (Compulsory elective subject)
Identifier	1311093
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2017
Valid until	-
Module level	Master
Content	The students will obtain an overview of various optical methods to be applied in material science, soft matter physics and biophysics. The students will execute a weekly delivered exercise sheet and present and discuss their results.
Learning Objectives/ Learning Outcomes	Lecture: The students will obtain an overview of various optical methods to be applied in material science, soft matter physics and biophysics. They are introduced to the foundations of basic optical methods and get an in-depth explanation of key concepts in optical spectroscopy and microscopy. The students will be able interpret experimental data, know which methodical approach has to be used for specific scientific questions, and can judge possibilities and limitations from case studies in a broad field of interdisciplinary applications. ; ; ; Exercise: The students will execute a weekly delivered exercise sheet and present and discuss their results. They will be able to interpret measured data quantitatively and can solve a wide variety of problems in the field of the above mentioned optical methods.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Jörg Fitter
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Optical Methods: Lecture and Exercises (131109302)	1st semester	no semester recommended	0	3
Optical Methods: Examination (131109301)	1st semester	no semester recommended	5	0

Module titel	Photoelectron Spectroscopy (Compulsory elective subject)
Identifier	1327822
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Methods: • The students know the principle of operation of electron spectrometers, vacuum ultraviolet and x-ray light sources, spin filters, and other. • They have a basic understanding of various techniques such as x-ray photoemission (XPS), angle-resolved photoemission (ARPES), spin-polarized ARPES, time-resolved ARPES, and other. • They understand the operation and data collection principles and can differentiate between various measurement modes. • They know various sample types and preparation procedures. Theory: • The students remember a theoretical description of the photoemission process on several levels. • They understand the phenomenological three-step model and can apply it to describe main features of the photoemission signal. • They understand that more accurate description is obtained through the one-step model and that photoemission signal from correlated materials is described by the spectral function. • The students are introduced to the key concepts in various photoemission variants such as time-resolved ARPES, spin-polarized ARPES. Applications • The students are introduced to the physics of selected material types such as Rashba systems, topological insulators, magnetic thin films, 2D materials, high-temperature superconductors, and other highly-correlated electron systems. • They understand which material properties can be characterized by which variant of the photoemission technique. • They know the exemplary results and understand parameters necessary to obtain meaningful results, such as energy resolution, temperature, sample orientation, or photon energy.
Learning Objectives/ Learning Outcomes	The students will know the basics of methods, theory, and applications of photoelectron spectroscopy (photoemission, PES). They understand which material properties can be characterized by which variant of PES. They know the semiclassical description of the PES process and the basics of the spectral function formalism. The lecture aims at demonstrating the richness of quantum phenomena that are imaged by the photoemission technique, involving magnetism, topology, low-dimensional effects, and electronic correlations.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation.

	Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Lukasz Plucinski
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Photoelectron Spectroscopy (132782201)	1st semester	no semester recommended	5	3

Physics of Graphene and 2D Materials (1311092)

Module titel	Physics of Graphene and 2D Materials (Compulsory elective subject)
Identifier	1311092
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	- Electronic band structure of graphene - Pseudo-spin and Berry phase - Electronic band structure of 2D transition metal dichalcogenides - Phonons and Mechanical properties of graphene - Membrane physics and Pseudo-magnetic fields - Electron transport and scattering mechanisms - Klein tunneling and quantum interferences - Quantum Hall effect - Electromechanical devices and resonators - Optical properties and Spin properties
Learning Objectives/ Learning Outcomes	This course aims to provide the fundamentals of the physics of graphene and novel two-dimensional (2D) materials. In particular, we will discuss the technological and physical basics of graphene (sp2 bound carbon) and other layered 2D materials. This includes the basic electronic, mechanical and optical properties of graphene and transition metal dichalcogenides (MoS_2, $MoSe_2$, WS_2 and WSe_2). The unique electronic band structures and their promises for technological applications will be addressed in detail. In addition we will focus on optical properties and electron transport in these materials, quantum Hall effect, quantized conductance, and interference effects.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Christoph Stampfer
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Physics of Graphene and 2D Materials: Lecture and Exercises (131109202)	2nd semester	no semester recommended	0	3
Physics of Graphene and 2D Materials: Examination (131109201)	2nd semester	no semester recommended	5	0

Module titel	Physics of Interfaces (Compulsory elective subject)
Identifier	1317006
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Frank Stefan Tautz
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Physics of Interfaces: Lecture and Exercises (131700602)	1st semester	no semester recommended	0	3

Physics of Interfaces: Examination (131700601)	1st semester	no semester recommended	5	0

Module titel	Research Techniques for Advanced Solid State Device Experiments (Compulsory elective subject)
Identifier	1328016
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	In the first part of the course, participants will work in small groups to develop learning modules on specific topics of high relevance for experimental research work that go beyond the content of the standard MSc curriculum. This part will be strongly guided by active researchers. In the second part, all participants will enroll in the modules developed. Topics will be assigned in the first meeting. An exemplary list of possible topics is given below. They come from the domain of quantum dot qubit research, but are to various degrees also relevant for other fields. • Noise spectroscopy measurements • Setup noise debugging (grounding, isolation, shielding) • Instrument noise characterization • Lockin amplifier • Designing low noise analog electronics for transport experiments • Fast buffered data acquisition • Nonlinear fitting • Heterostructure modelling • Thomas-Fermi Simulation of quantum dot devices • Qubit coherence modelling • Agile software engineering • Good coding and software engineering practices
Learning Objectives/ Learning Outcomes	• Participants gain practical experience in the development of innovative, partially self-guided learning modules for acquiring advanced technical skills for research work. • Participants gain expertise in select advanced technical skills at a level suitable for use in research work.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Some familiarity with research requirements, e.g. from a Bachelor’s thesis in a relevant field, will be helpful to motivate the relevance of the course topics. Note that this course does not follow an established concept, so participants should be motivated to be involved in developing an innovative but unproven course format.
References	-
Language	English
Examination Terms	25% Contribution in development of learning activity 25% Presentation of learning activity 50% Oral exam on content of other learning activities
Miscellaneous	-
Module coordinator	Hendrik Bluhm

ECTS Credits	10
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	15,0
Self-study hours (h)	285,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Research Techniques for Advanced Solid State Device Experiments (132801601)	1st semester	no semester recommended	10	4

Module titel	Scanning Probe Microscopy (Compulsory elective subject)
Identifier	1310613
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Introduction to scanning probe microscopy, technical aspects (piezo effect, vibration isolation, PI-controller, microscope designs, lock-in technique), image analysis, tip-sample interaction forces, detection methods in atomic force microscopy, static mode atomic force microscopy, dynamic atomic force microscopy, non contact atomic force microscopy, scanning tunneling microscopy, surface states, scanning tunneling spectroscopy, applications of scanning tunneling microscopy
Learning Objectives/ Learning Outcomes	The students are familiar with the operating principles of several types of scanning probe microscopes. The students can evaluate which scanning probe microscopy method should be applied for a specific measurement task. The students can apply scanning probe microscopy techniques to measurement tasks in surface physics and materials science. The students can understand and interpret the measured scanning probe microscopy data quantitatively.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Bert Voigtländer
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Scanning Probe Microscopy: Lecture and Exercises (131061302)	2nd semester	no semester recommended	0	3
Scanning Probe Microscopy: Examination (131061301)	2nd semester	no semester recommended	5	0

Module titel	Scattering Methods for Condensed Matter Science (Compulsory elective subject)
Identifier	1323318
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	Summer semester 2023
Module level	Master
Content	• Synchrotron radiation sources, properties of synchrotron radiation • Neutron sources, properties of neutron raditation - beam handling devices, detectors • Experimental techniques at synchroton raditation and neutron sources: diffraction, large scale structures, spectroscopy • Application of synchroton radiation and neutrons to topical problems of condensed matter science: quantum materials, thin film heterostructures, nanoparticles • The social practice at large scale facilities (proposal submission, peer review process, writing of an experimental report)
Learning Objectives/ Learning Outcomes	The students are introduced to the application of scattering methods at modern neutron and synchrotron radiation facilities. They have a basic understanding of the various experimental methods available at such large-scale facilities and can evaluate which experimental method is applicable to a specific experimental problem. They have a wide range of skills needed to design and safely conduct experiments at such facilities. They can develop an experimental plan, formulate a proposal for peer-review at large scale facilities and communicate the results of their scientific work in the form of an experimental report.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Oral presentation.
Miscellaneous	-
Module coordinator	Brückel, Thomas
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Scattering Methods for Condensed Matter Science (132331801)	1st semester	no semester recommended	5	2

Module titel	Seminar Physics of Nanostructures (Compulsory elective subject)
Identifier	1311094
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Each student can select one subject from a list of modern topics related to nanostructures or solid state physics.
Learning Objectives/ Learning Outcomes	The students understand the keys of a modern research topic on a level that they can explain it to peers. The students can select the most important concepts of a research topic from scientific literature. The students can present a complex scientific topic within a concise scientific talk. The students get familiar with a modern research field. The students know how to ask prolific questions after a scientific talk.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of quantum mechanical concepts, basic knowledge in solid state physics
References	Will be announced by the instructor, 2-3 month prior to the talk
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Markus Morgenstern
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Physics of Nanostructures (131109401)	1st semester	no semester recommended	10	2

Module titel	Seminar Physics of Novel Materials (Compulsory elective subject)
Identifier	1324279
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2021
Valid until	Summer semester 2023
Module level	Master
Content	Topics include materials based on magnetic nanoparticles, thin film heterostructures of ferromagnets, ferroelectrics, superconductors, correlated electron systems, functional materials for energy storage and energy conversion and (topological) quantum materials
Learning Objectives/ Learning Outcomes	- Advanced knowledge and understanding of topical materials and materials systems - Insight into the experimental methods to study their properties - Gaining an understanding of the microscopic mechanism leading to their functionalities
(Study-Specific) Prerequisites	-
(recommended) Requirements	Quantum mechanics, solid state physics, scattering methods and physical property measurements
References	-
Language	English
Examination Terms	Student's presentation
Miscellaneous	-
Module coordinator	Brückel, Thomas
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Physics of Novel Materials (132427901)	2nd semester	no semester recommended	5	2

Module titel	Structure, Composition, Functionality: Advanced Electron Microscopy Techniques in Solid State Physics (Compulsory elective subject)
Identifier	1321738
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	- Introduction and motivation: Challenges that can be answered by Transmission Electron Microscopy (TEM): Which atom is where? What is the charge distribution at the atomic scale? What are local distortions of the crystal structure and the resulting physical properties? TEM basics and setup. Lenses for electrons, aberrations, Fraunhofer optics. Ewald con-struction and kinematical scattering. Resolution due to Abbe, Scherzer conditions. - Bloch wave solution of the Schrödinger equation in forward scattering geometry for crystalline specimen. Structure factors, Atomic form factors, Debye-Waller Factors, exci-tation error. Analytical 2-beam case, numerical treatment of the many-beam case. Pen-dellösung plots describing the dynamic exchange of intensity among diffracted beams. Applications in electron diffraction: measurement of specimen thickness, crystallographic orientation. - Multislice solution of the Schrödinger equation for ideal crystals and systems with thermal and static disorder. Thermal diffuse scattering and its importance for high-angle scat-tering, e.g., in quantitative Z-contrast Scanning Transmission Electron Microscopy (TEM). - Partial temporal and spatial coherence, Wiener-Chintchen and Zernike-van-Zittert theorems. The importance for Scanning and plane-wave illumination TEM. Treatment in the framework of coherent envelopes, transmission cross-coefficients and the incoherent superposition of coherent images. - Scanning TEM basics. Probe formation, resolution. The Ronchigram: Detection of aber-rations, crystal tilt. Theorem of reciprocity and correspondence to TEM. Application to chemical composition mapping and the mapping of electric fields in 2D materials. - Phase retrieval by TEM methods. Focal series, Transport of intensity equation (TIE), holography. - Phase retrieval by STEM methods. Momentum-resolved STEM, First moment imaging, Differential phase contrast, Wigner distribution deconvolution ("Ptychography") and weak phase objects. - Scattering potentials from first principles. Isolated atom approximation. Density func-tional theory basics. Theorems of Hohenberg &Kohn, Kohn-Sham equations. Solutions for the electron density and Hellmann-Feynman forces. Application to quantitative electron diffraction: the fingerprints of electron redistributions due to chemical bonding.
Learning Objectives/ Learning Outcomes	The participants obtain an overview over the different characteristics of several scattering processes crucial for transmission electron microscopy (TEM) diffraction and imaging. This includes (multiple) elastic scattering and thermal diffuse scattering, as well as scattering at static disorder in crystals. In particular, the attendees will be enabled to accompany state-of-the-art electron microscopy experiments with simulations so as to extract reliable results. A detailed derivation of the two established approaches, the Bloch wave and the multislice method, is providing new insights into the rich diffraction phenomena observed in experiment, from a fundamental physics perspective starting with the Schrö-dinger equation. The lecture introduces the phenomena of partial spatial and temporal coherence from general optics considerations, and provides their detailed treatment for TEM and STEM imaging in the framework of three models of different complexity. With this knowledge, participants are trained in the comprehensive description of contrast formation in atomic-resolution TEM imaging going beyond the conventional linear imaging theory. Attendees are made familiar with advanced aberration-corrected (Scanning) TEM methods which enables them to understand and apply contemporary concepts used to meas-ure chemical composition and electric fields at the atomic scale. In particular, probe formation in STEM as well as high- and low-angle annular dark field imaging are key parts of the curriculum. Recent techniques for phase retrieval in STEM and TEM necessary for electrical and magnetic characterisations in materials science complement the compe-tencies acquired during the lecture. The emerging importance of density functional theory (DFT) in experimentalist's work, combined with the availability of user-friendly codes suggests an excursion to present fundamental DFT concepts in this lecture, and to make the attendees familiar with this powerful tool to achieve the ultimate agreement between experiment and simulation by including bonding effects in the scattering factors.

	Participants are furthermore trained in practical computer and TEM sessions where they achieve the visual insight into the phenomena treated in the lecture, and where they experience the computer and programming capabilities as powerful tools in advanced atomic-resolution TEM.
(Study-Specific) Prerequisites	none
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Knut Müller-Caspary
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Structure, Composition, Functionality: Advanced Electron Microscopy Techniques in Solid State Physics (132173801)	3rd semester	no semester recommended	5	3

Module titel	Oxide Thin Films for Information Technology: Materials and Properties (Compulsory elective subject)
Identifier	6017905
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	# Introduction to the physical properties of transition metal oxides # Polar properties of oxide insulators and their fields of applications # Metal to insulator transitions in oxides and their application for data storage # Multiferroic heterostructures and their application in information technology # Functional properties of epitaxial oxide heterointerfaces # Oxide high temperature superconductors and their possible fields of application
Learning Objectives/ Learning Outcomes	After participation the students are able to, # to understand the large variety of physical properties of the material class of oxides # to understand and assess novel concepts in the field of oxide electronics.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Basic knowledge in solid state physics
References	# R. Waser „Nanoelectronics and Information Technology“
Language	German/English
Examination Terms	oral examination (30min) or written examiation (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr. rer. nat. Regina Dittmann
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 or 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Oxide Thin Films for Information Technology: Materials and Properties (601790501)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Oxide Thin Films for Information Technology: Materials and Properties	1st semester	no semester recommended	-	3

Module titel	Nanomagnetism and Spin Dynamics (Compulsory elective subject)
Identifier	1319144
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	– Brief repetition of the basic physical properties of classical magnetism – Emerging properties due to the reduction of dimensionality – Ferromagnetism and Domain walls – Giant magneto-resistance and tunnel magneto-resistance – Superparamagnetism and blocking temperature – Magnetic anisotropy and spin-orbit-coupling – Coupling of spins: dipolar, direct exchange, orbital overlap, and super-exchange – Ising, Heisenberg, and Dzyaloshinskii-Moriya interactions – Excitations in coupled spins: Magnons and Spinons – Brief repetition of the basic physical properties of classical magnetism – Emerging properties due to the reduction of dimensionality – Ferromagnetism and Domain walls – Giant magneto-resistance and tunnel magneto-resistance – Superparamagnetism and blocking temperature – Magnetic anisotropy and spin-orbit-coupling – Coupling of spins: dipolar, direct exchange, orbital overlap, and super-exchange – Ising, Heisenberg, and Dzyaloshinskii-Moriya interactions – Excitations in coupled spins: Magnons and Spinons – Emerging effects by coupling to bath systems: Kondo effect and intra-gap states in superconductors – Dynamics of quantum spins, Bloch sphere and electron paramagnetic resonance – Magnetometry and magnetic imaging techniques at the nanoscale
Learning Objectives/ Learning Outcomes	The lecture intends to give an introduction to the field of nanomagnetism and spin dy-namics with some focus on recent experimental phenomena.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Ternes, Markus
ECTS Credits	5
Contact time (WSH)	3

Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nanomagnetism and Spin Dynamics (Examination) (131914401)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nanomagnetism and Spin Dynamics (Lecture/Exercises)	1st semester	no semester recommended	-	3

Module titel	Nanotechnology: From the Physical Concept to the Application (Students Seminar) (Compulsory elective subject)
Identifier	1310617
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	For the preparation and presentation of their own seminar talk and work, the students can choose among various topics related to Nanotechnology which all depend on fundamental physical concepts and lead to new applications. The detailed list of topics will be presented at the beginning of each semester.
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They shall learn how to gain knowledge in a new field by themselves by reading literature, connect this new knowledge with already known basic knowledge and finally be able to present their knowledge in an oral presentation. All of this will serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Markus Morgenstern
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nanotechnology: From the Physical Concept to the Application (Students Seminar) (131061701)	2nd semester	no semester recommended	10	2

Module titel	Optical Telecommunications - Devices (Compulsory elective subject)
Identifier	6017166
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	We will cover the basics of electro-optic and photonic devices: • optical waveguides and optical modes of propagation, • planar photonic circuits, • coupled-mode theory and perturbation theory, • electro-optic modulators, • photodetectors, • optical amplifiers, • solid-state and semiconductor lasers.
Learning Objectives/ Learning Outcomes	Students are expected to gain an advanced understanding of devices used for optical data transmission. In particular, the class will enable them to design photonic devices and to make informed choices in the selection of optical components for practical system design. Analysis of complete optical systems per see is not covered by this class, but by “Optical Telecommunications II: Systems”.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Basic knowledge of Electromagnetics and of Semiconductor Physics.
References	• Optical Fiber Telecommunications - IV-A -Components (Ivan Kaminow & Tingye Li) • Photonics: Optical Electronics in Modern Communications (Amnon Yariv & Pochi Yeh)
Language	English
Examination Terms	Written examination (90min) or oral examination (30min).
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Jeremy Witzens Ph. D.
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Optical Telecommunications - Devices (601716601)	1st semester	no semester recommended	5	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Optical Telecommunications - Devices	1st semester	no semester recommended	-	3

Module titel	Optical Telecommunications - Systems (Compulsory elective subject)
Identifier	6017167
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	We will cover: • optical receiver architectures, • basics of signal analysis, • bandwidth limitations and their compensation, • optical keying, • sources of noise in optical communication links, • fiber nonlinearities and the nonlinear Shannon limit, • metro and long-haul networks, fiber-to-the-home networks, datacom systems and their practical implementation, • quantum key distribution (as an outlook).
Learning Objectives/ Learning Outcomes	Students are expected to gain an advanced understanding of optical data transmission systems. In particular, students will be enabled to model state-of-the-art optical communications links, to make informed decisions on system trade-offs and to understand current trends in optical communications system design.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Basic knowledge of Electromagnetics and of Data Transmission Systems. Knowledge of the material covered in Optical Telecommunications - Devices will be helpful but is not a prerequisite.
References	• Optical Fiber Telecommunications - IV-B - Systems and Impairments (Ivan Kaminow & Tingye Li) • Photonics: Optical Electronics in Modern Communications (Amnon Yariv & Pochi Yeh)
Language	English
Examination Terms	Written examination (90min) or oral examination (30min).
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Jeremy Witzens Ph. D.
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Optical Telecommunications - Systems (601716701)	2nd semester	no semester recommended	5	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Optical Telecommunications - Systems	2nd semester	no semester recommended	-	3

Module titel	Fundamentals of Organic Electronics and Optoelectronics - Technology and Applications (Compulsory elective subject)
Identifier	6017143
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	Building on the basics of electronic devices and materials, a detailed review on the interesting topic of organic semiconductors (SC) is given. Besides basic properties of organic SC and their technology (fabrication, deposition, processing), main differences to inorganic SC and novel concepts are highlighted. Large parts are dedicated to the application fields of organic electronic circuits, organic and hybrid organic photovoltaics (OPV / HOPV) as well as organic light emitting diodes (OLED).
Learning Objectives/ Learning Outcomes	In this lecture, students shall become acquainted with the current topic of Organic Electronics and Optoelectronics. Understanding the special properties of organic semiconductors is essential, especially in aspects in which these properties are different from those of inorganic semiconductors. Also included in the lecture are fabrication and characterization of layers and devices. On this basis, current and future devices, circuits and applications are reviewed allowing the students to start further studies and research on that topic. In the examinations, various tasks and practical examples are introduced, analytically solved and discussed.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Basic knowledge of electronic devices and solid-state physic
References	• W. Brütting, Physics of Organic Semiconductors, Wiley-VCH • Markus Schwoerer et al., Organic Molecular Solids , Wiley-VCH
Language	English
Examination Terms	Oral examination (30 min) or written examination (90 min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Andrei Vescan
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Fundamentals of Organic Electronics and Optoelectronics - Technology and Applications (601714301)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Fundamentals of Organic Electronics and Optoelectronics - Technology and Applications	1st semester	no semester recommended	-	3

Module titel	Organic Electronics and Optoelectronics: Advanced Characterization, Physics, Devices (Compulsory elective subject)
Identifier	6018723
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	On the basis of prior knowledge on (opto) electronic devices and materials from part I of this lecture, the topics of this semester comprise special characterization techniques of organic semiconductor technology, specific aspects and applications as well as fundamental physical-technical basics in more detail. Current research topics such as non-linear optical phenomena, optical gain and lasing are part of the curriculum as well as electrochemistry, doping, holography and novel organic and hybrid devices.
Learning Objectives/ Learning Outcomes	In this lecture, the students will become familiar with the current topic of organic electronics and optoelectronics, including the combination of organic and inorganic materials (hybrid concepts). By taking part in the lecture, the students learn to understand more complex aspects of organic and hybrid semiconductor technology. Additionally, they will become acquainted with special characterization methods, suitable for organic films. In sum, the participants gain a comprehensive understanding of the state of the art and of currents research topics and challenges.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Basic knowledge of electronic devices and solid-state physics
References	• W. Brütting, Physics of Organic Semiconductors, Wiley-VCH • Markus Schwoerer et al., Organic Molecular Solids , Wiley-VCH
Language	English
Examination Terms	Oral examination (30 min) or written examination (90 min).
Miscellaneous	-
Module coordinator	Universitätsprofessor Andrei Vescan Holger Kalisch
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Organic Electronics and Optoelectronics: Advanced Characterization, Physics, Devices (601872301)	2nd semester	no semester recommended	5	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Organic Electronics and Optoelectronics: Advanced Characterization, Physics, Devices	2nd semester	no semester recommended	-	3

Module titel	Oxide Thin Films for Information Technology: Growth and Analysis (Compulsory elective subject)
Identifier	6017904
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	The lecture has the following content: # Overview over the physical properties of oxide thin films and their fields of application in information technology # Basics of thin film growth and methods for the deposition of oxide thin films # Defects in solids and thin films # Methods for the characterization of thin films # Working - and failure mechanisms of oxide thin film devices The exercises contain a theoretical and a practical part where the knowledge of the lecture should be applied. The practical coursed take place at FZ Jülich (Transport with JARA Shuttle will be organized).
Learning Objectives/ Learning Outcomes	After participation, the students are able, # to understand current and future fields of application and the special features of the material class of oxides with respect to thin film preparation and device fabrication # to understand the correlation between fabrication method, device function and failure mechanisms
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification. Basic knowledge of solid state physics
References	will be announced in the lecture.
Language	German/English
Examination Terms	oral examination (30min) or written examiation (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr. rer. nat. Regina Dittmann
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Oxide Thin Films for Information Technology: Growth and Analysis (601790401)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Oxide Thin Films for Information Technology: Growth and Analysis	2nd semester	no semester recommended	-	3

Module titel	Physical Sensors in Silicon Technology (Compulsory elective subject)
Identifier	6017803
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	The lecture “Physical Sensors in Silicon Technology” deals with the conception and the manufacturing methods of microsystems based on silicon fabrication technologies. A microsystem is the combination of sensors, actuators and signal processing to a functional unit with structural dimensions in the micrometer range. To achieve this goal, methods of silicon technologies are applied. This allows benefiting from the large experience in microelectronics and ensures compatibility. The first part of the lecture “Silicon-based Sensor and Actuator Systems” addresses operating principles of silicon-based microsensors and their implementation into marketable products. Current examples and applications will be presented. Besides an introduction to the physics of semiconductor devices, the lecture comprises the field of physical sensors. In detail, the lecture is divided into the following areas: sensors for thermal signals, flow sensors, radiation sensors, magnetic field sensors, pressure sensors, MEMS microphones, sensor transponders, accelerometers and gyroscopes. Presentation of the lecture: • Introduction to microsystem technology, attempt of definition, conceptualization of the different techniques • Introduction to the physics of semiconductor devices: atomic model, solid state, insulator, metal, semiconductor, band model, self-conduction, doping, p- and n-conductance, pn junction, diode, bipolar transistor, MOS transistor • Sensors for thermal signals: pn-junction, band gap, silicon temperature sensors, Pt-100 resistors, Ni-100 resistors, thermocouples • Flow sensors: Thermal properties of air and liquids, anemometry, air mass sensor, directional detection, pulsed operation • Sensors for radiation: visible light, CMOS-/ CCD-camera, color filter, IR and UV sensors • Magnetic field sensors: Hall effect, spinning current hallplate, magnetotransistors, magnetoresistivity, anisotropic magnetoresistive effect, flux gate sensor, GMR sensors, hard disk drive heads • Force and pressure sensors: strain gauges, capacitive pressure sensors, surface micromechanics, piezoelectric sensors, piezoresistive sensors, resonant structures, pressure sensor packaging, porous silicon • MEMS microphones and speakers: theory of vibration, electrostatic microphones, electret microphones, manufacturing processes, mikro speakers • Sensor transponders: basics of inductive telemetric systems, design, examples of pressure location transponders, retina stimulators and glucose sensors • Acceleration sensors: Theoretical basics, piezoresistive sensors in bulk micromechanics, capacitive sensors in surface micromechanics, sticking, thick EPI-Poly • Gyroscopes: rotation impulse maintenance, theory, embodiments
Learning Objectives/ Learning Outcomes	After successful participation in the module courses, students are able to: • understand the fundamentals of the production engineering for silicon-based sensor-actuator systems • understand the operating principles of physical sensors • explain the microsystems-technological designs/structures • to evaluate their advantages and disadvantages and to assess their suitability for different application areas.
(Study-Specific) Prerequisites	Keine

(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification.
References	• H. Baltes et al. Eds., „Sensors Update 1- 12“ VCH • T. M.Adams, R. A. Layton, „Introductory MEMs-Fabrication and Application“, Springer • F. Völklein, T. Zetterer, „Einführung in die Mikrosystemtechnik“, Vieweg Studium Technik Transducer-Technologien: • S. Büttgenbach, "Mikromechanik", Teubner Studienbücher • M. Elvenspoek, H. Jansen, „Silicon Micromachining“, Cambridge University Press • G. Gerlach, W. Dötzel, „Einführung im die Mikrosystemtechnik“, Hanserverlag • Carl Hander Verlag München Wien • U. Hilleringmann, „Mikrosystemtechnik auf Silizium", B.G. Teubner Stuttgart • Mohamed Gad-el-Hak ed., „The MEMS Handbook“, CRC Press • N. Schwesinger, C. Dehne, F. Adler, „Lehrbuch Mikrosystemtechnik“, Oldenbourg Wissenschaftsverlag • M. Madou, "Fundamentals of Microfabrication“, CRC Press • W. Menz, P. Bley, "Mikrosystemtechnik für Ingenieure“, VCH-Verlagsgesellschaft • U. Mescheder, “Mikrosystemtechnik“, B. G. Teubner Stuttgart • S. M. Sze, "Physics of Semiconductor Devices", John Wiley & Sons • S. M. Sze, "VLSI Technology", Mac Graw HillBoca Raton-New York
Language	English
Examination Terms	Oral examination (30min) or written examination (90min).
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Wilfried Mokwa
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	30 or 90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Physical Sensors in Silicon Technology (601780301)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Physical Sensors in Silicon Technology	1st semester	no semester recommended	-	3

Module titel	Physics of Nanostructures (Compulsory elective subject)
Identifier	1310618
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Joachim Mayer
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Physics of Nanostructures: Lecture and Exercises (131061802)	2nd semester	no semester recommended	0	6

Physics of Nanostructures: Examination (131061801)	2nd semester	no semester recommended	10	0

Module titel	Robotics and Man-Machine Interaction 2 (Compulsory elective subject)
Identifier	6010448
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	# External and internal sensors for industrial robots # Motors and gears for industrial robots # Grippers # Dynamic models of industrial robots: Canonic equations “Newton-Euler” - Canonic equations “Lagrange” # Control of industrial robots: Design of 1 DOF motion controllers - Non-linear control # Machine learning: Statistical methods - connectionist methods # Representation and processing of knowledge: Boolean logic - Predicate logic - Expert systems - Processing of unreliable data # Fuzzy logic
Learning Objectives/ Learning Outcomes	The students learn the essentials of robotics from a dynamic point of view as well as advanced topics in man-machine interaction systems
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Advanced mathematics,basics in control theory and basics in mechanics
References	# Bratko, I. (1987), Prolog - Programmieren für die künstliche Intelligenz, Addison-Wesley, Bonn. # Nilsson, N. J. (1998), Artificial Intelligence: A New Synthesis, Morgan Kaufmann Publ. Inc., USA # Runkler, T. A. (2000), Information Mining - Methoden, Algorithmen und Anwendungen intelligenter Datenanalyse, Vieweg Verlag. # Seegräber, L. (1993), Greifsysteme für Montage, Handhabung und Industrieroboter, expert Verlag. # Shafer, G. (1976), A mathematical theory of evidence, Princeton University Press, USA. # Zimmermann, H.-J. (1990), Fuzzy Sets Theory - and its Applications, Kluwer-Nijhoff Publ. USA
Language	German/English
Examination Terms	Written examination (90min) or oral examination (30min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Jürgen Roßmann
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Robotics and Man-Machine Interaction 2 (601044801)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Robotics and Man-Machine Interaction 2	2nd semester	no semester recommended	-	3

Module titel	Seminar Physics of Nanostructures (Compulsory elective subject)
Identifier	1311094
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Each student can select one subject from a list of modern topics related to nanostructures or solid state physics.
Learning Objectives/ Learning Outcomes	The students understand the keys of a modern research topic on a level that they can explain it to peers. The students can select the most important concepts of a research topic from scientific literature. The students can present a complex scientific topic within a concise scientific talk. The students get familiar with a modern research field. The students know how to ask prolific questions after a scientific talk.
(Study-Specific) Prerequisites	None
(recommended) Requirements	Knowledge of quantum mechanical concepts, basic knowledge in solid state physics
References	Will be announced by the instructor, 2-3 month prior to the talk
Language	English
Examination Terms	Presence in the seminar is compulsory. Module examination: Oral presentation including write-up
Miscellaneous	-
Module coordinator	Markus Morgenstern
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Physics of Nanostructures (131109401)	1st semester	no semester recommended	10	2

Module titel	Spinelectronics (Compulsory elective subject)
Identifier	1310619
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Introduction to low dimensional semiconductor structures Basic phenomena in magnetism Diluted magnetic semiconductors Spin injection Spin-orbit coupling and spin transistor Spin Hall effect Quantum spin Hall effect Topological insulators Spin quantum bits
Learning Objectives/ Learning Outcomes	After a successful attendance of the spintronics course the students understand the basic physical principles of spin electronic devices know about the different components of spin electronic devices can evaluate the pro and cons of different device concepts understand the properties of materials used in spin electronics
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Spintronics: fundamentals and applications, Zutic, I.; Fabian, J. and Sarma, S. D. Rev. Mod. Phys., 2004, 76, 323 Semiconductor Spintronics, Jianbai Xia, Weikun Ge, Kai Chang (Author) World Scientific Publishing Company, 2012
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Thomas Schäpers
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Spinelectronics: Lecture and Exercises (131061902)	1st semester	no semester recommended	0	3
Spinelectronics: Examination (131061901)	1st semester	no semester recommended	5	0

Module titel	Nanoelectronics Devices (Compulsory elective subject)
Identifier	6011266
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	# introduction to solid state physics fundamentals # fundamentals of MOSFETs, electronic transport, 'top-of-the barrier'- model, on/off state # FET scaling, short channel effects # graphene (nanoribbon) FETs, band structure, electronic transport, metal-graphene contacts # multi-gate transistors, nanowire FET, carbon nanotube and graphene FETs # 1D MOSFETs, quantum phenomena # ballistic transport, impact of scattering on electronic transport in transistors # Schottky-barrier MOSFETs # Band-to-band tunnel FETs # introduction into the simulation of devices
Learning Objectives/ Learning Outcomes	At the end of the module students are able to # understand the fundamentals of nanoelectronics field-effect transistors and their scaling behavior. # apply strategies to prevent the appearance of short channel effects. # evaluate the potential of novel materials such as III-V compound semiconductors, carbon nanotubes and graphene. # understand quantum mechanical electronic transport through nano-transistors based on the Landauer formalism # understand novel transistor concepts, in particular so-called steep slope switches (tunnel FETs) # compute independently the electrical characteristics of nanoelectronics devices. # understand the basic principles of quantum transport simulation tools for nanoelectronics devices and apply them.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Y. Taur, Fundamentals of Modern VLSI Devices, Cambridge University Press # S. Datta, Atom to Transistor, Cambridge University Press # R. Waser, Nanoelectronics and Information Technology, Wiley-VCH
Language	English
Examination Terms	written examination (60 minutes) or oral examination (30min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Joachim Knoch
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	60 oder 30

– Specialisation Courses
– Nanoelectronics
+ Nanoelectronics Devices (6011266)

Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Nanoelectronics Devices (601126601)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Nanoelectronics Devices	1st semester	no semester recommended	-	3

Module titel	Compound Semiconductors: Physics, Technology and Application (Compulsory elective subject)
Identifier	6017118
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• Physical properties of III-V semiconductors and semiconductor nanostructures • Comparison with silicon and other compound semiconductors • Metal-semiconductor and semiconductor-semiconductor junctions • Crystal growth and epitaxy Characterization of material and devices, new applicatio
Learning Objectives/ Learning Outcomes	Students are supposed to gain a basic/advanced understanding of • physical properties of compound semiconductors • a variety of technologies to fulfill semiconductor device requirements • characterization methods, their applications and their sources of error questions concerning laboratory and industrial issues
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Compound Semiconductor: Electronic, Photonic and Application
References	S. M. Sze: High-Speed Semiconductor Devices, John Wiley & Sons, 1990 • D. K. Schroder: Semiconductor Material and Device Characterization, John Wiley & Sons, 2006 • D. Jansen: Optoelektronik, Vieweg, 1993
Language	English
Examination Terms	Oral Examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	apl. Prof. Dr.-Ing. Michael Heuken
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Compound Semiconductors: Physics, Technology and Application (601711801)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Compound Semiconductors: Physics, Technology and Application	1st semester	no semester recommended	-	3

Module titel	Compound Semiconductors: Electronic, Photonic and Application (Compulsory elective subject)
Identifier	6017117
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• Semiconductor physics in new (opto-)electronic devices (FET, HBT, LED, LASER, solar cells) • Technology of semiconductor devices • AC and DC behavior of transistors (MOSFET, HFET, HBT) • Material and device measurement techniques • Typical circuits and industrial applications are analyzed.
Learning Objectives/ Learning Outcomes	Students are supposed to gain a basic/advanced understanding of • novel semiconductor devices (LED, LASER, HBT, HEMT, solar cells) • the influence of material quality onto the electrical and optical properties of the devices • interpreting AC and DC behavior of semiconductor devices with the help of equivalent circuits • the correlation between extrinsic device properties and intrinsic material properties
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	• S. M. Sze: High-Speed Semiconductor Devices, John Wiley & Sons, 1990 • D. K. Schroder: Semiconductor Material and Device Characterization, John Wiley & Sons, 2006 • D. Jansen: Optoelektronik, Vieweg, 1993
Language	English
Examination Terms	Oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	apl. Prof. Dr.-Ing. Michael Heuken
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Compound Semiconductors: Electronic, Photonic and Application (601711701)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Compound Semiconductors: Electronic, Photonic and Application	2nd semester	no semester recommended	-	3

Module titel	Spinelectronics (Compulsory elective subject)
Identifier	1310619
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	Introduction to low dimensional semiconductor structures Basic phenomena in magnetism Diluted magnetic semiconductors Spin injection Spin-orbit coupling and spin transistor Spin Hall effect Quantum spin Hall effect Topological insulators Spin quantum bits
Learning Objectives/ Learning Outcomes	After a successful attendance of the spintronics course the students understand the basic physical principles of spin electronic devices know about the different components of spin electronic devices can evaluate the pro and cons of different device concepts understand the properties of materials used in spin electronics
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Spintronics: fundamentals and applications, Zutic, I.; Fabian, J. and Sarma, S. D. Rev. Mod. Phys., 2004, 76, 323 Semiconductor Spintronics, Jianbai Xia, Weikun Ge, Kai Chang (Author) World Scientific Publishing Company, 2012
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Thomas Schäpers
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Spinelectronics: Lecture and Exercises (131061902)	1st semester	no semester recommended	0	3
Spinelectronics: Examination (131061901)	1st semester	no semester recommended	5	0

Module titel	Advanced Quantum Electronics (Compulsory elective subject)
Identifier	1320264
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	- quantization of electric circuits and microwave optics - superconducting circuits - input-output formalism - quantum noise and correlation functions - amplifiers.
Learning Objectives/ Learning Outcomes	Advanced understanding of quantum electronics.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Pletyukhov, Mikhail
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced Quantum Electronics (132026401)	2nd semester	no semester recommended	5	3

Module titel	Spin Qubits (Compulsory elective subject)
Identifier	1322705
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	Quantum computing is one of the four pillars of the rapidly growing field of Quantum Technology. In order to gain in depth knowledge of the current state of the art of one of the building blocks of a quantum computer, this course will cover the following topics: • Devices (Two-dimensional electron gas, etc…) • Coulomb blockade and charge transport (Single and double quantum dot devices, etc…) • Spin qubits in quantum dots (Exchange interaction, etc…) • Modelling and simulation (Finite element simulation, etc…) • Scaling concepts (Qubit arrays, etc…)
Learning Objectives/ Learning Outcomes	The students know the underlying facts of spin qubits to be used as one of the possible building blocks of a quantum computer. The students can gain thorough understanding of the different materials to make the quantum dots, charge transport in single and dou-ble quantum dots, spin qubits in quantum dots, qubit manipulation, etc… to name a few. The students can develop finite element simulations and model the experimentally observed data. The students are introduced to the principles of scientific work and can perform experiments on spin qubits for their research work. ; ; ; ;
(Study-Specific) Prerequisites	-
(recommended) Requirements	No prerequisite for admission to the module.
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. The mode of examination is announced by the beginning of the semester.
Miscellaneous	-
Module coordinator	Hendrik Bluhm
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Spin Qubits (1322705)	2nd semester	no semester recommended	5	3

Module titel	Quantum Measurement (Compulsory elective subject)
Identifier	1322704
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	Quantum measurement will be examined, both from a foundational perspective, and from the perspective of applications in quantum information processing. Specific topics include: • Basic theory of partial measurement - Kraus and superoperator representations • Charge measurements in quantum computing • Dispersive measurements in quantum computing • Amplification, quantum and classical • Continuous measurements - the stochastic calculus • Measurements of the vacuum - entanglement in the vacuum • Quantum Darwinism ; ; ; ;
Learning Objectives/ Learning Outcomes	The students can increase the basic understanding of quantum measurements and ex-tend their knowledge of quantum information theory. The students can apply the theoretical concepts to the real present-day laboratory quantum measurements. The students can master the theoretical skills for application in the research work.
(Study-Specific) Prerequisites	-
(recommended) Requirements	No prerequisite for admission to the module.
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. The mode of examination is announced by the beginning of the semester.
Miscellaneous	-
Module coordinator	David Di Vincenzo
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Measurement (132270401)	2nd semester	no semester recommended	5	3

Module titel	Groups and their Representation (Compulsory elective subject)
Identifier	1323320
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Abstract groups, matrix representation of groups, character tables, irreducible representations, point groups, reduction of tensor products, selection rules, real representation and time-reversal, representation of Clifford algebras
Learning Objectives/ Learning Outcomes	The students understand the notion of an irreducible representation of a finite group. They can reduce a general representation into the irreducible components. They are familiar with general selection rules and their importance in physical applications.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Oral presentation
Miscellaneous	-
Module coordinator	Hassler, Fabian
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Groups and their Representation (132332001)	1st semester	no semester recommended	5	2

Module titel	Path Integral Methods for Quantum Optics (Compulsory elective subject)
Identifier	1323319
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Path integrals in quantum mechanics, open systems (Lindblad master equation, Fokker-Planck equation), coherent states of harmonic oscillators, Martin-Siggia-Rose path integral for open systems, driven-dissipative phase transition, lasing transition, parametric amplifier
Learning Objectives/ Learning Outcomes	The students can apply path integral methods to a wide variety of problems in equilibrium and non-equilibrium systems. They can evaluate the applicability and limitations of such calculations. They are familiar with the framework of stochastic quantization and understand how the path integral method relates to other open-system methods. Additionally, the students are introduced to the basic principles of quantum optics as a foundation for performing their own research in this field.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. No prerequisite for admission to the module.
Miscellaneous	-
Module coordinator	Hassler, Fabian
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Path Integral Methods for Quantum Optics (132331901)	1st semester	no semester recommended	5	3

Module titel	Quantum Computing (Chalmers University) (Compulsory elective subject)
Identifier	1323420
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Elementary quantum gates and basic quantum computing formalism, Introduction to complexity classes and relevant conjectures, Circuit model for quantum computation, Foundational theorems for quantum computation: Solovey Kitaev theorem; Gottesman-Knill theorem, Other models for universal quantum computation beyond the circuit model: Measurement Based Quantum Computation and Adiabatic quantum computation, Quantum Fourier Transform and Phase estimation algorithms, Shor’s algorithm, Quantum Machine Learning, Quantum Cloud Computing exercise, Quantum algorithms for solving combinatorial optimization problems: quantum annealing and QAOA, Variational quantum eigensolver, Quantum superiority models: Boson sampling and the instantaneous quantum polynomial (IQP) protocol, Continuous-Variable (CV) quantum computation: MBQC and GKP encoding, CV Quantum superiority models: CV IQP, CV annealing.
Learning Objectives/ Learning Outcomes	The students learn modern relevant quantum algorithms and their purposes. The students understand the key principles of the various models of quantum computation (circuit, measurement-based, adiabatic model). The students obtain the basic structure of the quantum algorithms addressed in the course that are based on the circuit model, and to compute the outcome of basic quantum circuits. The students compare, in terms of time complexity, what quantum advantage is expected from the quantum algorithms addressed in the course with respect to their classical counterparts. The students program simple quantum algorithms on a cloud quantum computer or a cloud simulator. The students acquire understanding of the basic principles of the continuous variable encoding for quantum information processing. The students obtain examples of the motivation for applying quantum computing to machine learning and of what the obstacles are to achieving an advantage from doing so.
(Study-Specific) Prerequisites	keine
(recommended) Requirements	none
References	-
Language	English
Examination Terms	Written homework (30%) and written exam (70%)
Miscellaneous	-
Module coordinator	Di Vincenzo, David

ECTS Credits	8
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	240,0
Contact hours (h)	75,0
Self-study hours (h)	165,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Computing (Chalmers University) (1323420)	1st semester	no semester recommended	8	5

Module titel	Quantum Theory derived from Information Principles (Compulsory elective subject)
Identifier	1323558
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• Operational probabilistic theories (causal circuits, observation effects, preparation states, transformations, coarse-graining, refinement, tomographic dimension) • Information processing principles (information conservation, perfect discrimination, ideal encoding, causality, local discrimation, purification) • State-evolution correspondence (entanglement, transformation tomography, no information without disturbance) • Information dimension of states (state identification, remote steering, state teleportation, information dimension, emergence of Hilbert space) • Building states from qubits (emergence of superposition principle)
Learning Objectives/ Learning Outcomes	The students know the fundamental role of information in quantum theory and understand the contexts in which generalized probabilistic theories play a role (tomography, discrimination, precision tests, etc). They have an overview of how 6 information principles uniquely pick out quantum theory among all possible operational probabilistic theories and how it differs from classical theory by only one principle. They are trained in operational and probabilistic reasoning using causality, state- tomography and discrimination arguments. They have a working knowledge of operational circuit techniques and can apply these to directly derive quantum information results, independent of the Hilbert space formalism.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Quantum theory from first principles: An informational approach (Cambridge University Press, 2017), by G. M. D'Ariano, G. Chiribella, and P. Perinotti.
Language	English
Examination Terms	Oral examination (30 min) or written examination (90 min)
Miscellaneous	-
Module coordinator	-
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory derived from Information Principles (132355801)	1st semester	no semester recommended	5	3

Module titel	Selected Topics from Quantum Technology (Students Seminar) (Compulsory elective subject)
Identifier	1323524
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Selection of current topics in Quantum Technology
Learning Objectives/ Learning Outcomes	The students have a thorough understanding of selected topics in the growing field of Quantum Technology. The students have gained skills on presenting their research work in the form of a seminar to an expert audience and on writing a short scientific report.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	-
Language	English
Examination Terms	Oral presentation and written paper
Miscellaneous	-
Module coordinator	Di Vincenzo, David
ECTS Credits	10
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	30,0
Self-study hours (h)	270,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Selected Topics from Quantum Technology (Students Seminar) (132352401)	1st semester	no semester recommended	10	2

Module titel	Platforms for quantum technologies (RWTH Aachen/ Uni Cologne) (Compulsory elective subject)
Identifier	1324278
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	1) Basics of quantum information processing: qubits, quantum operations, measurements, circuit model, quantum teleportation, quantum algorithms (Deutsch, Grover, Shor), quantum communication and cryptography 2) AMO (atomic, molecular, optical) platforms: cavity quantum electrodynamics: single photon sources, implementation of phase gates; quantum simulators: gases of cold atoms, optical lattices, ground state and excitation dynamics 3) Solid state platforms: charge and electron spin qubits; superconducting qubits; qubit dynamics and control; decoherence; quantum supremacy 4) Topological platforms: topological insulators and superconductors; braiding; Majorana qubit design; topological surface code 5) Quantum error correction and topological codes: few-qubit error correcting codes, fault-tolerance, topological surface code and logical qubits
Learning Objectives/ Learning Outcomes	The students have an overview of key concepts for several quantum technologies and common hardware platforms including solid state, topological, atomic, molecular, and optical platforms. The students know the underlying facts about quantum information processing including qubits, quantum operations, measurements, circuit model, quantum teleportation, and quantum algorithms, The students can solve a wide variety of problems which will train them to quantitatively and qualitatively understand the device physics and dynamics of qubit devices.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Quantum Mechanics, Statistical Mechanics, Solid State Physics
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Bluhm, Hendrik
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-

Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Platforms for quantum technologies (RWTH Aachen/ Uni Cologne) (132427801)	2nd semester	no semester recommended	5	3

Module titel	Theory of spin qubits (RWTH Aachen/ TU Delft) (Compulsory elective subject)
Identifier	1324280
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	0) Introduction, relation to RWTH experimental program in spin qubits. 1) Qubits and spins. Choice of quantization axis and why it matters. Rotating frame, secular approximation. Rabi oscillations, weak vs. strong driving. 2) Spin-spin interactions. Exchange interactions (briefly). Dipole-dipole coupling. Like and unlike spins, secular Hamiltonians. Rare spins, singularities of dipolar coupling in this case (briefly). 3) Spin-spin interactions as noise. Noise models, Markovian noise, Ornstein-Uhlenbeck process. Cumulant expansion for noise models (briefly: situations where the cumulant expansion fails). 4) Bloch-Redfield theory of spin dynamics, comparison with quantum optics. Spin-phonon coupling and spin-phonon relaxation: direct process, two-phonon process, Orbach process. 5) Decoupling by strong Rabi driving. Static environment and Ornstein-Uhlenbeck process. (Optional - relation to dressed states in quantum optics) 6) Spin echo. Dynamical decoupling, toggling rotating frame, dynamical decoupling protocols. Magnus expansion. Floquet theorem, Floquet dynamics. 7) Few-spin dynamics. Electron-nuclear systems, partial secular approximation. ESEEM, toggling quantization axis. ESEEM for the system of non-interacting spins, connection to the noise model (small coupling limit). 8) Few-spin dynamics; like and unlike spins. Few-spin dynamical decoupling. Dipolar couplings, WHH and MREV sequences. 9) Natural Orbitals: quantum dots with multiple electrons with Coulomb interaction.

	10) Beyond Rotating Wave Approximation in Rabi driving. 11) Exchange only qubits -- three electrons in three dots. 12) Architectures and quantum error correction. ; ; ; ; ;
Learning Objectives/ Learning Outcomes	The students have understanding of an advanced theoretical knowledge of spin qubits. The students have the basic knowledge of qubits, spins, spin-spin interactions, theory of spin dynamics, exchange only qubits, architectures and quantum error correction, among many other spin qubit related topics. The course can complement the “Spin Qubits” course in Experimental Condensed Matter Physics study track at RWTH Aachen University.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Solid State Physics (Bachelor level), Quantum info or quantum optics courses
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	DiVincenzo, David
ECTS Credits	5
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	75,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theory of spin qubits (RWTH Aachen/ TU Delft) (132428001)	1st semester	no semester recommended	5	5

Module titel	Superconducting Qubit Circuits (Compulsory elective subject)
Identifier	1326812
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	0) Introduction, current environment of superconducting quantum computing 1) Lossless electric circuits, realization of classical mechanical principles. The Lagrangian 2) Inductive and Capacitive branches, the Josephson junction 3) First qubit example -- phase qubit 4) Sources: current source, voltage source, flux bias 5) Canonical quanitization and the electric circuit: some graph theory 6) The transmon 7) Coupling the transmon to a single-mode resonator, and a transmission line 8) Realization of the Jaynes-Cummings model 9) Quantum measurement in the resonator-coupled setting 10) S-matrix theory and Black-box quantization. Foster's theorem 11) Non reciprocal devices -- the circulator and the parametric amplifier 12) Choices made in the design of the Google Sycamore 54-qubit transmon processor 13) Quantum error correction vs. NISQ and the future of superconducting quantum processors
Learning Objectives/ Learning Outcomes	The students will understand how to apply the principles of classical and quantum mechanics to superconducting circuits. They will learn how these circuits are used to implement qubits. Optimal means of coupling for the execution of quantum gates will be covered. The students will learn how these principles have been applied in the implementation of various forms of superconducting processors build by D-Wave, Google, IBM, and the Chinese Academy of Sciences.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Quantum information or quantum optics masters-level courses
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	David Di Vincenzo
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0

Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Superconducting Qubits Circuits (132681201)	2nd semester	no semester recommended	5	3

Module titel	Quantum Magnetism, Spin Waves, and Light (Compulsory elective subject)
Identifier	1326813
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	1) Review of magnetism 2) Quantum magnetism 3) Spin waves and magnons 4) Interaction of magnets with electromagnetic fields 5) Electromagnetic cavities 6) Modern topics: Cavity Magnonics
Learning Objectives/ Learning Outcomes	The students are introduced to the foundations of quantum magnetism. They are familiar with the microscopic origins of magnetism, relevant interactions, basic model Hamiltonians, and possible ground states. They have a working knowledge of ;the Holstein-Primakoff transformation and can apply their knowledge to typical spin Hamiltonians. The students understand the concept of a magnon and can evaluate the applicability and limitations of of a bosonized spin Hamiltonian. They are ;familiar with spin waves and can apply their knowledge to obtain the dispersion in simple cases both for exchange and dipolar waves. The students are introduced to the working principles of the interaction of electromagnetic fields with ;magnetization in different regimes, including ferromagnetic resonance and magneto-optical effects. The students know the basic principles of electromagnetic field quantization in a cavity and how to obtain the Quantum Langevin Equations of ;motion for a cavity coupled to matter. They are introduced to the topic of cavity magnonics and can apply the above theoretical concepts to this particular modern topic of research. The students master collaborative learning, presentation of ;results and social peer support in small group discussions.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Oral exam
Miscellaneous	-
Module coordinator	Silvia Viola Kusminskiy
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	25
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Magnetism, Spin Waves, and Light (132681301)	2nd semester	no semester recommended	10	6

Module titel	Student Seminar Quantum Technology Open Master (Compulsory elective subject)
Identifier	1327135
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	Covers the breadth of the Quantum Technology Competence Framework: • Concepts of quantum physics • Physical foundations of quantum technologies • Enabling technologies • Hardware for quantum computers and sensors • Quantum computing and simulation • Quantum sensors and metrology • Quantum communication • Practical and soft skills
Learning Objectives/ Learning Outcomes	The students know the diverse topics covered in the field of Quantum Technology. The students gain thorough understanding of the foundations of quantum technologies, explore the emerging technologies including hardware for quantum computers and sensors, quantum communication, etc. to name a few. The students develop skills to think as an independent scientist by taking initiative to assemble their own program of study. The students are exposed to breadth of the Quantum Technology Competence Framework.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Hendrik Bluhm
ECTS Credits	5
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	15,0
Self-study hours (h)	135,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Student Seminar Quantum Technology Open Master (132713501)	2nd semester	no semester recommended	5	2

Module titel	Research Techniques for Advanced Solid State Device Experiments (Compulsory elective subject)
Identifier	1328016
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	In the first part of the course, participants will work in small groups to develop learning modules on specific topics of high relevance for experimental research work that go beyond the content of the standard MSc curriculum. This part will be strongly guided by active researchers. In the second part, all participants will enroll in the modules developed. Topics will be assigned in the first meeting. An exemplary list of possible topics is given below. They come from the domain of quantum dot qubit research, but are to various degrees also relevant for other fields. • Noise spectroscopy measurements • Setup noise debugging (grounding, isolation, shielding) • Instrument noise characterization • Lockin amplifier • Designing low noise analog electronics for transport experiments • Fast buffered data acquisition • Nonlinear fitting • Heterostructure modelling • Thomas-Fermi Simulation of quantum dot devices • Qubit coherence modelling • Agile software engineering • Good coding and software engineering practices
Learning Objectives/ Learning Outcomes	• Participants gain practical experience in the development of innovative, partially self-guided learning modules for acquiring advanced technical skills for research work. • Participants gain expertise in select advanced technical skills at a level suitable for use in research work.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Some familiarity with research requirements, e.g. from a Bachelor's thesis in a relevant field, will be helpful to motivate the relevance of the course topics. Note that this course does not follow an established concept, so participants should be motivated to be involved in developing an innovative but unproven course format.
References	-
Language	English
Examination Terms	25% Contribution in development of learning activity 25% Presentation of learning activity 50% Oral exam on content of other learning activities
Miscellaneous	-
Module coordinator	Hendrik Bluhm

ECTS Credits	10
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	15,0
Self-study hours (h)	285,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Research Techniques for Advanced Solid State Device Experiments (132801601)	1st semester	no semester recommended	10	4

Module titel	Experimental Quantum Computing with Superconducting Qubits (Compulsory elective subject)
Identifier	1328146
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	Basics of superconducting qubits, quantum electrical circuit description and qubit Hamiltonians, mesoscopic physics behind superconducting qubits, how to design a qubit, quantum operations, control and noise, physics of qubit coherence, coupled quantum systems, quantum gate design &; benchmarking, scalable system engineering, and implementing algorithms in real-world systems.
Learning Objectives/ Learning Outcomes	You'll get to know the underlying facts of superconducting qubits and how they can be used for constructing quantum processors. You gain an understanding of qubits and couplings as well as their implementations. We will cover how to apply modeling and numerical methods for quantum electrical circuits, and introduce you to the extrinsic and intrinsic mechanisms of decoherence. The students are introduced to the benchmarking and physical implementations of quantum gates. The goal is to prepare you for experimental research work in the field of quantum computing.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Quantum Mechanics and "Hardware Platforms for Quantum Technology" (core course for Quantum Technology specialization)
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Rami Barends
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Experimental Quantum Computing with Superconducting Qubits (132814601)	2nd semester	no semester recommended	5	2

Module titel	Quantum Algorithms (Compulsory elective subject)
Identifier	1328382
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	• Algorithms and computational complexity theory • Formalism of quantum information • Gate based model of quantum computation • Query complexity: Deutsch-Josza and Simon's algorithm • Quantum Fourier transform and Shor's algorithm • Phase estimation • Hamiltonian simulation • Fermion to qubit mappings and ground state energy estimation • Quantum linear system solvers • Data loading via quantum random access structures • Quantum signal processing and quantum eigenvalue transformation
Learning Objectives/ Learning Outcomes	This course aims to give a modern perspective on digital quantum algorithms development, in a hardware agnostic fashion. The focus is thereby on algorithms that promise significant (super-quadratic) quantum speed-ups for scientific computing. The lecture is advertised interdisciplinary and does not require knowledge of physics or theoretical computer science. The goal is for the students to understand the formalism of quantum computing and appreciate the qualitative and quantitative differences between classical and quantum computing. An emphasis is put on the ability to critically assess potential quantum speed-ups against state-of-the-art - and not just textbook - classical methods, with the idea of performing end-to-end complexity analyses that factor in all classical and quantum resources needed for solving a set out problem. Concretely, the students will achieve a working knowledge around quantum algorithms for the simulation of physical systems and solving systems of linear equations. A unifying framework will be provided, which will put the students in a position to start their thesis work on quantum algorithms by diving deeper into some of the subjects, both in terms of theory work and applied implementations.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Good working knowledge of linear algebra. Expertise of quantum mechanics and quantum information is helpful, but by no means necessary. No physics knowledge is required, as everything will be taught in a self-consistent applied mathematics style.
References	Basics: Quantum Computation and Quantum Information, Michael A. Nielsen and Isaac L. Chuang, Cambridge University Press Other, more extensive, and somewhat complementary lecture notes: (i) Quantum Computing, Ronald de Wolf, available online arxiv.org/abs/1907.09415 and (ii) Quantum Algorithms, Andrew M. Childs, available online www.cs.umd.edu/~amchilds/qa/
Language	English
Examination Terms	Admission to module examination: Written Homework Module examination: Written or oral exam
Miscellaneous	-

Quantum Algorithms (1328382)

Module coordinator	Mario Berta
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Algorithms (132838201)	2nd semester	no semester recommended	5	3

+ Advanced Quantum Electronics (1320264)

Module titel	Advanced Quantum Electronics (Compulsory elective subject)
Identifier	1320264
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	- quantization of electric circuits and microwave optics - superconducting circuits - input-output formalism - quantum noise and correlation functions - amplifiers.
Learning Objectives/ Learning Outcomes	Advanced understanding of quantum electronics.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Pletyukhov, Mikhail
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced Quantum Electronics (132026401)	2nd semester	no semester recommended	5	3

Module titel	Computational Many-Body Theory (Compulsory elective subject)
Identifier	1311131
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	External Module: • Fermi gas and liquid • quantum statistics • second quantization • Green functions • linear response theory • applications from nuclear or condensed matter physics
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: Understanding of basic notions of quantum theory of many particles and its their implementation in practical simulations. Nicht fachbezogene Lernziele: Ability to explain and discuss the solution to the exercises in class. Using the computer as a problem-solving tool (scripting/ plott
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Veranstaltungsliteratur: • A.L. Fetter and J.D. Walecka: Quantum Theory of Many-Particle Systems, Dover, 2003 • H. Bruus and K. Flensberg: Many-Body Quantum Theory, Oxford., 2004 • W. Nolting and W.D. Brewer: Fundamentals of Many-Body Physics, Springer, 2009 empfohlene weiterführende Literatur: • E.Pavarini, E.Koch, F.Anders, and M.Jarrell: From Models to Materials, FZ-Jülich,2012
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Eva Pavarini
ECTS Credits	5
Contact time (WSH)	5
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	75,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Computational Many-Body Theory: Lecture and Exercises (131113102)	2nd semester	no semester recommended	0	5
Computational Many-Body Theory: Examination (131113101)	2nd semester	no semester recommended	5	0

Module titel	Density Functional Theory and Electronic Structure (Compulsory elective subject)
Identifier	1315031
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	-
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics. They especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Stefan Blügel
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Density Functional Theory and Electronic Structure: Lecture and Exercises (131503102)	1st semester	no semester recommended	0	6
Density Functional Theory and Electronic Structure: Examination (131503101)	1st semester	no semester recommended	10	0

Module titel	Electron Correlations (Compulsory elective subject)
Identifier	1311103
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Atoms and transition metal ions • Adding angular momenta • Relativistic corrections • Many-electrons: mean-field approximation • Numerical solution of the radial Schrödinger equation • Many-electrons: second quantization • Atomic multiplets • Exchange mechanisms • Hubbard and Heisenberg model, Mott transition • Crystal field theory
Learning Objectives/ Learning Outcomes	Understanding the effects of electron correlation in finite systems and of the methods for their efficient simulation. Planning and managing of a small scientific software project. Presentation and discussion of the results.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Patrik Fazekas: Lectures on Electron Correlation and Magnetism, World Scientific, 1999 Eva Pavarini, Erik Koch, Frithjof Anders, and Mark Jarrel (eds.): Correlated Electrons: From Models to Materials, Forschungszentrum Jülich, 2012 Eva Pavarini, Erik Koch, and Ulrich Schollwöck (eds.): Emergent Phenomena in Correlated Matter, Forschungszentrum Jülich, 2013
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Erik Koch
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Electron Correlations: Lecture and Exercises (131110302)	2nd semester	no semester recommended	0	3
Electron Correlations: Examination (131110301)	2nd semester	no semester recommended	5	0

Module titel	From Molecular to Continuum Physics I (Compulsory elective subject)
Identifier	1314951
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	Principles of Thermodynamics and Statistical Mechanics. Basics of Molecular Dynamics sampling technique. Simulation of statistical properties in different statistical ensembles. Introduction to free energy calculations.
Learning Objectives/ Learning Outcomes	The students can apply their knowledge to typical thermodynamical problems in laboratory. They are also provided with an overview of the key concepts related to statistical mechanics and free energy calculations. They can also use ;the computer technology to simulate and visualize data. In particular, they know how to employ molecular dynamics computational approach to extract statistical information on simple molecular systems, also employing high-end ;(community) codes.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Frenkel and Smit: Understanding Molecular Simulation (2002) Leach: Molecular Modeling: Principle and Applications (2001) Marx and Hutter: Ab initio Molecular Dynamics: Basic Theory and Advanced Methods (2009)Rothlisberger and Carloni: Drug-Target Binding Investigated by Quantum Mechanical Molecular Mechanical (QM/MM) Methods, Lect. Notes Phys. 704, 447-476; Springer-Verlage Berlin Heidelberg, 2006
Language	English
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Paolo Carloni
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise From Molecular to Continuum Physics I (131495102)	1st semester	no semester recommended	0	3
Exam From Molecular to Continuum Physics I (131495101)	1st semester	no semester recommended	5	0

Module titel	Introduction to soft matter physics (Compulsory elective subject)
Identifier	1311133
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	1) Polymers, 2) Polymer gels 3) Liquid crystals and 4) Colloids
Learning Objectives/ Learning Outcomes	Students will become acquainted with selected research topics dealing with the physical properties and application of a soft matter. Theoretical concepts of related phenomena will be introduced and also discussed in the context of experimental data. The learned research topics will especially serve as preparation for the Master's thesis.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	1) M. Doi ”Soft matter physics” (Oxford University Press, 2013) 2) R. Jones “Soft condensed matter” (Oxford University Press, 2002)
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Dmitry Chigrin
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to soft matter physics: Lecture and Exercises (131113302)	1st semester	no semester recommended	0	3
Introduction to soft matter physics: Examination (131113301)	1st semester	no semester recommended	5	0

Module titel	Nonequilibrium Thermodynamics (Compulsory elective subject)
Identifier	1319143
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	In the equilibrium thermodynamics one deals with processes taking place at infinitely slow rate through a sequence of equilibrium states. In the nonequilibrium thermodynam-ics rapid changes both in time and space are allowed, leading to dramatic consequences in possible system evolution. Different theoretical approaches to describe far-from-equilibrium systems will be presented. Applications to physical, chemical and biological systems will be discussed.
Learning Objectives/ Learning Outcomes	The aim of the class is to give an introduction in the nonequilibrium thermodynamics, that is the thermodynamics in the far-from-equilibrium situation.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Dmitry Chigrin
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nonequilibrium Thermodynamics (Examination) (131914301)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nonequilibrium Thermodynamics (Lecture/Exercises)	1st semester	no semester recommended	-	3

Module titel	Quantum Optics (Compulsory elective subject)
Identifier	1311124
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Quantization of the light field and description of states of the light field and their various phase-space representations and statistical (noise) properties. Interaction between light and matter and its description with simple models which include dissipation. Description of the physics of light and light- atom interaction in cavities, ion traps or optical lattices.
Learning Objectives/ Learning Outcomes	To understand the properties, description and manipulation of non-classical light and its interaction with atoms in modern physics.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Will be announced by the instructor
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Barbara Terhal
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Optics: Lecture and Exercises (131112402)	1st semester	no semester recommended	0	3
Quantum Optics: Examination (131112401)	1st semester	no semester recommended	5	0

Module titel	Quantum Transport (Compulsory elective subject)
Identifier	1311128
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2015
Valid until	-
Module level	Master
Content	Landauer-Büttiker formalism universal conductance fluctuations weak-localization corrections quantum Hall-effect
Learning Objectives/ Learning Outcomes	The lecture provides an introduction to coherent transport of electrons. At the end of the course, the students will have acquired knowledge how quantum mechanics correct the “classical” Drude result of conductivity in different circumstances.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Fabian Hassler
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Transport: Lecture and Exercises (131112802)	2nd semester	no semester recommended	0	3
Quantum Transport: Examination (131112801)	2nd semester	no semester recommended	5	0

Module titel	Statistical Mechanics of Neural Networks (Compulsory elective subject)
Identifier	1311134
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2016
Valid until	-
Module level	Master
Content	The neural networks of the brain form one of the most complex systems we know. Many qualitative features of the emerging collective phenomena, such as correlated activity, stability, response to inputs, chaotic and regular behavior, can, however, be understood in simple models that are accessible to a treatment in statistical mechanics. This course presents the fundamentals behind contemporary developments in neural network theory [e.g. 1,2] that are based on methods from statistical mechanics of classical systems with a large number of interacting degrees of freedom. The only prerequisite for this course is basic (undergraduate) knowledge in statistical physics as all other concepts will be introduced. The focus on classical systems allows us to introduce the standard language and tools employed in statistical field theory in a simple and didactic form (moments, cumulants, generating function[al]s, Wick's theorem, linked cluster theorem, perturbation theory, Feynman diagrams, mean-field approximation, loopwise expansion). We will explain and derive these concepts as far as they are needed in the context of neural networks. This first part will be familiar to students with some knowledge in (quantum) field theory and statistical physics. In the second part we will introduce stochastic differential equations (in the Ito-formulation) and in particular their treatment in the Martin–Siggia–Rose-De Dominicis path integral formalism [3,4, recently reviewed in 5]. In this language, we will explain how standard perturbation theory [5] as well as the mean-field approximation and its generalization, the loopwise expansion [8], are applied to systematically study the fluctuating and correlated dynamics of these systems. In the last part we will investigate a particularly relevant class of systems that have quenched (time independent) disorder. In neural networks, the main source of disorder arises from random synaptic couplings between neurons. These systems are in many respects similar to spin glasses. We will here follow the De Dominicis approach [4] to spin glasses rather than standard replica theory. This allows us to derive the dynamic mean-field theory of Sompolinsky and Zippelius [6]. The formalism explains the collective phenomena arising in these networks, such as the structure of correlations and the emergence of different phases with regular and chaotic dynamics [7,1,2].
Learning Objectives/ Learning Outcomes	After completion of the course the students will be familiar with the following concepts: basic statistics: probability distributions, moment and cumulant generating functions and their relation Langevin equations and their description by path-integrals (Martin-Siggia-Rose-De Dominicis formalism) perturbation theory, mean-field theory and loopwise expansion descriptions of neuronal networks in the context of statistical physics basics of disordered systems and their treatment in the De Dominicis approach
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	J Aljadeff, M Stern, and T Sharpee (2015) Transition to Chaos in Random Networks with Cell-Type-Specific Connectivity Phys Rev Lett 114 088101 S Goedeke, J Schuecker, M Helias (2016) Noise dynamically suppresses chaos in neural networks arXiv:1603.01880 [q-bio.NC]

	P C Martin, E D Siggia, H A Rose (1973) Statistical mechanics of classical systems Phys Rev A 8(1) C De Dominicis (1978) Dynamics as a substitute for replicas in systems with quenched random impurities Phys Rev B 18(9) M Buice, C Chow (2015) Path integral methods for stochastic differential equations Journal of Mathematical Neuroscience 5(8) H Sompolisky, A Zippelius (1982) Relaxational dynamics of the Edwards-Anderson model and the mean-field theory of spin-glasses Phys Rev B 25(11) H Sompolinsky, A Crisanti, H J Sommers (1988) Chaos in Random Neural Networks Phys Rev Lett 61(3) M Buice, C Chow (2007) Field-theoretic approach to fluctuation effects in neural networks Phys Rev E 75, 051919
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Moritz Helias
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Statistical Mechanics of Neural Networks: Lecture and Exercises (131113402)	1st semester	no semester recommended	0	3
Statistical Mechanics of Neural Networks: Examination (131113401)	1st semester	no semester recommended	5	0

Module titel	Symmetries and the Many-Electron Problem (Compulsory elective subject)
Identifier	1315978
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2017
Valid until	-
Module level	Master
Content	Symmetries reveal essential properties of phyiscal systems. This lecture will cover the basics of group theory and some of its application to the central problem of solid-state physics, the many-electron problem.
Learning Objectives/ Learning Outcomes	Topic covered: - introduction to group theory - representation theory - symmetries and conservation laws - symmetries and degeneracies - Lie algebra - the hydrogen atom and its hidden symmetry - from atoms to solid-state systems - double groups, spinors and spinor representations - time-reversal and Kramers degeneracy - the N-electron problem and the symmetric group - many-electron states and multiplets - tensors and the Wigner-Eckart theorem
(Study-Specific) Prerequisites	None
(recommended) Requirements	Keine
References	-
Language	English
Examination Terms	Zulassung zur Modulprüfung: Schriftliche Hausaufgaben, praktische Übungen oder ein Referat. Modulprüfung: Klausurarbeit, mündliche Prüfung oder Referat
Miscellaneous	-
Module coordinator	Eva Pavarini
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Symmetries and the Many-Electron Problem: Lecture and Exercises (131597802)	1st semester	no semester recommended	0	3
Symmetries and the Many-Electron Problem: Examination (131597801)	1st semester	no semester recommended	5	0

Module titel	Topology in Condensed Matter Theory (Compulsory elective subject)
Identifier	1322708
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	• Basic notions of topology, topological defects and homotopy groups, Kosterlitz-Thouless transition, particle-vortex duality • Geometric phases, fiber bundles and holonomy, Chern number and magnetic monopols • Berry phases in Bloch bands, quantum Hall effect and TKNN formula • Dirac Fermions and Haldane model, QAH and QSH effects • Topological insulators, edge states and bulk-boundary correspondence, symmetry classification • Topological terms in quantum magnetism, Haldance conjecture • Topological order, quantum spin liquids and ;dimer models
Learning Objectives/ Learning Outcomes	The students are familiar with several fundamental examples for the use of concepts from topology in modern condensed matter theory. They know the basic mathematical concepts behind topology and their relation to measurable physical quantities in condensed matter systems. The students can identify the distinct notions of topology in topological phase transition, topological insulators and topologically ordered phases of matter. They are familiar with basic models displaying such behavior and their distinct physical properties. Students can present selected topics on the subject matter in a seminar talk and participate in discussions.
(Study-Specific) Prerequisites	-
(recommended) Requirements	No prerequisite for admission to the module.
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. The mode of examination is announced by the beginning of the semester
Miscellaneous	-
Module coordinator	Stefan Weßel
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Topology in Condensed Matter Theory (132270801)	2nd semester	no semester recommended	5	3

Module titel	Correlated Electrons in One Dimension (Compulsory elective subject)
Identifier	1322707
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	• Introduction • Perturbation Theory • Bosonization of the electron gas • Bosonization of the field operator • The single-particle spectral function • Two-particle correlation functions • Thermodynamic properties • Towards universality: Wilson momentum shell RG
Learning Objectives/ Learning Outcomes	The students are provided with an overview of the key concepts, important models, and a selection of fundamental analytical methods related to many-body effects in nonrelativistic, one-dimensional fermionic systems. The students can evaluate the applicability and limitations of the theoretical concepts and methods in the present context. They acquire an understanding of the idea of universality and gain a basic understanding of renormalization group methods.
(Study-Specific) Prerequisites	-
(recommended) Requirements	No prerequisite for admission to the module.
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module exami-nation is acquired by written homework, practical exercises or a student's presentation. The mode of examination is announced by the beginning of the semester.
Miscellaneous	-
Module coordinator	Volker Meden
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Correlated Electrons in One Dimension (132270701)	2nd semester	no semester recommended	5	3

Module titel	Advanced Theory of Topological Insulators (Compulsory elective subject)
Identifier	1322701
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	The course covers an outline of the mathematical theory and classification of topological ; insulators together with a selection of special topics: • Dirac's magnetic monopole • Geometric Berry's phase • Mathematical theory of topology in arbitrary dimension • Classification of symmetry protected topological insulators and superconductors • Topological adiabatic pumping • Spin quantum Hall effect • Topological field theories, Chern-Simons theory • Topological magnetic textures (skyrmions, merons) • Topological classification of defects in crystals
Learning Objectives/ Learning Outcomes	The students understand the physcis of of topological insulators.
(Study-Specific) Prerequisites	-
(recommended) Requirements	No prerequisite for admission to the module.
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. The mode of examination is announced by the beginning of the semester.
Miscellaneous	-
Module coordinator	Schoeller, Herbert
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced Theory of Topological Insulators (132270101)	3rd semester	no semester recommended	5	3

Module titel	Groups and their Representation (Compulsory elective subject)
Identifier	1323320
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Abstract groups, matrix representation of groups, character tables, irreducible representations, point groups, reduction of tensor products, selection rules, real representation and time-reversal, representation of Clifford algebras
Learning Objectives/ Learning Outcomes	The students understand the notion of an irreducible representation of a finite group. They can reduce a general representation into the irreducible components. They are familiar with general selection rules and their importance in physical applications.
(Study-Specific) Prerequisites	None
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Oral presentation
Miscellaneous	-
Module coordinator	Hassler, Fabian
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Groups and their Representation (132332001)	1st semester	no semester recommended	5	2

Module titel	Path Integral Methods for Quantum Optics (Compulsory elective subject)
Identifier	1323319
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Path integrals in quantum mechanics, open systems (Lindblad master equation, Fokker-Planck equation), coherent states of harmonic oscillators, Martin-Siggia-Rose path integral for open systems, driven-dissipative phase transition, lasing transition, parametric amplifier
Learning Objectives/ Learning Outcomes	The students can apply path integral methods to a wide variety of problems in equilibrium and non-equilibrium systems. They can evaluate the applicability and limitations of such calculations. They are familiar with the framework of stochastic quantization and understand how the path integral method relates to other open-system methods. Additionally, the students are introduced to the basic principles of quantum optics as a foundation for performing their own research in this field.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation. No prerequisite for admission to the module.
Miscellaneous	-
Module coordinator	Hassler, Fabian
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Path Integral Methods for Quantum Optics (132331901)	1st semester	no semester recommended	5	3

Module titel	Quantum Theory derived from Information Principles (Compulsory elective subject)
Identifier	1323558
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• Operational probabilistic theories (causal circuits, observation effects, preparation states, transformations, coarse-graining, refinement, tomographic dimension) • Information processing principles (information conservation, perfect discrimination, ideal encoding, causality, local discrimation, purification) • State-evolution correspondence (entanglement, transformation tomography, no information without disturbance) • Information dimension of states (state identification, remote steering, state teleportation, information dimension, emergence of Hilbert space) • Building states from qubits (emergence of superposition principle)
Learning Objectives/ Learning Outcomes	The students know the fundamental role of information in quantum theory and understand the contexts in which generalized probabilistic theories play a role (tomography, discrimination, precision tests, etc). They have an overview of how 6 information principles uniquely pick out quantum theory among all possible operational probabilistic theories and how it differs from classical theory by only one principle. They are trained in operational and probabilistic reasoning using causality, state- tomography and discrimination arguments. They have a working knowledge of operational circuit techniques and can apply these to directly derive quantum information results, independent of the Hilbert space formalism.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Quantum theory from first principles: An informational approach (Cambridge University Press, 2017), by G. M. D'Ariano, G. Chiribella, and P. Perinotti.
Language	English
Examination Terms	Oral examination (30 min) or written examination (90 min)
Miscellaneous	-
Module coordinator	-
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0

Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Theory derived from Information Principles (132355801)	1st semester	no semester recommended	5	3

Module titel	Hands-on Tensor Networks (Compulsory elective subject)
Identifier	1324281
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	In this hands-on course about the density matrix renormalization group (DMRG) the students will learn and implement their own version of a modern DMRG code set up in the natural language of matrix product states (one incarnation of a tensor network). We will write usable code for questions of topical research interest such as for non-equilibrium time-evolution and finite temperature in (quasi) one-dimensional systems, which are at the frontiers of research today.
Learning Objectives/ Learning Outcomes	The goal of this course is to teach the details of DMRG -- a powerful numerical method in the fields of contemporary condensed matter physics, cold quantum gases and beyond -- as well as provide every participant with a fully functioning implementation of this tool.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	The module examination is passed through successful completion of written homework or successful participation in practical exercises. The module is ungraded.
Miscellaneous	-
Module coordinator	Kennes, Dante
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Hands-on Tensor Networks (132428101)	2nd semester	no semester recommended	10	-

Module titel	Quantum Magnetism, Spin Waves, and Light (Compulsory elective subject)
Identifier	1326813
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	1) Review of magnetism 2) Quantum magnetism 3) Spin waves and magnons 4) Interaction of magnets with electromagnetic fields 5) Electromagnetic cavities 6) Modern topics: Cavity Magnonics
Learning Objectives/ Learning Outcomes	The students are introduced to the foundations of quantum magnetism. They are familiar with the microscopic origins of magnetism, relevant interactions, basic model Hamiltonians, and possible ground states. They have a working knowledge of ;the Holstein-Primakoff transformation and can apply their knowledge to typical spin Hamiltonians. The students understand the concept of a magnon and can evaluate the applicability and limitations of of a bosonized spin Hamiltonian. They are ;familiar with spin waves and can apply their knowledge to obtain the dispersion in simple cases both for exchange and dipolar waves. The students are introduced to the working principles of the interaction of electromagnetic fields with ;magnetization in different regimes, including ferromagnetic resonance and magneto-optical effects. The students know the basic principles of electromagnetic field quantization in a cavity and how to obtain the Quantum Langevin Equations of ;motion for a cavity coupled to matter. They are introduced to the topic of cavity magnonics and can apply the above theoretical concepts to this particular modern topic of research. The students master collaborative learning, presentation of ;results and social peer support in small group discussions.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Oral exam
Miscellaneous	-
Module coordinator	Silvia Viola Kusminskiy
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	25
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantum Magnetism, Spin Waves, and Light (132681301)	2nd semester	no semester recommended	10	6

Module titel	Astronomy and Astrophysics (Compulsory elective subject)
Identifier	1311138
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Electromagnetic radiation, astronomical coordinates, astrophysical instruments, planetary systems. Stars: spectral classes of stars, Hertzsprung-Russel-diagram, variable stars, interior of stars,stellar fusion, stellar evolution, late stages supernovae, white dwarfs, neutron stars, black holes. Galaxies: classification, dynamics,active galaxies, Hubble law. Cosmology: cosmological principle, Robertson-Walker metrics, Friedman equation,cosmic micro-wave background, nuclear synthesis structure formation, gravitational lensing
Learning Objectives/ Learning Outcomes	Observational methods and observational results in modern astrophysics and astronomy
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	Carroll, D.A. Ostlie, An Introduction to Modern Astrophysics, Addison Wesley A. Weigert, H.J. Wendker, L. Wisotzki, Astronomie und Astrophysik, Wiley-VCH A. Unsöld, B. Baschek, Der neue Kosmos, P.Schneider: Einführung in die Extragalaktische Astronomie und Kosmologie, Springer 2006
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Christopher Wiebusch
ECTS Credits	10
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	300,0

Contact hours (h)	90,0
Self-study hours (h)	210,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Astronomy and Astrophysics: Lecture and Exercises (131113802)	1st semester	no semester recommended	0	6
Astronomy and Astrophysics (131113801)	1st semester	no semester recommended	10	0

Module titel	Laboratory Course Astronomy and Astrophysics (Compulsory elective subject)
Identifier	1310582
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2013
Valid until	-
Module level	Master
Content	Lecture: Discussion of special topics in astronomy. Additional to the lecture astronomy Laboratory course: Observation and analysis of astronomical data: Radio telescope, rotation of milky way, pulsars, tully fisher, astronomical pictures, moon rotation, moon craters cepheids, Jupiter mass, venus phases. Seminar: Presentation of the performed observation and analysis.
Learning Objectives/ Learning Outcomes	Independent planning of experimentation, accurate notation, experimentation, estimation of uncertainties, elaboration of the experimental results including error determination and detailed discussion of the results.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Christopher Wiebusch
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory Course Astronomy and Astrophysics (131058201)	1st semester	no semester recommended	5	3

Module titel	Biomedical Imaging (Compulsory elective subject)
Identifier	6011065
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	# Planar X-Ray Imaging: Physics of X-ray generation, interaction of X radiation with matter, Detectors for X radiation. # Computed Tomography: CT image acquisition, CT image reconstruction, Filtered Back Projection, System and Components. # Magnetic Resonance Imaging: classical physics, magnetization, relaxation, Bloch's equations, tomography reconstruction # Imaging in Nuclear Medicine: basics from nuclear physics, radiopharmaceuticals, detectors: gamma-camera, single-photon emission computed tomography (SPECT), positron emission tomography (PET). # Medical Ultrasound Imaging: Physics of sound wave, Ultrasound transducer, Image quality: noise and artifacts, Doppler ultrasound, 3D imaging. # Microscopy: Principles of Light Microscopy (Abbe #s resolution formula), Fluorescence Microscopy Techniques (Deconvolution, Laser Scanning Confocal Microscopy, Multiphoton Confocal Microscopy, Superresolution Microscopy, Light Sheet Microscopy). # Magnetic Particle Imaging: Basic principle and components, Limitations in spatial resolution and SNR, Current and future system. # Clinical Trends: Trends in Healthcare and the role of Imaging, Technical Advancements and clinical examples, Advanced Image Processing.
Learning Objectives/ Learning Outcomes	At the end of the module students will be able # to understand the basic physics of medical imaging including x-ray techniques, magnetic resonance imaging, imaging in nuclear medicine with a focus on PET and SPECT, microscopy with a focus on superresolution microscopy and magnetic particle imaging. # to apply image reconstruction techniques. # to explain limitations of biomedical imaging modalities
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# O. Dössel, Bildgebende Verfahren in der Medizin, Springer 2000. # Oppelt (Ed.): Imaging Systems for Medical Diagnostics, Publicis Coroprate Publishing, Erlangen, 2005. # T. Buzug: Einführung in die Computer-Tomographie, Springer, 2004 .
Language	English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr.-Ing. Dorit Merhof
ECTS Credits	4

Contact time (WSH)	3
Examination duration (min)	90 or 30
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Biomedical Imaging (601106501)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Biomedical Imaging	1st semester	no semester recommended	-	3

Module titel	Electrophysiology and Measurement Technology (Compulsory elective subject)
Identifier	9010783
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Introduction to biomedical engineering • Physical and physiological measurements • The resting potential of cells from a technical point of view. • The measurement of the resting potential. • The excitation of cells • The action potential from a technical point of view • The excitation spread • The electrical field at the cell membrane • The body as a volume conductor • Devices for the detection of biosignals • EMG-Signals and movement analysis • ECG-Signals • The cardiac pacemaker • EEG-Signals and evoked potentials • Safety requirements for electrical devices used in medical applications. • Practical demonstrations
Learning Objectives/ Learning Outcomes	• The students know and understand the principle physiological basics of cell's resting potential, excitation and excitation spread. • The students are able to explain the origin of biosignals based on the phenomena at the cell membrane. • The students have the ability to independently design a device / measurement system for the detection of biosignals. • The students know the safety requirements for electrical devices used in medical applications. • The students know the most frequent sources of error, how to reduce interferences and enhance signal quality. • The students are capable of realising test set-ups based on the theoretical knowledge learnt. • Through the lectures the students are qualified to transfer their specialised knowledge in mechanical engineering to other disciplines like electrical engineering or medicine. • Ince the lectures are interdisciplinary the students learn to think outside their major subject area.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	• Physiologiebücher • Hutten: Biomedizinische Technik
Language	German
Examination Terms	written examination (90min) or oral examination (30min)
Miscellaneous	-
Module coordinator	Modulangebotsorganisator:

+ Electrophysiology and Measurement Technology (9010783)

	Dr. rer. medic. Marion GrandeModellierungsteamverantwortlicher: Vanessa Ziemons M. A.Modulverantworlicher: Universitätsprofessorin Dr. rer. nat. Catherine Dißelhorst-Klug Ph. D.
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Electrophysiology and Measurement Technology (901078301)	1st semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Electrophysiology and Measurement Technology	1st semester	no semester recommended	-	3

Module titel	Artificial Organs I for Scientists and Engineers (Compulsory elective subject)
Identifier	9026650
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Innerhalb der Vorlesung Künstliche Organe für Naturwissenschaftler und Ingenieure werden die Anatomie und Physiologie verschiedener Organsysteme erklärt und darauf aufbauend die grundlegenden Anforderungen und Auslegung der Künstlichen Organe als technischer Ersatz der nativen Organe gelehrt. In Künstliche Organe I werden Grundlagen im Bereich der Blutströmung und Hämokompatibilität gelegt sowie Medizinprodukte und Therapien zur Unterstützung und zum Ersatz vom Herzen (Stents, Endovaskuläre Prothesen, Herzklappenprothesen, Herzunterstützungspumpen und künstliche Herzen) behandelt. Neben den theoretischen Kenntnissen werden in Gastvorlesungen von klinischen Wissenschaftlern auch die praktische Anwendung der Produkte und Therapien im Klinikalltag gezeigt.
Learning Objectives/ Learning Outcomes	Nach der Vorlesung Künstliche Organe I sind grundlegende anatomische Kenntnisse der Organsysteme Blut und Herz vorhanden. Darauf aufbauend sind die Anforderungen an technische Ersatzsysteme sowie Kenntnisse in der theoretischen und konstruktiven Auslegung solcher Systeme bekannt. Insbesondere wurden Einblicke in aktuelle Medizinprodukte und Forschungsrichtung der benannten Organsysteme gegeben.
(Study-Specific) Prerequisites	-
(recommended) Requirements	keine
References	-
Language	German
Examination Terms	Klausur
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Dr. Marion Grande Modulverantwortliche: Prof. Dr. Ulrich Steinseifer, Dr. Sebastian Jansen
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Artificial Organs I (902665001)	2nd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Artificial Organs I	2nd semester	no semester recommended	-	2
Practical Course Artificial Organs I	2nd semester	no semester recommended	-	1

Module titel	Artificial Organs II for Scientists and Engineers (Compulsory elective subject)
Identifier	9026651
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Innerhalb der Vorlesung Künstliche Organe für Naturwissenschaftler und Ingenieure werden die Anatomie und Physiologie verschiedener Organsysteme erklärt und darauf aufbauend die grundlegenden Anforderungen und Auslegung der Künstlichen Organe als technischer Ersatz der nativen Organe gelehrt. In Künstliche Organe II werden Medizinprodukte und Therapien zur Unterstützung und zum Ersatz von den Organsystemen Lunge (Oxygenatoren, Extrakorporale Zirkulation), Niere (Dialyse und ähnliche Verfahren) und Leber (Albumindialyse und andere Verfahren) behandelt. Neben den Organsystemen werden auch Fragen zur Zulassung und zum Reimbursement von Medizinprodukten angeschnitten. Neben den theoretischen Kenntnissen werden in Gastvorlesungen von klinischen Wissenschaftlern auch die praktische Anwendung der Produkte und Therapien im Klinikalltag gezeigt.
Learning Objectives/ Learning Outcomes	Nach der Vorlesung Künstliche Organe II sind grundlegende anatomische Kenntnisse der Organsysteme Lunge, Niere und Leber vorhanden. Darauf aufbauend sind die Anforderungen an technische Ersatzsysteme sowie Kenntnisse in der theoretischen und konstruktiven Auslegung solcher Systeme bekannt. Insbesondere wurden Einblicke in aktuelle Medizinprodukte und Forschungsrichtung der benannten Organsysteme gegeben.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	German
Examination Terms	Klausur
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Dr. Marion Grande Modulverantwortliche: Prof. Dr. Ulrich Steinseifer, Dr. Sebastian Jansen
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0

Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Artificial Organs II (902665101)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Artificial Organs II	1st semester	no semester recommended	-	2
Practical Course Artificial Organs II	1st semester	no semester recommended	-	1

Module titel	Medical Imaging I (Compulsory elective subject)
Identifier	9010762
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	Introduction X-ray Production X-ray Interaction Radiography I: Film, Detectors Radiography II: Image Intensifiers, Digital Radiography Computed Tomography I: Physics Computed Tomography II: Applications Image Quality Radiation Protection Magnetic Resonance Tomography I: Physics Magnetic Resonance Tomography II: Applications Ultrasound I Ultrasound II Nuclear Medicine
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: Die Studierenden sollen ein grundlegendes Verständnis der Methoden und Verfahren der medizinischen Bildgebung erwerben, wie sie in Klinik, Praxis und Forschung eingesetzt werden. Nicht fachbezogene Lernziele: Die Studierenden sollen ein Verständnis der Arbeitsabläufe in Klinikabteilungen mit medizinischer Diagnostik sowie der Arbeitsweise der dort arbeitenden Ärzte und des midizinischen Fachpersonals entwickeln. Den Studierenden wird medizinische Fachterminologie aus dem Bereich der medizinischen Bildgebung sowie aus angrenzenden Themen vermittelt.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Keine
References	A. Oppelt: Imaging Systems for Medical Diagnostics. Publicis J.T. Bushberg, J.A. Seibert, E.M. Leidholdt, Jr., J.M. Boone. The Essential Physics of Medical Imaging. Lippincott Williams &; Wilkins
Language	English
Examination Terms	eine Klausur
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Dr. rer. medic. Marion Grande Modellierungsteamverantwortlicher: Vanessa Ziemons M. A. Modulverantworlicher: Universitätsprofessor Dr. med. Dipl.-Ing. Thomas Schmitz-Rode
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Medical Imaging I (901076201)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung/Praktikum Medical Imaging I	1st semester	no semester recommended	-	3

Module titel	Medical Imaging II (Compulsory elective subject)
Identifier	4011671
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Introduction • Repetition: Essentials of Medical Imaging I • Image Guided Non-Vascular Interventions: Parenchymatous Organs • Image Guided Non-Vascular Interventions: Non-Vascular Hollow Organs, Skeletal System • Imaging and Navigation • Image Guided Therapy in the Vascular System I • Image Guided Therapy in the Vascular System II • Image Guided Cardiac Intervention and Monitoring • Endoscopy • Laparoscopy • Optical and Experimental Molecular Imaging • Iage Guided Therapy in Oncology • Image Guided Radiation Therapy • State of Scientific Research
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: • Die Studierenden sollen ein grundlegendes Verständnis der Methoden und Verfahren der medizinischen Bildgebung erwerben, wie sie in Klinik, Praxis und Forschung eingesetzt werden. Nicht fachbezogene Lernziele: • Die Studierenden sollen ein Verständnis der klinischen Arbeitsabläufe in den Klinikabteilungen für bildgeführte Therapie sowie der Arbeitsweise der dort arbeitenden Ärzte und des medizinischen Fachpersonals entwickeln. • Den Studierenden wird medizinische Fachterminologie aus dem Bereich der bildgeführten Therapie sowie aus angrenzenden Themen vermittelt.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	keine
References	• T. Peters, K. Cleary. Image-Guided Interventions. Springer
Language	English
Examination Terms	eine Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. med. Dipl.-Ing. Thomas Schmitz-Rode
ECTS Credits	4
Contact time (WSH)	3

Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Medical Imaging II (401167101)	2nd semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung/Praktikum Medical Imaging II	2nd semester	no semester recommended	-	3

Module titel	Medical Engineering I (Compulsory elective subject)
Identifier	4013321
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2008
Valid until	-
Module level	Bachelor/Master
Content	1 • Einführung in die Medizintechnik • Entwicklung, Aufgabengebiete und Randbedingungen der Medizintechnik; Überblick zur Diagnose-, Therapietechnik 2-4 • Medizinische Bildgebung (I) • Grundlagen insbesondere der Röntgenbildgebung (inkl. CT), Magnet-Resonanztomographie und Ultraschallbildgebung (Weiterführung und Vertiefung zur Medizinischen Bildgebung in Medizintechnik II) • Darstellung von Materialien und Strukturen (Morphologie/ physikalische/mech. Eigenschaften, …,Funktion) im Bild • Berücksichtigung spezifischer Wechselwirkungen bei Materialauswahl und Gestaltung 5 • Biokompatibilität und Biofunktionalität • Definition und Bedeutung von Biokompatibilität und Biofunktionalität; Prüfverfahren; Gewebeeigenschaften; Reaktionen des menschlichen Organismus 6-8 • Biomechanik • Überblick und Grundlagen der Biomechanik, Bedeutung in der Diagnose und Therapietechnik • Biomechanik von Stütz- und Bewegungsapparat, Implantate, Endo- und Exoprothesen (ausgewählte Beispiele, Vertiefung in „Grundlagen der Biomechanik des Stütz- und Bewegungsapparates“ und „Medizintechnik II“) • Kurzer Überblick zur Biomechanik von Herz und Kreislauf, Atmung, Niere, Ersatz- und Unterstützungssysteme (Weiterführung und Vertiefung in „Physiologische und technische Grundlagen natürlicher und künstlicher Organe“) 9 • Hygiene und Hygienetechnik • Grundlagen der Hygiene; Verfahren und Wirkprinzipien der Desinfektion und Sterilisation; Komponenten und Bauweisen sterilisierbarer Instrumente und Geräte; Krankenhaushygiene 10-13 • Biomaterialien • Einführung und Überblick; mechanische Eigenschaften, Korrosionsbeständigkeit, Biokompatibilität und Hauptanwendungsgebiete metallischer Werkstoffe (einschl. FGL) • Herstellung und Verarbeitung, Sterilisation und Biokompatibilität, Eigenschaften und Anwendungen biokompatibler synthetischer Polymere • Degradationsmechanismen biodegradierbarer Polymere; Struktur und Eigenschaften, Gewinnung, Verarbeitung und Anwendung natürlicher Polymere • Herstellung, Eigenschaften und Anwendungen keramischer Werkstoffe und Faserverbundwerkstoffe in der Medizintechnik 14 • Ausgewählte Fertigungsverfahren für die Medizintechnik • Generative Fertigung von Individualimplantaten, Beschichtung von Implantaten, Herstellung von Zellträgersystemen

	15 • Medizinprodukterecht, Qualität und Sicherheit • Überblick, rechtliche Grundlagen, Konformitätsbewertungsverfahren, Qualitäts- u. Risikomanagement, Sicherheitskonzepte, Schutzmassnahmen und Sicherheit (Weiterführung und Vertiefung in „Ergonomie und Sicherheit von Medizinprodukten“)
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden verfügen über grundlegende Kenntnisse der Medizintechnik (Materialien, Bauweisen, Einsatz- und Randbedingungen,…) als Einführung insbesondere für den konstruktiven Bereich der Entwicklung von Instrumenten und Geräten oder auch Organersatz- und Unterstützungssystemen, und damit u.a. über eine Basis für weiterführende Veranstaltungen im Bereich/ Schwerpunkt Medizintechnik. Sie sind in der Lage, unterschiedliche Anwendungsbereiche und -beispiele sowie spezifische Randbedingungen der Medizintechnik für Diagnose und Therapie zu nennen und zu erläutern. • Die Studierenden verfügen über Grundkenntnisse zu normativen Anforderungen bei der Zulassung von Medizinprodukten und deren Bedeutung für die Entwicklung. Sie können ihre Kenntnisse über die besonderen Randbedingungen und Sicherheitsanforderungen der Medizintechnik bei der Bewertung von medizintechnischen Lösungen anwenden. Die Studierenden kennen die wichtigsten Bildgebungsverfahren in der Medizin und können deren grundlegende physikalische Wirkprinzipien erklären. Diese Kenntnisse können sie bei der Auswahl von Materialien im Rahmen der Konstruktion von Komponenten und Systemen anwenden. Die Studierenden sind in der Lage, die Begriffe Biokompatibilität und Biofunktionalität und deren Bedeutung für medizintechnische Produkte zu erläutern und an Beispielen zu verdeutlichen. Sie kennen grundlegende Gewebeeigenschaften und Gewebereaktionen. Die Studierenden kennen die Bedeutung der Hygiene in der Medizintechnik, können Verfahren und Wirkprinzipien der Desinfektion erläutern und diese Kenntnisse bei der Entwicklung bzw. Bewertung von technischen Lösungen anwenden. Insbesondere verfügen sie über Kenntnisse zu geeigneten Konstruktionswerkstoffen und Gestaltungsprinzipien für unterschiedliche medizintechnische Anwendungen und können Besonderheiten hinsichtlich der Eigenschaften, Herstellung und Anwendung erläutern und bei der Lösungssynthese und –evaluation umsetzen. Die Studierenden verfügen über grundlegende Kenntnisse zu ausgewählten Fertigungsverfahren zur Herstellung von Individualimplantaten, zur Beschichtung von Implantaten sowie von Zellträgersystemen, können diese in Grundzügen erklären und bei der Auswahl bzw. Entwicklung konstruktiver Lösungen auf diese Kenntnisse zurückgreifen und bedarfsweise vertiefen.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …) • Einführung in die Medizin (Baumann); (ggf. auch parallel) • Physik, Mathematik • Grundvorlesungen Maschinenbau (Semester 1-4: Mechanik, Werkstoffkunde, Maschinengestaltung, Elektrotechnik, Strömungsmechanik I, Messtechnik,…) Voraussetzung für (z.B. andere Module) • Medizintechnik II
References	1. • Hutten, H.: Biomedizinische Technik 1-4, Springer-Verlag 1992 2. • Wintermantel, E., Ha, S-W.: Medizintechnik mit biokompatiblen Werkstoffen und Verfahren. 3. • Aufl. Springer-Verlag 2002 3. Enderle, J., Blanchard, S., Bronzino, J.: Introduction to Biomedical Engineering. 2nd Edition, Elsevier Academic Press 2005 4. • B.D. Ratner, A.S. Hoffmann, F.J. Schoen, J. E. Lemons: Biomaterial Science. 2nd Edition, Elsevier 2004 5. • Kramme, R.: Medizintechnik. Verfahren, Systeme und Informationssysteme, 2. Aufl., Springer Verlag 2002

	6. • St. Silbernagl, A. Despopoulos: Taschenatlas der Physiologie, 6. Aufl., Thieme-Verlag, 2003 7. • B. Kummer: Biomechanik. Deutscher Ärzteverlag, 2005 8. • Zeitschrift für Biomedizinische Technik (…zahlreiche weitere Bücher und Zeitschriften zu Teilaspekten; besonders geeignete Artikel werden als Kopien in der Vorlesungen/Übung nach Bedarf bereitgestellt) 9. • Umdruck/Foliensammlung zur Vorlesung
Language	German
Examination Terms	Eine Klausur
Miscellaneous	-
Module coordinator	Modulverantworlicher: Universitätsprofessor Dr.-Ing. Klaus M. Radermacher
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	120
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Medical Engineering I (401332101)	1st semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung/Übung Medizintechnik I	1st semester	no semester recommended	-	4

Module titel	Medical Engineering II (Compulsory elective subject)
Identifier	4014433
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2005
Valid until	-
Module level	Bachelor/Master
Content	1 • Einführung • Überblick zur Instrumenten- und Gerätetechnik • Überblick Krankenhaustechnik • Stellenwert, Entwicklungen und Trends 2-4 • Medizinische Bildgebung (II) • Überblick und Gegenüberstellung der wichtigsten medizinischen Bildgebungsverfahren (Röntgen, Computertomographie, MR-Tomographie, PET, SPECT, Ultraschall, Endoskopie, Mikroskopie, OCT, …; Eigenschaften, Anwendungsgebiete und Grenzen) • Aufbau, Bauformen und zugrundeliegenden Verfahren der Bilderfassung bzw. -rekonstruktion 5-6 • Biosignalerfassung, Funktionsdiagnostik und Monitoring • Übersicht zu den wichtigsten Verfahren zur Erfassung von Biosignalen und anderer Vitalparameter • Gerätesysteme für Funktionsdiagnostik und Monitoring (Wirkprinzipien, Eigenschaften, Anwendungsbereiche) 7 • Krankenhaus- und OP-Technik • Infrastruktur, Komponenten und Gerätesysteme • Informationsflüsse und –verarbeitung, Arbeitsabläufe • Übersicht zu Normen und Richtlinien 8 • Anästhesie und Intensivpflege • Überblick Narkose, Beatmung, Notfallmedizin • Gerätetechnik (Wirkprinzipien, Eigenschaften, Anwendungsbereiche) 9 • Laser in der Medizin • Medizinische Lasersysteme (Aufbau, Medien, Eigenschaften) • Biophysikalische Wirkung und Anwendungen • Gerätesysteme und Applikatoren • Sicherheitstechnische Aspekte und Normen 10 • Hochfrequenzchirurgie • Überblick und Entwicklung • Physikalische und technische Grundlagen • Monopolare und bipolare Technik • Sicherheitstechnische Aspekte und Normen 11 • Chirurgische Instrumente- und Gerätetechnik • Chirurgische Motorensysteme und Instrumente • Systeme und Komponenten für die endoskopische Chirurgie • Überblick dentaltechnische Instrumente

	• Überblick zur computerunterstützten Chirurgie 12 • Strahlentherapie • Physikalische und technische Grundlagen • Biophysikalische Wirkung und Anwendungen • Systeme und Komponenten • Sicherheitstechnische Aspekte 13 • Therapeutische Anwendung von Ultraschalll, Stoßwellentherapie • Physikalische und technische Grundlagen • Biophysikalische Wirkung und Anwendungen • Systeme und Bauweisen • Sicherheit 14 • Rehabilitationstechnik • Funktionelle Analyse • Funktionelle Stimulation • Künstliche Gliedmaßen • Rollstuhltechnik • Kommunikationshilfen 15 • Repetitorium
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen Aufbau, Theorie und Wirkungsweise wichtiger diagnostischer und therapeutischer Instrumente, Geräte und Systeme und eren Eigenschaften, Stellenwert und Anwendungsbereiche und können diese in Grundzügen erläutern • Sie können die wesentlichen Komponenten der Krankenhaus- und OP-Technik benennen und erklären und kennen die Bedeutung grundlegender Prozesse, Informationsflüsse und Arbeitsabläufe und können einzelne Komponenten einordnen • Sie kennen die wichtigsten Normen und Sicherheitsanforderungen für die jeweiligen Komponenten und Systeme bzw. können die jeweils aktuellen Bestimmungen ermitteln und anwenden Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden sind in der Lage selbständig ein Themengebiet aus vorgegebener interdisziplinärer Literatur aufzuarbeiten, diese durch eigene Recherchen zu ergänzen, und aus ingenieurwissenschaftlicher Sicht zu analysieren und zu bewerten. • Die Studierenden können sowohl interdisziplinäre wie auch ingenieurwissenschaftliche Aspekte des bearbeiteten Themengebietes in einer Präsentation zusammenfassend darstellen, erläutern und diskutieren. • In den Übungen erfolgt die Arbeit teilweise in Kleingruppen, so dass kollektive Lernprozesse gefördert werden (Teamarbeit)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Medizintechnik I • Einführung in die Medizin (Baumann) • Physik, Mathematik • Grundvorlesungen Maschinenbau
References	• Hutten, H.: Biomedizinische Technik 1-4, Springer-Verlag 1992 • Wintermantel, E., Ha, S-W.: Medizintechnik mit biokompatiblen Werkstoffen und Verfahren. 3. Aufl. Springer-Verlag 2002 • Enderle, J., Blanchard, S., Bronzino, J.: Introduction to Biomedical Engineering. 2nd Edition, Elsevier Academic Press 2005 • B.D. Ratner, A.S. Hoffmann, F.J. Schoen, J. E. Lemons: Biomaterial Science. 2nd Edition, Elsevier 2004 • Kramme, R.: Medizintechnik. Verfahren, Systeme und Informationssysteme, 2. Aufl., Springer Verlag 2002 • St. Silbernagl, A. Despopoulos: Taschenatlas der Physiologie, 6. Aufl., Thieme-Verlag, 2003

	• B. Kummer: Biomechanik. Deutscher Ärzteverlag, 2005 • Zeitschrift für Biomedizinische Technik (…zahlreiche weitere Bücher und Zeitschriften zu Teilaspekten; besonders geeignete Artikel werden als Kopien in der Vorlesungen/Übung nach Bedarf bereitgestellt) • Umdruck/Foliensammlung zur Vorlesung
Language	German
Examination Terms	Eine mündliche Prüfung
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Klaus M. Radermacher
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Medical Engineering II (401443301)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung/Übung Medizintechnik II	2nd semester	no semester recommended	-	4

Module titel	Ultra-High Field MRI - Towards Personalized Imaging (Compulsory elective subject)
Identifier	9028684
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	Das Seminar führt in die Neurobildgebung mittels Hochfeld MRT ein und erläutert sowohl die Vorteile als auch die technologischen Herausforderungen bei Feldstärken von 7T und mehr. Es werden MRT Methoden zur funktionellen Bildgebung, Diffusions- und Perfusionsmessungen sowie spektroskopische Aufnahmen bei hohen Feldstärken besprochen sowie Anwendungen bei verschiedenen neurologischen Erkrankungen vorgestellt. Im Rahmen des Seminars werden ebenfalls 2 praktische Messtermine am 7T MRT in Jülich angeboten.
Learning Objectives/ Learning Outcomes	* Kenntnisse der MR-Physik und der Bildgebung mittels MRT * Kenntnisse von Vor- und Nachteilen der UHF MRT in der medizinischen Bildgebung * Exemplarische Anwendungen der UHF MRT in der medizinischen Bildgebung * Kenntnisse von vorteilhaften Kontrastmechanismen in der UHF MRT
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	-
Language	German/English
Examination Terms	Benoteter Seminarvortrag
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Marion Grande Modulverantwortliche: Jörg Felder
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Ultra-High Field MRI - Towards Personalized Imaging (9028684)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Course Presentation Ultra-High Field MRI - Towards Personalized Imaging (902868401)	2nd semester	no semester recommended	5	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Ultra-High Field MRI - Towards Personal-ized Imaging	2nd semester	no semester recommended	-	3

Module titel	Advanced Molecular Dynamics Simulations (Compulsory elective subject)
Identifier	1314152
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2009
Valid until	-
Module level	Master
Content	• Introduction Basics of classical mechanics: Equations of motion • Basics of statistical physics: Phase space, ensembles, expectation values, fluctuations • Basics of molecular dynamics simulations: Integration schemes, time reversible integration schemes, periodic boundary conditions, neighbor lists, long-range interactions • Advanced molecular dynamics simulations: Constant temperature and constant pressure molecular dynamics simulations, extended phasespace methods for simulations of various ensembles
Learning Objectives/ Learning Outcomes	The students are introduced to state-of-the art concepts in molecular and mesoscale simulation approaches. They master theoretical concepts of molecular simulations for classical mechanics, hydrodynamics, and its combinations. They can evaluate the applicability, suitability, and limitations of various simulation approaches. The students are able to develop computer programs to solve large-scale simulation problems in classical mechanics and specific applications of hydrodynamics. The students can develop and contact a scientific project. They can communicate the results of their scientific work by an oral presentation.
(Study-Specific) Prerequisites	None
(recommended) Requirements	none
References	M. P. Allen and D. J. Tildesley, Computer Simulation of Liquids, Clarendon Press, Oxford, 1987
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Roland Winkler
ECTS Credits	3
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	45,0
Self-study hours (h)	45,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Advanced Molecular Dynamics Simulations (131415201)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Advanced Molecular Dynamics Simulations	1st semester	no semester recommended	-	3

Module titel	Atomistic and Molecular Simulation Methods (Compulsory elective subject)
Identifier	1627576
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	In this lecture, computer models and simulation approaches for modeling different biological, physical and chemical systems are discussed. The applicability, accuracy and other technical aspects such as the computational complexity of the models will be evaluated and analyzed. In addition, the basics of simulation methods are presented in more detail to highlight and understand their main characteristics, as well as their differences. Various computer-based models corresponding to a wide range of time and length scales are presented and discussed. In the seminar, different modeling aspects and possible applications will be studied in more detail and in depth. An important part will be to familiarize students with the research field of computational natural sciences, from the broad spectrum of which topics will be selected. At the same time, novel research topics will be designed and their computational modeling will be assessed using the methods discussed. ;
Learning Objectives/ Learning Outcomes	Upon completion of the module, students will be able to know and understand various simulation methods used in the field of computational Life and Physical Sciences. They will also understand the critical and essential aspects of computationational modeling, such as method selection, design, accuracy, computational effort, and be able to apply and critically evaluate these. Likewise, the students are able to assign the application areas and questions to the simulation methods and independently design the strategy of a modeling approach depending on the scientific question. The students are further able to put the results generated from the literature into context with the known methodology. As a background to these learning objectives, the students will become familiar with the relevant terminology and physical theories related to scientific computing. The students will gain a good understanding of the technical literature and will conceptualize and critically approach the modeling procedures. In addition, they will be prepared to present and discuss their conclusions in a technical manner. The content of the module and the skills gained build upon and go beuond the level of a bachelor's module in the natural sciences. The in-depth content of the module, as well as the corresponding competencies will be acquired at the master's level. The learning objectives of the lecture and seminar can be summarized through the following points: 1. become familiar with simulation methods in the natural sciences. 2. critically compare different modeling approaches. 3. deal with relevant technical terms related to scientific computing. 4. investigate, understand, and critically evaluate application areas and the relevant scientific questions that can be addressed through computational modeling. 5. independently learn and read a research paper. In doing so, the student should be able to understand, critically discuss, compare with similar problems, and present the state-of-the-art literature. 6. conceptualize novel research topics using computer-assisted methods.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in Mathematics and Physics and experience with computers and programming in any programming language is helpful but not required.
References	Literatur:

	1. Daan Frenkel and Berend Smit.**"Understanding Molecular Simulation".** Academic Press, San Diego, ;**2002**. ; 2. Rapaport, D. C.. ;**"The Art of Molecular Dynamics Simulation".** Cambridge University Press, ;**2004**. ; 3. Andrew Leach. ;**"Molecular Modelling: Principles and Applications".** Pearson Education Ltd., ;**2001**. ; E-Book: Kieron Burke et al.,University of California, 2007
Language	German/English
Examination Terms	The grade of the module is composed as follows: • Exam (50%) • Preparation of the presentation and discussion of the scientific literature within the seminar (25%) • Presentation and question-round within the seminar (25%)
Miscellaneous	-
Module coordinator	Modulverantwortlichkeit: Prof. Dr. Maria Fyta
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Atomistic and Molecular Simulation Methods (162757601)	1st semester	no semester recommended	3	0
Seminar Atomistic and Molecular Simulation Methods (162757602)	1st semester	no semester recommended	3	2

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Atomistic and Molecular Simulation Methods	1st semester	no semester recommended	-	2

Module titel	Cell Biology (Compulsory elective subject)
Identifier	1612756
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2005
Valid until	-
Module level	Bachelor
Content	Thema 1: Einführung in die Zellbiologie 1.1 Zellen als Grundbausteine des Lebens 1.2 Größe von Zellen 1.3 Grundlegende biochemische Prinzipien in Zellen Thema 2: Chemische Grundlagen 2.1 Aufbau von Atomen 2.2 Chemische Bindungen 2.3 Bedeutung von Kohlenstoff für das Leben 2.4 Bioplymere Thema 3: Kohlenhydrate 3.1 Grundlagen der Kohlenhydratchemie 3.2 Monosacchride (Glukose, Fruktose) 3.3 Disaccharide (Saccharose, Maltose, Lactose) 3.4 Polysaccharide (Glykogen, Stärke, Cellulose, Chitin) Thema 4: Nukleinsäuren 4.1 Nukleotide 4.2 Aufbau DANN 4.3 Aufbau RNA 4.4 ATP als Energieträger Thema 5: Aminosäuren und Proteine 5.1 Aminosäuren 5.2 Peptidbindung 5.3 Primär-, Sekundär-, Tertiär- und Quartärstruktur von Proteinen 5.4 Enzyme Thema 6: Lipide 6.1 Aufbau von Lipiden 6.2 Eigenschaften von Lipiden Thema 7: Aufbau von Biomembranen 7.1 Phospholipide 7.2 Sterole 7.3 Membranfluidität 7.4 Membranproteine 7.5 Fluid-mosaic model Thema 8: Transport über Biomembranen 8.1 Osmose 8.2 Kanäle 8.3 Passive Transporter 8.4 Aktive Transporter Thema 9: Eukaryoten-Prokaryoten und zelluläre Kompartmentalisierung 9.1 Vergleich Prokaryoten-Eukaryoten 9.2 Zellkompartimente 9.3 Organellen 9.4 Methoden zur Organellenanreicherung Thema 10: Kern und Ribosomenbiogenese 10.1 Kernaufbau (Poren und Lamina) 10.2 Kernimport 10.3 Chromatin 10.4 Histone 10.5 Nukleolus und Ribosomenbiogenese

	Thema 11: Ribosomen und Proteinbiosynthese 11.1 genetischer Code 11.2 tRNAs 11.3 Translation Thema 12: Proteinabbau 12.1 Proteinfaltung und Chaperone 12.2 Proteasom 12.3 (Poly-)Ubiquitinierung Thema 13: Endomembransystem - das Endoplasmatische Reticulum 13.1 Sekretorischer Weg 13.2 Vesikeltransport 13.3 Aufbau ER 13.4 Signalpeptidhypothese 13.5 Biosynthese integraler Mebranproteine Thema 14: Golgi-Apparat, Vakuole und Lysosomen 14.1 Aufbau Golgi-Apparat 14.2 Modifikation der Glykosylierung 14.3 Lysosomen und Vakuole 14.4 Autophagie Thema 15: Peroxisomen 15.1 Biochemische Reaktionen in Peroxisomen 15.2 Beta-Oxidation von Fettsäuren 15.3 Photorespiration 15.4 Mobilität und Proteinimport Thema 16: Endosymbionten-Hypothese 16.1 Grober Aufbau von Mitochondrien und Plastiden 16.2 Evidenzen der Endosymbionten-Hypothese 16.3 Herkunft der Endosymbionten 16.4 Gen-Transfer in den Kern Thema 17: Mitochondrien 17.1 Chemiosmotische Kopplung 17.2 Aufbau von Mitochondrien 17.3 Oxidative Phosphorylierung 17.4 Elektronentranportkette Thema 18: Plastiden 18.1 Typen und Aufbau von Plastiden 18.2 Photosynthese (Überblick) 18.3 Lichtreaktion 14.4 Dunkelreaktion 18.5 Organellengenome 18.6 Proteinimport in Mitochondrien und Plastiden
Learning Objectives/ Learning Outcomes	Nach erfolgreicher Teilnahme: Nach erfolgreicher Teilnahme an den Modulveranstaltungen haben die Studierenden grundlegende Kenntnisse der wichtigsten Biomoleküle und des grundlegenden Aufbaus von Zellen. Wissen und Verstehen: Die Studierende haben Grundkenntnisse des Aufbaus und der Funktion von Zellen erworben. Fertigkeiten und Kompetenzen: Die Studierenden sind in der Lage, die wichtigsten Biomoleküle zu benennen und deren Aufbau zu beschreiben. Sie kennen den Aufbau pro- und eukaryotischer Zelllen und sind mit der Struktur und Funktion eukaryotischer Organellen vertraut. Die Studierenden können wichtige biochemische Prozesse und Funktionen den einzelnen Organellen zuordnen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	keine
References	Alberts et al. Molekularbiologie der Zelle Lodish et al. Zellbiologie bzw. deren englische Originalausgaben
Language	German
Examination Terms	The module grade is the exam grade.
Miscellaneous	-

Module coordinator	Modulangebotsorganisator: Kevin Rosar, M.Sc. Modellierungsteamverantwortlicher: Dr. Katja Petzoldt Modulverantworlicher: Prof. Dr. Ralph Panstruga
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Cell Biology (161275601)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Cell Biology	1st semester	no semester recommended	-	3

Module titel	Biological Information Processing (Compulsory elective subject)
Identifier	1613106
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	1. Nervous sytem of the vertebrate 1.1. Nerve cells 1.2. Anatomie oft he vertebrate nervous system 1.3. Structure oft he human brain 1.4. Autonomous nervous system 2. Evolution of nervous systems 2.1. Definition of nervous system 2.2. Orthogonal nervous systems 2.3. Nervous systems of molluscs 2.4. Ventral nerve cord 2.5. Nervous system of chordata 2.6. Phylogenetic relationships 2.7. Inversion hypothesis and morphogenes 2.8. Arguments for a common ancestor 3. Resting and action potential, ion channels 3.1. Functional morphology of neurons 3.2. Resting membrane potential – biohysical basis 3.3. Measurement of electrical signals 3.4. Hodgkin and Huxley model 3.5. Electric circuits oft he membrane 3.6. Action potential physiology 3.7. Action potential - molecules 4. Developmental Neurobiology 4.1. Neurolation 4.2. Neurogenesis 4.3. Determination of anterior-posterior and ventral-posterior axes 4.4. Morphogenes 4.5. Development of the PNS 4.6. Axonal pathfinding 4.7. Apoptosis 5. Synapses 5.1. History 5.2. Types of connection –juxtaposis, apposition, gap junctions, chemical synapses 5.3. Types of chemical synapses 5.4. Chemical synapses – presynaptic part 5.5. Vesicle and transmitter recycling 5.6. Chemical synapses – postsynaptic part 5.7. Computation on dendritic level 6. Motor system I 6.1. Four types of movement – reflex, rhythmical and voluntary movements, fixed action patterns 6.2. Spinal cord, brainstem 6.3. Cortical motor systems 6.4. Functional anatomy of motor cortex 6.5. Voluntary movements

	6.6. Sensory feedback 7. Motor system II 7.1. Cerebellum - anatomy, circuits, motor learning and pathophysiology 7.2. Basal ganglia - anatomy, circuits and pathophysiology 7.3. Sensory motor interface
Learning Objectives/ Learning Outcomes	The students are introduced into basic facts of biological information processing. The basic mechanisms may be compared and transferred on the algorithmic level to problems in other disciplines. The following topics will be discussed: nervous system organisation, basic neurophysiology (membrane potential, action potential, conduction of potentials, synapses), sensory and motor systems and cognitive neuroscience. The basic knowledge of information processing in living system may be transferred to technical systems.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	• Kandel ER, Schwartz JH, Jessell TM: Principles of neural science, 5th Edition, Elsevier, New York, 2009. • Kandel ER, Schwartz JH, Jessell TM: Neurowissenschaften, Spektrumverlag, Heidelberg, 1996.
Language	German
Examination Terms	written examination (60min)
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Kevin Rosar, M.Sc. Modellierungsteamverantwortlicher: Dr. Katja Petzoldt Modulverantworlicher: Prof. Dr. Marc Spehr
ECTS Credits	4
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Biological Information Processing (161310601)	1st semester	no semester recommended	4	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Biological Information Processing	1st semester	no semester recommended	-	2

Module titel	Biophysics I - Cellular Biophysics (Compulsory elective subject)
Identifier	1316297
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2012
Valid until	-
Module level	Bachelor/Master
Content	Biophysics is an interdisciplinary field of science that deals with the structure, function and dynamics of biological systems. Biological systems are quantitatively studied and described using physical approaches and methods. In addition, biophysics is covering the development and improvement of physical methods for studying biological processes. In the lecture, basic knowledge of biological building blocks and their supramolecular structures as well as corresponding methods for their characterization will be introduced. The functional principles of biomolecular machineries will be demonstrated on the example of nerve conduction, transport, and energy. Reductionist concepts will be introduced that allow to reach quantitative statements, despite the complexity of biological matter. The course is aimed primarily at graduate students with an interest in interdisciplinary research.
Learning Objectives/ Learning Outcomes	The students will be introduced to the basic concepts of biophysics, in which biological systems are quantitatively studied and described with the help of physical approaches and methods. In addition, new and further development of physical methods for the investigation of biological processes are presented.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Andreas Offenhäusser
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0

Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Biophysics I - Cellular Biophysics: Lecture and Exercises (131629702)	1st semester	no semester recommended	0	3
Biophysics I - Cellular Biophysics: Examination (131629701)	1st semester	no semester recommended	5	0

Module titel	Biophysics II: Molecular biophysics- structure and dynamics of bio-molecules (Compulsory elective subject)
Identifier	1310581
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2012
Valid until	-
Module level	Master
Content	We present many applications of approaches in modern molecular biophysics by showing case studies on protein folding, functional conformational changes and molecular signal transduction. The following techniques and methods will be introduced: Absorption spectroscopy: UV-Vis-, IR-, CD-spectroscopy Dynamic light scattering, Raman-spectroscopy Fluorescence spectroscopy: e.g. Förster resonance energy transfer (FRET), fluorescence correlation spectroscopy (FCS) Calorimetry: DSC /ITC The Scope of single molecule spectroscopy (some examples of fluorescence based methods)
Learning Objectives/ Learning Outcomes	Lecture: The students will obtain an overview of fundamental properties of biological macromolecules and their roles in the cell. They will have a basic understanding of typical biological problems and which experimental techniques can be employed to handle them. ; ; ; They are introduced to the foundations of protein structure-function relation and get an overview of key concepts to employ spectroscopic techniques to obtain experimental access to the biomolecule structure on a nanometer length scale. The students will be able interpret experimental data, know which methodical approach has to be used for specific scientific questions, and can judge possibilities and limitations from case studies in a broad field of interdisciplinary applications. Exercise: The students will execute a weekly delivered exercise sheet and present and discuss their results. They will be able to interpret measured data quantitatively and can solve a wide variety of problems in the field of molecular biophysics and structural biology.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Jörg Fitter
ECTS Credits	5
Contact time (WSH)	3

Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Biophysics II: Molecular biophysics- structure and dynamics of bio-molecules: Lecture and Exercises (131058102)	2nd semester	no semester recommended	0	3
Biophysics II: Molecular biophysics- structure and dynamics of bio-molecules: Examination (131058101)	2nd semester	no semester recommended	5	0

Module titel	Biospectroscopy: Laboratory Course (Compulsory elective subject)
Identifier	1311142
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2013
Valid until	-
Module level	Master
Content	The following practical “hands-on” experiments will be conducted by the students: Absorptions spectroscopy with retinal proteins (kinetics of the photo-cycle) Protein folding and protein stability: Intrinsic fluorescence spectroscopy, CD-spectroscopy and dynamic light scattering Protein labeling and Förster resonance energy transfer (FRET) spectroscopy Fluorescence correlation spectroscopy (FCS): Protein diffusion measured with a confocal fluorescence microscope
Learning Objectives/ Learning Outcomes	The students will have a practical understanding of biological sample preparation and characterization. Based on practical “hands-on” experiments with modern spectrometer setups, they will be able to perform calibration and sample measurements. The students have a fundamental understanding of the experimental setup, how to perform measurements and how to analyze and interpret the obtained data. They can evaluate the measurement outcome and compare it with the expectation. Furthermore, they are also able to analyze the precision of their measurements and will be able to discuss various sources of uncertainty. Finally, the students know how to write a proper documentation (experimental protocol) of their experiment and the obtained results and how to present the results in a scientific discussion.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Jörg Fitter
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Biospectroscopy: Laboratory Course (131114201)	1st semester	no semester recommended	5	4

Module titel	Computational Neuroscience (Compulsory elective subject)
Identifier	1613090
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	two semesters
Cycle (Semester)	winter semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	a) Modelle von Neuronen, Synapsen und Netzwerken; Konzepte der neuronalen Kodierung und kortikaler Informations-verarbeitung; Plastizität und Lernen b) Datenanalyse und Visualisierung mit selbst geschriebenen Programmen; Einsatz von wissenschaftlichen Programmiersprachen wie Matlab und Python zur Dokumentation von Analysen; Testen von Hypothesen durch Erzeugung gezielt gestörter Daten mit dem Rechner; Simulation von neuronalen Schaltkreisen c) Das Seminar befasst sich mit wechselnden Themen
Learning Objectives/ Learning Outcomes	Studierende sollen grundlegende Kenntnisse theoretischer Konzepte und Modellbildung neuronaler Informationsverarbeitung erlernen und anwenden Die gelehrten Inhalte dieses Moduls gehen, ebenso wie die zu vermittelnden Kompetenzen, über das Niveau eines Bachelormoduls hinaus. Aufbauend auf den Inhalten des Bachelors werden hier tiefergehende Inhalte / Kompetenzen auf Masterniveau erworben.
(Study-Specific) Prerequisites	-
(recommended) Requirements	keine
References	-
Language	German
Examination Terms	The contents of the lecture will be examined in an exam. Detailed protocols and a presentation of the results will be required on the subject matter of the exercise. In the seminar a separate presentation is required. The module grade results from the exam grade. The presentation in the context of the seminar and the minutes in the context of the exercises are not graded. Attendance is compulsory for the seminar and the exercises.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Timur Toygar M. A.Modellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessorin Dr. rer. nat. Sonja Annemarie Grün
ECTS Credits	10
Contact time (WSH)	5
Examination duration (min)	0

+ Computational Neuroscience (1613090)

Total hours (h)	300,0
Contact hours (h)	75,0
Self-study hours (h)	225,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Cortical Structure and Function (161309002)	1st semester	no semester recommended	3	2
Exam Computational Neuroscience (161309001)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Introduction to Computational Neuroscience	1st semester	no semester recommended	-	1
Übung Introduction to Computational Neuroscience	1st semester	no semester recommended	-	2

Module titel	Lab Course: Introduction to Bioelectronic Interfaces (Compulsory elective subject)
Identifier	1311139
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2012
Valid until	-
Module level	Master
Content	The following questions will be addressed: 1) What is the motivation for cell-chip coupling? 2) What kind of chip-based bioelectronics cell interfaces do exist and are currently being developed? 3) How is the coupling mechanism for the extracellular detection of electrophysiological action potentials on microelectrode arrays? 4) How do we record neurotransmitter release from cells in real-time? 5) What methods exist for the chip-based stimulation of cellular activity? 6) How can we reconstruct defined neuronal networks on a chip?
Learning Objectives/ Learning Outcomes	This practical course including lectures gives an introduction into state-of-the-art cell-chip communication devices and will explore novel tools that might advance the concept of on-chip neuroscience in the coming years.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Andreas Offenhäusser Professor als Juniorprofessor Dr. rer. nat. Bernhard Wolfrum
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0

Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lab Course: Introduction to Bioelectronic Interfaces (131113901)	1st semester	no semester recommended	6	4

Module titel	Single Molecule Fluorescence Microscopy: Laboratory Course (Compulsory elective subject)
Identifier	1311143
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2014
Valid until	-
Module level	Master
Content	Some of the following practical “hands-on” experiments will be conducted by the participants: • Imaging surface immobilized single molecules • Resolution limited imaging • Identification and properties of single molecules • Time trace analysis of single molecules • Studies of diffusing molecules in a confocal microscope • Fluorescence correlation spectroscopy (ACS, CCS) • Burst analysis and pulsed interleaved excitation • Single molecule FRET studies
Learning Objectives/ Learning Outcomes	Based on practical “hands-on” experiments with state-of-the-art high resolution fluorescence microscopy equipment, the students will be able to perform calibration and sample measurements. The students have a fundamental understanding of the experimental setup, how to perform measurements and how to analyze and interpret the obtained data. They can evaluate the measurement outcome and compare it with the expectation. Furthermore, they are also able to analyze the precision of their measurements and will be able to discuss various sources of uncertainty or possible artifacts. Finally, the students know how to write a proper documentation (experimental protocol) of their experiment and the obtained results and how to present the results in a scientific discussion.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	See module: Single molecule techniques in life sciences -Advanced experimental methods in modern biophysics
Language	English
Examination Terms	Presence in the lab course is compulsory. Module examination by grading of the lab work
Miscellaneous	-
Module coordinator	Jörg Fitter
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0

Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Single Molecule Fluorescence Microscopy: Laboratory Course (131114301)	1st semester	no semester recommended	5	4

Module titel	Single Molecule Techniques in Life Sciences -Advanced Experimental Methods in Modern Biophysics (Compulsory elective subject)
Identifier	1311140
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2013
Valid until	-
Module level	Master
Content	The motivation of single molecule techniques is explained and illustrated by some key studies (e.g., protein folding, protein dynamics, enzymatic reactions). The following methods will be discussed in more detail Historical studies (patch clamp, low temperature studies, etc.) Fluorescence based single molecule techniques (e.g., FCS, FRET, single particle tracking) Force based methods: optical tweezers, AFM, magnetic tweezers, etc. New and upcoming techniques: SERS, single particle diffraction, applications with the free electron laser (FEL)
Learning Objectives/ Learning Outcomes	Lecture: The students are provided with an overview of biological background knowledge to get the idea of single molecule studies in biology. Furthermore, the students will understand key concepts of experimental approaches and the particular methodical challenges and practical limitations. They will acquire knowledge about the interdisciplinary nature of biology based problems and physics based experimental methods in the field single molecule studies. The students will have a basic understanding of the various S/N issues occurring in measured data which are most relevant in this research topic. ; ; Exercise: The students will execute a weekly delivered exercise sheet and present and discuss their results. They understand underlying principles of typical measurement setups can interpret measured data quantitatively. The students can solve a wide variety of problems in the field of single molecule applications.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Jörg Fitter
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0

Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Single Molecule Techniques in Life Sciences -Advanced Experimental Methods in Modern Biophysics: Lecture and Exercises (131114002)	1st semester	no semester recommended	0	3
Single Molecule Techniques in Life Sciences -Advanced Experimental Methods in Modern Biophysics: Examination (131114001)	1st semester	no semester recommended	5	0

Module titel	Statistics and Dynamics of Biopolymers (Compulsory elective subject)
Identifier	1320700
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	• Introduction • Equations of motion: Langevin equation, Fokker-Planck equation • Stokes equation • Hydrodynamic interactions • Models for macromolecules • Solutions of the equations of motion for macromolecular systems • Active matter and microswimmers • Simulations of stochastic systems: Brownian dynamics simulations • Introduction to mesoscopic simulation methods: Dissipative Particle Dynamics, Lattice Boltzmann and Multiparticle Collison Dynamics methods • Examples of mesoscale simulations of biomolecules and colloidal systems
Learning Objectives/ Learning Outcomes	The students are introduced to fundamental concepts of stochastic process and fluid-mediated interactions (hydrodynamics), with applications to (bio)-macromolecule systems. The students are able to apply the concepts to and develop mathematical models for basic problems of classical mechanics. They are able to evaluate the limitations of the theoretical concepts and possible adaptations of stochastic processes. The students can develop and contact a scientific project. They can communicate the results of their scientific work by an oral presentation.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Roland Winkler
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0

Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Statistics and Dynamics of Biopolymers (132070001)	2nd semester	no semester recommended	5	3

Module titel	Systems and Computational Biology in Theory and Practice (Compulsory elective subject)
Identifier	1627196
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	This module is for students who want to gain in-depth experience in systems biology and computational life sciences. The content of the module is designed to demonstrate the interdisciplinary and quantitative nature of biological research, and to deepen previous experience and skills. In particular, we will cover topics of: 1.) metabolic networks, 2.) biochemical regulation, ; 3.) enzyme kinetics, and 4.) basics of mathematical modelling, ; with practical tasks such as: 5.) data analysis, 6.) statistical data analysis, 7.) data visualisations, and 8.) kinetic model construction. ; In this course, programming languages (e.g., python, R www.r-project.org) will be introduced. Although photosynthetic organisms serve here as model organisms, the majority of the approach learned is transferable to other organisms and thus universally applicable. The findings are presented scientifically in a biological context and discussed with experts in the field.
Learning Objectives/ Learning Outcomes	**Learning outcomes:** • To explore, explain and set in context basic concepts of Systems Biology, mathematical and computational modeling. • Independently generate a working hypothesis regarding observed phenomenon. • Practice and execute integration of quantitative biological data. • Gain experience in the area of data analysis e.g., data visualization and statistics. • To comprehend and practice translation of a biological network into a mathematical model. • Adapt existing models to test the hypotheses; independently solve biological questions with computational methods. • Explain and distinguish biological processes at the systems level. • Use remote repository to provide reproducible and transparent computational models. • Being able to critically discuss, communicate and present scientific results.
(Study-Specific) Prerequisites	-

(recommended) Requirements	Basic mathematical knowledge and good biochemical principles are desirable but not required. Previous experience in programming will be an advantage. The module builds on prior knowledge in biochemistry, molecular biology, bioinformatics and mathematics. Attendance is compulsory for exercises and seminars.
References	References: 1. Klipp, Systems Biology: A Textbook. (2009), Wiley-VCH Verlag GmbH &; Co. KGaA. ISBN 978-3-527-31874-2. 2. Berg,Tymoczko, Stryer, Stryer Biochemie (2013), Springer, ISBN 978-3-8274-2988-9 3. Alberts et al., Molecular Biology of THE CELL, Garland Science, 2015, ISBN 978-0-8153-4464-3 4. Scientific literature on the topic
Language	German/English
Examination Terms	The grade of the module is calculated from the grades of the seminar and the exercise; weighted according to CP.
Miscellaneous	-
Module coordinator	Modulverantwortlichkeit: Jun.Prof. Dr. Lisa Fürtauer, Jun.Prof. Dr. Anna Matuszy#ska
ECTS Credits	6
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	75,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Systems and Computational Biology in Theory (162719601)	1st semester	no semester recommended	3	2
Exercise Systems and Computational Biology in Theory (162719602)	1st semester	no semester recommended	3	3

Module titel	Theoretical Neuroscience - Correlation Structure of Neural Networks (Compulsory elective subject)
Identifier	1311141
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2012
Valid until	-
Module level	Master
Content	This lecture is part of the module "Biophysics" of the physics master program, but it is open to students at the bachelor level and students from other domains as well. After an overview and introduction into the field, we will systematically develop the theory of fluctuations and correlations in neuronal networks. This active topic of current research addresses the foundations of many aspects of network function like plasticity and learning, and will serve us to introduce the prominent neuronal-network models and theoretical tools presently in use. Starting from linear Ornstein-Uhlenbeck processes (Langevin equations), over the classical binary (spin) network model to the spiking leaky integrate-and-fire model, the de-facto standard of contemporary computational neuroscience, we will develop the methods required to gain an analytical understanding of the network dynamics. The sequence of models from low to high realism and corresponding analytical complexity will allow us to first clarify the concepts, and subsequently treat the analytically more challenging topics. 1. Course introduction 2. Pairwise correlations in spike trains 3. Theory of correlations in linear rate models 4. Mean-field theory of binary networks 5. Theory of equal-time correlations in binary networks 6. Time-resolved covariance functions for binary neurons 7. Spiking neurons 8. Linear-response theory for spiking neurons 9. Mean-field theory and transfer function for LIF neuron 10. Review of residue theorem and Greens functions: application to oscillations in networks 11. Self-consistent correlations and oscillations in LIF networks 12. Decorrelation of neural-network activity by inhbitory feedback
Learning Objectives/ Learning Outcomes	The student will get acquainted with elementary methods from linear system's theory, Fourier methods, point processes, as well as methods from statistical mechanics (Markov processes, master equation, Chapman-Kolmogorov equation, noise and diffusion processes, Fokker-Planck equation and non-equilibrium steady states) as they are applied in theoretical neuroscience. The neuroscientific topics will include the mean-field theory for binary and spiking networks, the balanced state in non-spiking and spiking networks, the mechanisms of decorrelation and of oscillations in recurrent cortical networks, the classical mean-field theory of pairwise correlations in binary (spin) networks, the corresponding state-of-the art theory for spiking networks, including the temporal structure of correlations. The weekly lecture (45 minutes) is accompanied by exercises (90 minutes) to discuss the homework. Homeworks will consist of a mixture of theoretical exercises and (simple) programming and simulation exercises (preferably using NEST and python/numpy/scipy/matplotlib) to

	deepen the topics of the lecture.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Markus Diesmann
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Neuroscience - Correlation Structure of Neural Networks: Lecture and Exercises (131114102)	2nd semester	no semester recommended	0	3
Theoretical Neuroscience - Correlation Structure of Neural Networks: Examination (131114101)	2nd semester	no semester recommended	5	0

Module titel	Applied Quantum Chemistry for Engineers (Compulsory elective subject)
Identifier	4012503
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	1 • Introduction • Applications • Mathematical basics, experimental evidene of QM effects 2 • Properties of the Schrödinger equation and of wave functions • Discussion of the analytical solutions for a particle in a box and the harmonic oscillator 3 • Discussion of the analytical solutions for the rigid rotator and the hydrogen atom 4 • Approximations for the helium atom and multi-electron atoms • Bron-Oppenheimer approximation 5 • LCAO approximation • Hybrid orbitals • Hückel Theory 6 • Roothaan expansion (basis sets I) and Hartree-Fock method • Geometry optimization I • Gaussian software package 7 • Fermi and Coulomb correlation: configuration interaction, Möller-Plesset perturbation theory, Coupled Cluster Theory • Geometry optimization II 8 • Calculation of ideal gas functions 9 • Basis sets II 10 • Electron Correlation II: Static electron correlation • Calculations in the condensed phase I: Car-Parinello MD, Continuum solvation models 11 • Calculations in the condensed phase II: intermolecular interaction & predictive Equation of state 12 • Density functional theroy: basics & most relevant functionals 13 • ab initio reaction kinetics: calculation of potential energy surfaces, transition state theory, tunneling
Learning Objectives/ Learning Outcomes	With respect to the subject: • Understanding of the theoretical basics of quantum mechanics. • Knowledge of the strengths and weaknesses of the most important approximation methods. • In the tutorials the students will aquire the skills necessary to use quantum mechanical software packages to compute properties required in practical engineering applications Not with respect to the subject (e.g. Team work, Presentation, Project Management, etc.): • none
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	• Handouts are available • Books available in the library will be suggested for further reading
Language	English
Examination Terms	Eine mündliche Prüfung
Miscellaneous	-
Module coordinator	apl. Professor Dr. rer. nat. Kai Leonhard
ECTS Credits	4
Contact time (WSH)	-
Examination duration (min)	-
Total hours (h)	120,0

Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Applied Quantum Chemistry for Engineers (401250301)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Applied Quantum Chemistry for Engineers	1st semester	no semester recommended	-	2
Exercise Applied Quantum Chemistry for Engineers	1st semester	no semester recommended	-	1

Module titel	Advanced Solid State Chemistry - Syntheses, Structures, Properties, Applications (Compulsory elective subject)
Identifier	1512623
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	Präparationsverfahren der Festkörperchemie, Methoden der strukturellen Charakterisierung, kristallchemische Konzepte, chemische Bindung im Feststoff, neuartige Materialien (bspw. stickstoffbasiert, Intermetallika), Phasenbeziehungen, optische und dielektrische Eigenschaften, kooperativer Magnetismus, Supraleitung.
Learning Objectives/ Learning Outcomes	Die Studierenden besitzen Kenntnisse über die chemische Darstellung und Charakterisierung moderner Feststoffmaterialien.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	none
References	L. Smart, E. Moore: Solid State Chemistry: An Introduction, Chapman &; Hall, London 1995; R. J. D. Tilley: Understanding Solids: The Science of Materials, Wiley, New York 2004.
Language	German
Examination Terms	Klausur oder mündliche Prüfung
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Chemie Modulverantworlicher: Univ.-Prof. Dr. rer. nat. Richard Dronskowski
ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced Solid State Chemistry - Syntheses, Structures, Properties, Applications (151262301)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Advanced Solid State Chemistry - Syntheses, Structures, Properties, Applications	1st semester	no semester recommended	-	2

Module titel	Computer Simulation and Spectroscopy of Solids (Compulsory elective subject)
Identifier	1512621
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2010
Valid until	Summer semester 2023
Module level	Master
Content	Thermodynamische Monte Carlo-Simulation, Monte Carlo-Simulation zur Diffusion, Atomistische Simulation von Defekten in Festkörpern mit Semiempirischen und Dichtefunktionalmethoden, Spektroskopie an Festkörpern.
Learning Objectives/ Learning Outcomes	Die Studierenden besitzen vertiefte Kenntnisse der Computersimulation und der Spektroskopie an Festkörpern. Die Studierenden verstehen unter Anwen-dung des erlernten Wissens grundlegende physikalisch-chemische Phänomene in Festkörpern und nutzen Wissen zur Planung, Durchführung und Analyse von Experimenten.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	none
References	K. Binder, D. W. Heermann, Monte Carlo Simulation in Statistical Physics: An Introduction, Springer, 2002; H. Kuzmany, Solid-State Spectroscopy: An Introduction, Springer, 2002; D. Sholl, J. A. Steckel, Density Functional Theory: A Practical Introduction, Wiley-Interscience, 2009
Language	German/English
Examination Terms	In der Veranstaltung Computersimulation und Spektroskopie an Festkörpern ist die folgende Leistung zu erbringen: - Klausur (60 Minuten) oder mündliche Prüfung (30 Minuten) zur Vorlesung
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Chemie Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Univ.-Prof. Dr. rer. nat. Manfred Martin
ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Computer Simulation and Spectroscopy of Solids (151262101)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Computer Simulation and Spectroscopy of Solids	1st semester	no semester recommended	-	2

Module titel	Computer Simulation and Spectroscopy in the Condensed Phase (Compulsory elective subject)
Identifier	1528470
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	Thermodynamische Monte Carlo-Simulation, Monte Carlo-Simulation zur Diffusion, Atomistische Simulation von Defekten in Festkörpern mit Semiempirischen und Dichtefunktionalmethoden, Spektroskopie in kondensierter Phase (Röntgenabsorption, elektronischer Circulardichroismus), Simulation von elektronischen Anregungen mithilfe quantenchemischer Methoden
Learning Objectives/ Learning Outcomes	Die Studierenden besitzen vertiefte Kenntnisse der Computersimulation und der Spektroskopie an Festkörpern und Molekülen in der kondensierten Phase. Die Studierenden verstehen unter Anwendung des erlernten Wissens grundlegende physikalisch-chemische Phänomene in Festkörpern und von flexiblen Molekülen in Lösung. Sie nutzen Wissen zur Planung, Durchführung und Analyse von Experimenten und unterstützenden Rechnungen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	keine
References	K. Binder, D. W. Heermann, Monte Carlo Simulation in Statistical Physics: An Introduction, Springer, 2002; H. Kuzmany, Solid-State Spectroscopy: An Introduction, Springer, 2002; D. Sholl, J. A. Steckel, Density Functional Theory: A Practical Introduction, Wiley-Interscience, 2009
Language	German
Examination Terms	Prüfung: Klausur oder mündliche Prüfung Übung: unbenotete schriftliche Hausaufgaben
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Chemie Modulverantwortliche: Prof. Dr. Christoph Bannwarth
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Computer Simulation and Spectroscopy in the Condensed Phase (152847001)	2nd semester	1st semester	1	1
Exam Computer Simulation and Spectroscopy in the Condensed Phase (152847002)	2nd semester	1st semester	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Computer Simulation and Spectroscopy in the Condensed Phase	2nd semester	1st semester	-	2

Module titel	Principles of Nuclear Chemistry (Compulsory elective subject)
Identifier	5110539
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	Historischer Überblick, Natürliche und künstliche Radioaktivität, Zerfallsgesetze, Kernreaktionen, Wechselwirkung von Strahlung mit Materie, Chemie der Actiniden, Grundzüge des Kernbrennstoffkreislaufs, Dosimetrie und Strahlenschutz.
Learning Objectives/ Learning Outcomes	Die Studierenden haben grundlegende Kenntnisse der Kernchemie.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	none
References	K. H. Lieser, Einführung in die Kernchemie, 3rd Edition ed., VCH Verlagsgesellschaft mbH, Weinheim, 1991.
Language	German
Examination Terms	In der Wahlpflichtveranstaltung Grundlagen der Kernchemie ist die folgende Leistung zu erbringen: Unbenotete Hausarbeit
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher ChemieModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Unbekannt
ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Principles of Nuclear Chemistry (511053901)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Grundlagen der Kernchemie	1st semester	no semester recommended	-	2

Module titel	Mathematical Aspects in Computational Chemistry (Compulsory elective subject)
Identifier	1113574
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2016
Valid until	-
Module level	Master
Content	Computational chemistry repeatedly uses mathematical concepts in the modelling and the following discretization of the models. We present some models of theoretical chemistry from a mathematical perspective. Topics include electro-static interaction of molecular systems, the passage from classical to quantum mechanics, an introduction to quantum mechanics, the Hartree-Fock model and Density Functional Thoery as well as its discretization.
Learning Objectives/ Learning Outcomes	The aim of this class is to gain more insight of mathematical aspects in computational chemistry. The student should get familiar with some well-known concepts in theoretical chemistry and learn the mathematical aspects behind these concepts.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Teilweise: Cancès, E., Defranceschi, M., Kutzelnigg, W., Le Bris, C., &; Maday, Y. (2003). Computational quantum chemistry: a primer. In Handb. Numer. Anal., X (pp. 3– 270). Amsterdam: North-Holland. Chapters 1 and 2.
Language	English
Examination Terms	Written or oral examination. Type and length of the exam will be announced in the beginning of the semester.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Benjamin Stamm
ECTS Credits	5
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Mathematical Aspects in Computational Chemistry (111357402)	1st semester	no semester recommended	0	1
Exam Mathematical Aspects in Computational Chemistry (111357401)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung: Mathematical aspects in computational chemistry	1st semester	no semester recommended	-	2

Module titel	Optical Spectroscopy and Microscopy (Compulsory elective subject)
Identifier	1528466
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	• Grundlagen der Quantenmechanik • Rotationsspektroskopie • Schwingungsspektroskopie • UV/VIS-Spektroskopie • (ATR-)Infrarotspektroskopie • Ramanspektroskopie • Fluoreszenzspektroskopie und -mikroskopie • Einzelmolekülfluoreszenzspektroskopie • superauflösende Fluoreszenzmikroskopie • Summenfrequenzspektroskopie • ;zeitaufgelöste optische Spektroskopie
Learning Objectives/ Learning Outcomes	Die Studierenden haben einen detaillierten Überblick über verschiedene molekulare Spektroskopiemethoden und wissen, welche Informationen aus der Vielfalt der verschiedenen Methoden gewonnen werden können. Die Studierenden sind mit der technischen Realisierung der verschiedenen Methoden vertraut und verstehen den Weg von der Messung über die Auswertung bis zur Interpretation. Den Studierenden können die Ergebnisse spektroskopischer Untersuchungen kritisch beleuchten und deren statistische Signifikanz einschätzen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	keine
References	Lakowicz, Principles of Fluorescence Spectroscopy. Sauer, Hofkens, Enderlein, Handbook of Fluorescence Spectroscopy and Imaging Skoog, Leary, Instrumentelle Analytik. Hesse, Maier, Zeeh, Spektroskopische Methoden in der organischen Chemie.
Language	German
Examination Terms	Prüfung: Klausur oder mündliche Prüfung Übung: unbenotete schriftliche Hausaufgaben
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Chemie Modulverantwortliche: Prof. Dr. Dominik Wöll
ECTS Credits	5
Contact time (WSH)	3

Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Optical Spectroscopy and Microscopy (152846601)	1st semester	2nd semester	2	1
Exam Optical Spectroscopy and Microscopy (152846602)	1st semester	2nd semester	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Optical Spectroscopy and Microscopy	1st semester	2nd semester	-	2

Module titel	Physical Chemistry VI (Compulsory elective subject)
Identifier	1515596
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	1 • Einführung und Übersicht • Kristallgitter 2 • Bindungen und Bänder in Festkörpern • Bänder • Metalle • Freies Elektronengas • Wärmekapazität des freien Elektronengases • Elektrische Leitfähigkeit • Isolatoren und Halbleiter • Dotierung • Halbleiterbauelemente 3 • Festkörperthermodynamik • Ionenkristalle: Struktur • Ionenkristalle: Gitterenergie • Gitterschwingungen 4 • Defekte in Festkörpern (Defektchemie) • Makroskopische Evidenz für Gitterfehler • Mikroskopische Modelle von Punktdefekten • Thermodynamik von Punktdefekten • Nichtstöchiometrische Verbindungen 5 • Diffusion • Diffusionsmechanismen • Selbstdiffusion • Sekundärionenmassenspektrometrie • Tracerdiffusion • Diffusion im Konzentrationsgradienten • Temperaturabhängigkeit der Diffusion • Irreversible Thermodynamik • Chemische Diffusion 6 • Festkörperreaktionen 7 • Brennstoffzellen
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen Gegenstand, Entwicklung und Trends der Physikalischen Chemie fester Stoffe.

	• Die Studierenden können theoretische Modelle der Festkörperstruktur auf aktuelle Fragestellungen übertragen. • Die Studierenden sind fähig, experimentelle Resultate sinnvoll zu interpretieren und können Konsequenzen ableiten und vorhersagen. • Die Studierenden können die logische Richtigkeit einer wissenschaftlichen Argumentation beurteilen. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden werden über die Übungseinheiten befähigt, Problemstellungen zu analysieren, Lösungsvorschläge zu erarbeiten und zu bewerten (Methodenkompetenz). • Im Rahmen der Übungen werden von Studierenden Arbeitsergebnisse vorgestellt, so dass die Übungen dazu beitragen, kommunikative Fähigkeiten zu verbessern (Präsentation).
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	none
References	• R.J. Borg, G.J. Dienes, The Physical Chemistry of Solids, Academic Press Ltd., San Diego, 1992 • A.R. West, Grundlagen der Festkörperchemie, Wiley-VCH, New York, 2000 • Skript zur Vorlesung
Language	German
Examination Terms	Eine schriftliche Klausur oder eine mündliche Prüfung
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher ChemieModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessor Dr. rer. nat. Manfred Martin
ECTS Credits	3
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	60,0
Self-study hours (h)	30,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam/Oral Exam Physical Chemistry of Solids (151559601)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Physical Chemistry of Solids Lecture	1st semester	no semester recommended	-	2
Physical Chemistry of Solids Exercise	1st semester	no semester recommended	-	2

Module titel	Secondary ion mass spectrometry (SIMS) - Modern Solid State Analytics at the Nano-scale (Compulsory elective subject)
Identifier	1510541
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	Prinzip und Geschichte; Wechselwirkung zwischen hochenergetischen Ionen und Festkörpern; Vor- und Nachteile der SIMS-Methode; Quantifizierung und die SIMS-Gleichung; Betriebsarten (statische SIMS und dynamische SIMS) und Datenverarbeitung (Oberflächenspektrometrie, Bildaufnahme, Tiefenprofilierung); Aufbau von SIMS-Maschinen: Vakuumerzeugung, Ionenquellen, Massenspectrometer (Flugzeit, Quadrupol und Magnetsektorfeld); Anwendungsbeispiele aus der Cosmo- und Geochemie, aus der Katalyse, aus der Halbleiterindustrie, und aus der physikalischen Festkörperchemie; Andere Ionenstrahlmethoden
Learning Objectives/ Learning Outcomes	Die Studierenden kennen sowohl theoretische als auch praktische Aspekte der Sekundärionen-Massenspektrometrie (SIMS)-Analyse von Festkörpern. Ihnen sind dieStärken und Grenzen der Methode bewusst. Darüber hinaus kennen sieden Aufbau und die Funktionsweise von Sekundärionen-Massenspektrometern.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	none
References	Secondary Ion Mass Spectrometry: Basic Concepts, Instrumental Aspects, Applications, and Trends, A. Benninghoven, F. G. Rüdenauer, and H. W. Werner, Wiley, New York, (1987). Secondary Ion Mass Spectrometry: Principles and Applications, eds. J. C. Vickerman, A. Brown and N. M. Reed, Clarendon Press, Oxford, (1989). Secondary Ion Mass Spectrometry: A practical handbook for depth profiling and bulk impurity analysis, R. G. Wilson, F. A. Stevie and C. W. Magee, Wiley, New York, (1989). ToF-SIMS: Surface Analysis by mass spectrometry, eds. J. C. Vickerman and D. Briggs, IM Publications and Surface Spectra (2001).
Language	German
Examination Terms	Klausur oder mündliche Prüfung
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Chemie Modulverantworlicher: Prof. Dr. rer. nat. Roger de Souza
ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	30,0

Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Secondary Ion Mass Spectrometry (SIMS) - Modern Solid State Analytics at the Nano-scale (151054101)	1st semester	no semester recommended	3	3

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Secondary ion mass spectrometry (SIMS) - Modern solid state analytics at the nano-scale	1st semester	no semester recommended	-	2

Module titel	Theoretical Chemistry (Compulsory elective subject)
Identifier	1528469
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	Formale Quantenmechanik, Lineare Operatoren, Variationstheorie, Hartree-Fock-Theorie, Elektronenkorrelation, Born-Oppenheimer-Näherung, Normalkoordinatenanalyse, Zeitabhängige Schrödinger-Gleichung
Learning Objectives/ Learning Outcomes	Grundlagen und Verfahren der Quantenchemie sind den Studierenden geläufig und einfache Rechenverfahren der Quantenchemie (z.B. die Hartree-Fock-Methode) können angewendet werden.
(Study-Specific) Prerequisites	-
(recommended) Requirements	keine
References	I.N. Levine, Theoretical Chemistry; P. W. Atkings, R. S. Friedman, Molecular Quantum Mechanics; A. Szabo, N. S. Ostlund, Modern Quantum Chemistry.
Language	German/English
Examination Terms	Prüfung: Klausur oder mündliche Prüfung Übung: unbenotete schriftliche Hausaufgaben
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Chemie Modulverantwortliche: Prof. Dr. Arne Lüchow
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Theoretical Chemistry (152846901)	1st semester	2nd semester	2	1
Exam Theoretical Chemistry (152846902)	1st semester	2nd semester	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Theoretical Chemistry	1st semester	2nd semester	-	2

Module titel	Theoretical chemistry and molecular spectroscopy (Compulsory elective subject)
Identifier	1515618
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2013
Valid until	Summer semester 2023
Module level	Master
Content	Theoretische Chemie: Formale Quantenmechanik, Lineare Operatoren, Variationstheorie, Störungstheorie, Hartree-Fock-Theorie, Elektronenkorrelation, Born-Oppenheimer-Näherung, Normalkoordinatenanalyse, Zeitabhängige Schrödinger-Gleichung. Molekülspektroskopie: Grundlagen der Quantenmechanik, Rotations- und Schwingungsspektren, Rotations-Schwingungs-Wechselwirkungen, Symmetrieprinzipien.
Learning Objectives/ Learning Outcomes	Theoretische Chemie: Grundlagen und Verfahren der Quantenchemie sind den Studierenden geläufig und einfache Rechenverfahren der Quantenchemie (z.B. die Hartree-Fock-Methode) können angewendet werden. Molekülspektroskopie: Die Studierenden verstehen den Aufbau hochaufgelöster Molekülspektren und sind in die Lage, diese zu interpretieren und zugrunde liegende physikalischchemische Parameter zu extrahieren.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	none
References	Theoretische Chemie: I. N. Levine, Theoretical Chemistry; P. W. Atkins, R. S. Friedman, Molecular Quantum Mechanics; A. Szabo, N. S. Ostlund, Modern Quantum Chemistry. Molekülspektroskopie: J.L. McHale, Molecular Spectroscopy, Prentice Hall, New Jersey.
Language	German/English
Examination Terms	Written exam, oral exam or student's presentation The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	Modulangebotsorganisation: Modulangebotsverantwortung Chemie Modulverantwortung: Univ.-Prof. Dr. rer. nat. Arne Lüchow

+ Theoretical chemistry and molecular spectroscopy (1515618)

ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	**Recommended Semester (Study start winter)**	**Recommended Semester (Study start summer)**	**ECTS Credits**	**Contact time (WSH)**
Molecular Spectroscopy: Lecture and Exercise (151561801)	1st semester	no semester recommended	0	2
Theoretical Chemistry: Lecture and Exercise (151561803)	1st semester	no semester recommended	0	2
Exam Theoretical Chemistry and Molecular Spectroscopy (151561802)	1st semester	no semester recommended	6	0

Module titel	Alternative Energy Technologies (Compulsory elective subject)
Identifier	4012502
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Bachelor/Master
Content	1 • Übersicht über die Energiewirtschaft (Weltweite und Deutsche Entwicklung, Reserven, Ressourcen, CO2-Problem, Energieverbrauch, Prognosen 2 • Bewertungsgrößen (Wirkungsgrade, Kumulierter Energieaufwand, Amortisationszeit, Erntefaktor) • Betriebliche, Ökologische Ökonomische Bewertungsgrößen • Soziale und Gesellschaftliche Aspekte 3 • Kraft-Wärmekopplung, Fernwärme, Tertiäre Ölgewinnung, Ölgewinnung aus Ölsand und Ölschiefer 4 • Rationelle Energieumwandlung 5 • Neue Verfahren der Kohlenutzung (Kohlevergasung, -verflüssigung 6 • Solarenergie (Solarfarm, -tower, Niedertemperatur Kollektor) 7 • Photovoltaik 8 • Windenergie 9 • Wasserkraftwerke (Laufwasser, Pumpspeicher, OTEC) 10 • Gezeitenenergie, Wellenenergie, Geothermische Energie 11 • Biomasse 12 • Wasserstoffwirtschaft 13 • Brennstoffzelle 14 • Innovative Reaktorkonzepte 15 • Kernfusion

- Subsidiary Subjects
- Energy Technology
+ Alternative Energy Technologies (4012502)

Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen energiesystematische und energiewirtschaftliche Zusammenhänge • Die Studierenden können unterschiedliche Energiesysteme bezüglich ihres Wirkungsgrades sowie ökonomischer Kriterien untersuchen, berechnen und bewerten • Die Studierenden sind in der Lage verschiedene Energiesysteme (fossil, nuklear, regenerativ) bewerten und zu klassifizieren • Sie Studierenden können die Methoden zur thermodynamischen Bewertung und Optimierung auf Prozesse der Energieumwandlung anwenden • Die Studierenden sind fähig verschiedenste Energieumwandlungssysteme kritisch aus verschiedenen Blickwinkeln zu bewerten (Wärmetechnik, Ökologie, Ökonomie, Resourcenschonung, Risikoanalyse, gesellschaftliche Gesichtspunkte) Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden können Problemstellungen analysieren und bewerten
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	-
References	Vorlesungskript
Language	German
Examination Terms	Eine schriftliche Klausur Bonuspunkteregelung: Zugeordnete Bonusveranstaltung: Energieversorgungsysteme (SS) Im Rahmen der Veranstaltung Energieversorgungsysteme wird eine Hausaufgabe vergeben, durch die ein Bonus von maximal 10% auf die Prüfung erlangt werden kann. • Es ist auch ohne Bonuspunkt möglich, die Prüfung mit der bestmöglichen Note zu absolvieren. • Erlangte Bonuspunkte haben keinen Einfluss auf das Prüfungsergebnis, wenn dieses ohne die Bonuspunkte "nicht bestanden" (5.0) lautet.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dirk Müller
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Alternative Energy Technologies (401250201)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Alternative Energy Technologies	2nd semester	no semester recommended	-	2
Lecture Alternative Energy Technologies	2nd semester	no semester recommended	-	2
Bonus Alternative Energy Technologies	2nd semester	no semester recommended	-	0

Module titel	Basics of Final Disposal (Compulsory elective subject)
Identifier	5126545
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The module consists of two courses: *Final disposal and projects* and *Geological and engineering basics of final disposal*. **The Final disposal and projects** lecture aims at providing those students who have not received basic knowledge of radioactive waste disposal in their Bachelor's degree, e.g. because they come from external universities. However, the relevant subject aspects are only roughly touched upon, since these are dealt with in greater depth in the other lectures. Due to the fact that the specialisation "repository safety" is aimed at both bachelor students of mining engineering and geosciences, the lecture **Geological and engineering basics of final disposal** has to transfer the missing subject content to the respective cohort from other subjects. ; This means that students of geosciences are taught the basics of mining engineering required for final disposal. Conversely, students with a background in mining engineering will be taught the basics of geology related to disposal. The following subjects are taught in ;**Final disposal and projects:** * ;Waste management fundamentals * ;International waste management standards and national regulations * Barrier and disposal concepts * International repository projects The following subjects are taught in **Geological and engineering basics of final disposal:** Geoscientific fundamentals: * ;Formation, properties and regional distribution of host rocks * Host rock-specific ad- and disadvantages * Fundamentals of groundwater flow * Geomechanic fundamentals ; Mine Engineering fundamentals: * ;Introduction to mining methods * Excavation methods * Rock breaking, conveying and transport of mine debris * Support of mine workings

	* Shaft sinking methods and shaft hoisting technology * Backfilling of mining cavities * Mine infrastructure, ventilation, water management and surveying
Learning Objectives/ Learning Outcomes	The Students will learn the fundamentals regarding deep geological disposal of radioactive waste and the required knowledge about geological and engineering tasks to carry out planning, constructing, operating, closing and assessing the long-term safety of a repository for radioactive waste. In this course students will obtain the necessary understanding of the main geological plus engineering methods, processes and applications which are crucial in the interdisciplinary field of final disposal and for attending further modules in the specialization course *Repository Safety*. The students will be able to: * Comprehend the relevance and implication of geological and mining engineering challenges related to repository selection, design and safety * Understand the influence of climatic and geologic exogenic and endogenic processes and their relevance in the context of site selection, repository design and safety * Identify the advantages, disadvantages and characteristics of the three host rocks (rock salt, claystone and crystalline rock) which are relevant for the final disposal of high-level waste * Comprehend the governing principles of flow and radionuclide transport process in the saturated and unsaturated zone * Understand the most important methods (field, laboratory, and computer-based methods) used in geology and hydrogeology and identify which data and tools are needed for the application of these methods * Understand engineering fundamentals of subsurface mine operation * Perform calculations related to mining processes, rock mechanics and mine ventilation * Identify and select suitable mining methods (e.g. rock breaking and shaft sinking method) and mining equipment in the context of repository safety * Develop problems solving and critical thinking skills through the adoption of logical scientific approach.
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	Will be announced during the first lecture, as well as via the online learning room (RWTHmoodle).
Language	English
Examination Terms	Passing of module components is required to take the exam. The mark of the module is calculated from the examinations in the module which are weighted by their particular Credit Points (CP).
Miscellaneous	-
Module coordinator	-
ECTS Credits	7
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	210,0

Contact hours (h)	75,0
Self-study hours (h)	135,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Final Disposal and Projects (512654501)	1st semester	no semester recommended	3	-
Gelogogical and Engineering Basics of Final Disposal (512654502)	1st semester	no semester recommended	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Final Disposal and Projects	1st semester	no semester recommended	-	2
Gelogogical and Engineering Basics of Final Disposal	1st semester	no semester recommended	-	3

Module titel	Battery Storage Systems (Compulsory elective subject)
Identifier	6015526
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2010
Valid until	-
Module level	Bachelor/Master
Content	# Determination of open circuit voltage via thermodynamic equations # Kinetics of batteries: ohmic resistances, butler-volmer equation, diffusion # Basic concepts of battery storage systems technology # Lithium-ion batteries, lead-acid batteries and supercaps technology in detail: basic electrochemical setup and used materials, safety of different materials, electrical properties, current- and temperature dependencies, typical aging processes, charging and discharging behavior, deduction of appropriate battery management strategies, necessary components of battery management systems # System technical elements of battery packs: Design of chargers and charging method, Cell balancing systems, Thermal management, Modeling approaches, Basic algorithms for battery diagnostics, Protection of battery packs, Total integration of battery cells in battery packs # Approaches to accelerated lifetime tests # Training of presentation techniques
Learning Objectives/ Learning Outcomes	This module gives a fundamental understanding for rechargeable batteries and supercaps. After the end of the module students are able: # to evaluate different battery technologies. # to understand and apply basic principles of thermodynamics and kinetics of batteries. # to understand the fundamental electrochemical processes in batteries. # to understand the basic configuration of batteries and evaluate safety and electrical performance characteristics. # to calculate theoretical and practical energy density of batteries. # to understand essential differences between lithium-ion batteries, leadacid batteries and supercaps. # to apply different approaches to modeling. # to implement methods of battery diagnostics and modeling. # to find an appropriate battery technology for a certain application and develope the battery pack design. # to develop system solutions in group work # give a speech about technical subjects
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Module energy storage technologies beneficial
References	Script
Language	German
Examination Terms	Presentation with team (optional), oral examination (30min) (German/English) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Dirk Uwe Sauer

+ Battery Storage Systems (6015526)

ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Battery Storage Systems (601552601)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Battery Storage Systems	1st semester	no semester recommended	-	3

Module titel	Battery Storage Systems (Compulsory elective subject)
Identifier	6015523
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2010
Valid until	-
Module level	Bachelor/Master
Content	Determination of open circuit voltage via thermodynamic equations # # Kinetics of batteries: ohmic resistances, butler-volmer equation, diffusion # Basic concepts of battery storage systems technology # Lithium-ion batteries, lead-acid batteries and supercaps technology in detail: basic electrochemical setup and used materials, safety of different materials, electrical properties, current- and temperature dependencies, typical aging processes, charging and discharging behavior, deduction of appropriate battery management strategies, necessary components of battery management systems # System technical elements of battery packs: Design of chargers and charging method, Cell balancing systems, Thermal management, Modeling approaches, Basic algorithms for battery diagnostics, Protection of battery packs, Total integration of battery cells in battery packs # Approaches to accelerated lifetime tests # Training of presentation techniques
Learning Objectives/ Learning Outcomes	This module gives a fundamental understanding for rechargeable batteries and supercaps. After the end of the module students are able: # to evaluate different battery technologies. # to understand and apply basic principles of thermodynamics and kinetics of batteries. # to understand the fundamental electrochemical processes in batteries. # to understand the basic configuration of batteries and evaluate safety and electrical performance characteristics. # to calculate theoretical and practical energy density of batteries. # to understand essential differences between lithium-ion batteries, lead-acid batteries and supercaps. # to apply different approaches to modeling. # to implement methods of battery diagnostics and modeling. # to find an appropriate battery technology for a certain application and develope the battery pack design. # to develop system solutions in group work # give a speech about technical subjects
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Module energy storage technologies beneficial
References	Script
Language	English
Examination Terms	Written examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Dirk Uwe Sauer

- Subsidiary Subjects
- Energy Technology
+ Battery Storage Systems (6015523)

ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Battery Storage Systems (601552301)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Battery Storage Systems	1st semester	no semester recommended	-	3

Module titel	Energy Storage Systems (Compulsory elective subject)
Identifier	6017099
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	• Typical application areas for electrical and thermal energy storage (portable devices, consumer products, industrial processes, solar systems, UPS, power grids, vehicles, etc.) • High-and low-temperature thermal storage systems • Mechanical systems for electrical energy storage (flywheel, pumped storage, Compressed air energy storage) • Electric storage (inductors, capacitors, super caps) • Electrochemical energy storage for electrical energy • Primary batteries of various technologies • Rechargeable electrochemical energy storage for electrical energy • • Lead-acid batteries • • Lithium-Ion Batteries • • NiCd / NiMH • • NaS / NaNiCl (high temperature) • • redox flow batteries • • Hydrogen Storage Systems • Feasibility studies for various applications • For all storage technologies, technological development, the electric and thermal properties, safety aspects, recyclability and demands on the Battery technology discussed. Where necessary, questions of material availability discussed. Exercise is done as team work with 4 to 6 students preparing a presentation on a specific topic. This sums up the most important aspects of the lecture. Presentations are presented and discussed during a seminar day with the Professor.
Learning Objectives/ Learning Outcomes	Students are supposed to gain a basic overview and an advanced understanding of various energy storage technologies and their applications.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	Skript
Language	German/English
Examination Terms	Written Examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Dirk Uwe Sauer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90

Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Energy Storage Systems (601709901)	1st semester	no semester recommended	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Energy Storage Systems	1st semester	no semester recommended	-	3

Module titel	Future Energy System - Part 1: Power Generation from Renewable Energies (Compulsory elective subject)
Identifier	6021918
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	Energy demand and supply, global problems of energy supply – potential renewable energy sources – Cost Accounting - Photovoltaic: physical basics Manufacturing processes, systems engineering - Wind, hydro and other renewable sources: solar thermal, biomass, geothermal, etc. - integration of renewable sources in the Electricity Supply - Development Status and Prospects.
Learning Objectives/ Learning Outcomes	Students are supposed to gain an understanding of the technical issues about deployment of renewable energy. Therefore, presentations from various departments of electric power engineering give a broad overview of the demand for energy and potential technologies for their production from renewable sources. In addition to the theoretical foundations of each technology, concrete examples are shown.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Bachelor degree should be completed
References	-
Language	English
Examination Terms	Written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Sauer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90 Minuten
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Future Energy System - Part 1: Power Generation from Renewable Energies (602191801)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Future Energy System - Part 1: Power Generation from Renewable Energies	1st semester	no semester recommended	-	3

Module titel	Future Energy System – Part 2: Sector Coupling (Compulsory elective subject)
Identifier	6022710
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2020
Valid until	-
Module level	Master
Content	Energy demand and supply, global problems of energy supply - Flexibilities and sector coupling in future energy system - Solar thermal power plants - Geothermal energy for heat and power supply - Integrated energy infrastructures - Natural and synthetic gas systems - Hydrogen economy and fuel cells - Digitalisation - Distributed intelligent systems - Life cycle assesment - Mobility - Demand, generation, storage and distribution of heat in the building sector - Power to fuel technologies - Social factors of the future energy system Lernergebnisse: DE Die Studierenden sollen die technischen Aspekte und die systemischen
Learning Objectives/ Learning Outcomes	Students are supposed to gain an understanding of the technical and system issues about deployment of renewable energy. Therefore, presentations from various departments of electric power engineering and additional interfacing topics give a broad and comprehensive overview of the demand for energy and potential technologies for their production from renewable sources. In addition to the theoretical foundations of each technology, concrete examples are shown. Of major concern is the interdisciplinary understanding of the different technologies and their system links.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	No general text book, in some lectures additional literature will be shown, content of examinations is fully covered by the presented materials and exercises
Language	English
Examination Terms	-
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Dirk Uwe Sauer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Future Energy System – Part 2: Sector Coupling (602271001)	2nd semester	no semester recommended	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Future Energy System – Part 2: Sector Coupling	2nd semester	no semester recommended	-	3

Module titel	Fundamentals of Nuclear Power (Compulsory elective subject)
Identifier	4010979
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Bachelor/Master
Content	1. Übersicht über die heutige Kernenergienutzung 2. Radioaktiver Zerfall, Kernspaltung 3. Kettenreaktion, Kritikalität 4. Wärmeproduktion im Reaktor 5. Wärmeabfuhr aus dem Reaktorkern 6. Brennelementaufbau 7. Kernauslegung 8. Reaktorkomponenten 9. Gesamtanlage 10. Störfälle, Unfälle 11. Brennstoffversorgung 12. Entsorgung (Zwischenlagerung, Endlagerung, Transmutation)
Learning Objectives/ Learning Outcomes	• Die Studierenden sollen die grundsätzliche Funktionsweise von derzeit zur Stromerzeugung eingesetzten kerntechnischen Anlagen verstehen. Dies beinhaltet auch das entsprechende physikalische Hintergrundwissen, soweit dies zum Verständnis der Anlagen erforderlich ist.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen: • Höhere Mathematik • Grundlegende Physikkenntnisse insb. der Mechanik, Elektrotechnik und Thermodynamik
References	• Vorlesungsumdruck
Language	German
Examination Terms	Eine schriftliche Klausur Bonuspunkteregelung: Zugeordnete Bonusveranstaltung: Thermohydrauliktutorium (SS + WS (vorgesehen) Im Rahmen des Thermohydrauliktutoriums wird eine Hausaufgabe vergeben, durch die ein Bonus von maximal 10% auf die Prüfung erlangt werden kann. • Es ist auch ohne Bonuspunkt möglich, die Prüfung mit der bestmöglichen Note zu absolvieren. • Erlangte Bonuspunkte haben keinen Einfluss auf das Prüfungsergebnis, wenn dieses ohne die Bonuspunkte "nicht bestanden" (5.0) lautet.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Hans Josef Allelein
ECTS Credits	4
Contact time (WSH)	3

Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Fundamentals of Nuclear Power (401097901)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Fundamentals of Nuclear Power	1st semester	no semester recommended	-	2
Bonusveranstaltung Grundlagen der Kerntechnik	1st semester	no semester recommended	-	0
Exercise Fundamentals of Nuclear Power	1st semester	no semester recommended	-	1

Module titel	Nuclear Regulations, Site Selection and Participation (Compulsory elective subject)
Identifier	5126571
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The module consists of two courses: *Nuclear Regulations* and *Site Selection and Public Participation* The following subjects are taught in **Nuclear Regulations:** * International Regulations and Standards (Joint Convention, EURATOM Basic Standards, IAEA Safety Standards, OECD-NEA Recommendations, ICRP-Recommendations) * National regulations in Germany (Atomic Energy Act, (National Waste Management Program (NaPro), BMI Safety Requirements of 1983, Site Selection Act (StandAG) and associated ordinances (EndlSiAnfV, EndlSiUntV), Radiation Protection Act, Radiation Protection Ordinance, Planning approval legislation AtVfV, Environmental Impact Assessment (UVP), water law approval * Comparison of national regulations in different countries Sweden, Finland, France, Switzerland, Canada… The following subjects are taught in **Site Selection and Public Participation** * Objectives of the Site Selection Act, institutions involved * Phases of the Site selection procedure: Sub-areas, siting regions, surface exploration, underground exploration, final disposal site decision * Definitions Barriers: technical, geotechnical and geological barriers, effective containment zone, storage area etc. * Selection criteria: Geoscientific exclusion criteria, minimum requirements, geoscientific weighing criteria, scientific planning criteria, preliminary safety analyses * Retrievability, recoverability of emplaced waste * Related Ordinances: Final Repository Safety Requirements Ordinance, Repository Safety Investigation Ordinance * Public participation procedure and strategies: Basics of public participation and decision making, sub-areas conferences, regional conferences, council of the regions conference, National Monitoring Board, international participation strategies and experiences: Switzerland, France, Sweden, Finland etc.
Learning Objectives/ Learning Outcomes	The students will * gain a basic-level understanding of international standards and recommendations in nuclear waste management as well as the framework for national nuclear regulations and its' implementation in Germany and in other countries (Sweden, Finland, France, Switzerland, Canada etc). * acquire knowledge about the history of the search for a repository site of high-level radioactive waste in Germany and be deeply familiarized with the site selection act *StandAG* (the law regulating the search

	and selection of a suitable site for the repository) especially the safety technical site selection criteria and will be able to critically and professionally evaluate site selection decisions. * be introduced to the different strategies and participation forms provided by the stakeholders for the general public, to take part in the debate accompanying the site selection procedure. By case-based and reactive learning methods (simulation games, presentations) the students will develop important communication and presentation skills.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None required
References	Will be announced during the first lecture, as well as via the online learning room (RWTHmoodle).
Language	English
Examination Terms	Passing of module components is required to take the exam. The mark of the module is calculated from the examinations in the module which are weighted by their particular Credit Points (CP).
Miscellaneous	-
Module coordinator	-
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nuclear Regulations (512657101)	1st semester	no semester recommended	3	-
Site Selection and Public Participation (512657102)	1st semester	no semester recommended	3	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Nuclear Regulations	1st semester	no semester recommended	-	2

Site Selection and Public Participation	1st semester	no semester recommended	-	2

Module titel	Photovoltaics (Compulsory elective subject)
Identifier	6010480
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	Lecture: # Technical potential of solar energy # The solar spectrum # The photovoltaic effect # Generation and recombination in semiconductors # Semiconductor junctions # The detailed-balance limit # Crystalline silicon solar cells # Silicon-based thin-film solar cells # Polycrystalline thin-film solar cells # Electrochemical and plastic solar cells # Light concentration, incoupling and trapping Exercise: # Solar irradiation on Earth # Break-even point and carbon dioxide balance # Absorption of light in solar cells # Recombination mechanisms # Diffusion length # PN-Junction # Resistances in solar cells # Efficiency of solar cells # Light trapping # Tandem solar cells
Learning Objectives/ Learning Outcomes	Lecture: Students are supposed to gain a basic understanding of the potential of photovoltaics in general and of the physical effects occurring in a solar cell. Furthermore, the manufacturing processes of different kinds of solar cells will be explained. Also, basic concepts for the improvement of solar cells by light trapping will be introduced. Exercise: The students are supposed to apply the equations of physical effects as taught in the lecture. This shall help the students to understand the relations of different parameters and effects and their respective effects on the efficiency of a solar cell.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Physics of Semiconductor Devices, S. Sze, K. K. Ng, John Wiley & Sons # Third Generation Photovoltaics: Advanced Solar Energy Conversion, M. Green, Springer # Physics of Solar Cells, J. Nelson, World Scientific Pub # Photovoltaik: Solarstrahlung und Halbleitereigenschaften, Solarzellenkonzepte und Aufgaben, H. G. Wagemann, H. Eschrich, Vieweg + Teubner Verlag # Photovoltaic Solar Energy Generation, A. Goetzberger, V. U. Hoffmann, Springer # Physics of Solar Cells: From Basic Principles to Advanced Concepts, P. Würfel, Wiley-VCH Verlag
Language	German

Examination Terms	oral examination (30min) or written examiation (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Uwe Rau
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	30 oder 90
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Photovoltaics (601048001)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Photovoltaics	1st semester	no semester recommended	-	3

Module titel	Photovoltaic 2 - Characterization of Solar Cells (Compulsory elective subject)
Identifier	6010478
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	Lecture: # Repetition of the relevant basics from Photovoltaics 1 # Characterisation methods: # External quantum efficiency # Photoconductance # Thermography # Electroluminescence # UV/VIS Spectroscopy # Ellipsometry # Angular Resolved Scattering Exercise: # Repetition of basics from Photovoltaics 1 # Data-analysis for characterisation methods # Hands-on sessions on state-of-the-art numerical simulations # Optical (FDTD, Fresnel) # Electrical (1D Drift-Diffusion via FEM)
Learning Objectives/ Learning Outcomes	Lecture: Students are supposed to gain a basic understanding of characterisation methods for solar cells, as well as the relevant physical effects and consequences for the photovoltaic device. Exercise: Students are supposed to reiterate the relevant information from Photovoltaics 1 and gain insight into state-of-the-art numerical modeling used in data analysis.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification Recommended: Photovoltaics 1
References	# Physics of Semiconductor Devices S. Sze, K. K. Ng John Wiley & Sons # Third Generation Photovoltaics: Advanced Solar Energy Conversion M. Green Springer # Physics of Solar Cells J. Nelson World Scientific Pub # Photovoltaik: Solarstrahlung und Halbleitereigenschaften, Solarzellenkonzepte und Aufgaben H. G. Wagemann, H. Eschrich Vieweg + Teubner Verlag # Photovoltaic Solar Energy Generation A. Goetzberger, V. U. Hoffmann Springer # Physics of Solar Cells: From Basic Principles to Advanced Concepts P. Würfel Wiley-VCH Verlag
Language	German
Examination Terms	oral examination (30min) or written examiation (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Uwe Rau
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	30 oder 90
Total hours (h)	120,0
Contact hours (h)	45,0

Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Oral Exam Photovoltaic 2 - Characterization of Solar Cells (601047801)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Photovoltaic 2 - Characterization of Solar Cells	1st semester	no semester recommended	-	3

Module titel	Radiation Protection, Nuclear Technology and Applications (Compulsory elective subject)
Identifier	5126548
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The module consists of two courses: *Radiation Protection and Nuclear Waste Management* and *Nuclear Technology and Applications*. The following subjects are taught in **Radiation Protection and Nuclear Waste Management** * Basic atomic physics and radiation * Radiation dosimetry, detection and measurement * Legal and regulatory basis of Radiation Protection * Organization of radiation protection * Operational radiation protection, hazard and risk assessment * Sources and classification of nuclear waste: Types, Inventory, waste streams * Nuclear waste management and policies and strategies * Pre-treatment and conditioning of radioactive * Radiological characterization of waste packages and casks The following subjects are taught in **Nuclear Technology and Applications:** * Basics of nuclear engineering and energy generation * Reactors and reactor technology in Germany * Nuclear power plant operation * Fundamentals of Fusion technology for energy production * Radioactivity and radiation emission * Decommissioning of nuclear * New and prospective reactor concepts * Reprocessing of spent nuclear fuel * Partitioning and Transmutation * Interim storage of spent fuel elements
Learning Objectives/ Learning Outcomes	* Students are introduced to basic knowledge on biological effects of radiation, factors that affect the dose-effect relationship and a deeper knowledge on radiation protection for ionizing and non-ionizing radiation, both in legislation and practical radiation protection technology. In this module,

	the theoretical, conceptual and analytical skills in technical, environmental and policy issues of waste management associated with nuclear decommissioning, conditioning and packaging for interim storage and final disposal. * This module also covers the basics of nuclear science in several areas of application: Energy production, nuclear medicine, research and industry. The students will acquire fundamental knowledge in nuclear engineering with focus on nuclear energy generation as well as about the principles of nuclear fission, activation and the nuclear fuel cycle. They will be able to understand the process of decommissioning, assessment of radioactivity inventory of a nuclear facility needed for different dismantling phases. The students will be familiar with the laws of the activation and decay including the radiation source of the activated material of a nuclear reactor. They will acquire knowledge on the interaction of the radiation with matter and calculation of the radiation dose rate and shielding structures. The course also brings out overview on the utilization of radionuclides for medical physics application for diagnostic and irradiation purposes, as well as for scientific and industrial processes.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None required
References	Lecture hand-outs and online in CMS (RWTHmoodle) *John R. Lamarsh &; Anthony J. Baratta, "Introduction to Nuclear Engineering" PEARSON comp.; 4th edition, 2017, ISBN-10:0134570057 ;* *Haydee Domenech, Radiation Safety (ISBN 978-3-319-42669-3)* *J. Lilley, Nuclear Physics - Principles and Application, J. Wiley, Chichester, 2002, ISBN 0-471-97936-8* *C.R. Bayliss, K.F. Langley: Nuclear Decommissioning, Waste Management, and Environ- mental Site Remediation, Butterworth-Heinemann, 2003* *Fundamentals of Nuclear Science and Engineering, 3rd Edition, from J. Kenneth Shultis and Richard E. Faw (CRC Press, 2017)*
Language	English
Examination Terms	Passing of module components is required to take the exam. The mark of the module is calculated from the examinations in the module which are weighted by their particular Credit Points (CP).
Miscellaneous	-
Module coordinator	-
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Radiation Protection and Nuclear Waste Management (512654801)	2nd semester	no semester recommended	3	-
Nuclear Technology and Applications (512654802)	2nd semester	no semester recommended	3	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Radiation Protection and Nuclear Waste Management	2nd semester	no semester recommended	-	2
Nuclear Technology and Applications	2nd semester	no semester recommended	-	2

Module titel	Reactor Safety (Compulsory elective subject)
Identifier	4014351
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • Aufgabenfelder der Reaktorsicherheit 2 • Radioaktivität • Radioaktive Inventare 3 • Sicherheitskonzept, Begriffe 4 • Nachwärmeproduktion, Nachwärmeabfuhr 5 • Kernschmelzunfälle und Folgen 6 • Reaktivitätsfragen, Temperaturkoeffizienten • Reaktordynamische Gleichung 7 • Reaktivitätsstörfälle 8 • Kühlmittelverluststörfälle 9 • Spezielle Störfälle (Rohrbruch im Dampferzeuger) • Sicherheit des Reaktordruckbehälters • Schäden an der Turbinenanlage • Ausfall der Stromversorgung 10 • Äußere Einwirkungen auf kerntechnische Anlagen 11 • Ausbreitung radioaktiver Stoffe 12 • Risikokonzept, Risikoanalysen • Ereignisabläufe, Fehlerbäume • Zuverlässigkeitsanalysen • Ergebnisse von Risikoanalysen 13 • Störereignisse TMI, Tschernobyl • Anforderungen an zukünftige Reaktoren • Prinzipien der inhärenten Sicherheit • Neue Leichtwasserreaktoren mit erhöhter Sicherheit

	14 • Sicherheitskonzept von Kernreaktoren ohne Kernschmelzen (HTR) • Sicherheitsfragen im Brennstoffkreislauf
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen die Sicherheitstechnik von Kernkraftwerken • Die Studierenden können die verschiedenen Reaktortypen unter Sicherheitsgesichtspunkten bewerten • Die Studierenden sind in der Lage verschiedene Störfallszenarien zu bewerten und zu klassifizieren • Die Studierenden können wichtige Aspekte bei Störfallszenarien berechnen • Die Studierenden sind fähig Reaktor- und Sicherheitskonzepte kritisch aus verschiedenen Blickwinkeln zu Bewerten (Wärmetechnik, Strahlenschutz, Reaktortechnik, Risikoanalyse, gesellschaftliche Gesichtspunkte) Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden können Problemstellungen analysieren und bewerten • Die Übung erfolgt in Kleingruppen so dass kollektive Lernprozesse gefördert werden (Teamarbeit)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	-
References	Vorlesungsskript
Language	German
Examination Terms	Eine mündliche Prüfung Bonuspunkterelegung: Zugeordnete Bonusveranstaltung: Accident Management Seminar (SS) Im Rahmen des Accident Management Seminars wird eine Hausaufgabe vergeben, durch die ein Bonus von maximal 10% auf die Prüfung erlangt werden kann. • Erlangte Bonuspunkte verfallen in dem Semester, in dem das Accident Management Seminar erneut angeboten wird. • Es ist auch ohne Bonuspunkt möglich, die Prüfung mit der bestmöglichen Note zu absolvieren. • Erlangte Bonuspunkte haben keinen Einfluss auf das Prüfungsergebnis, wenn dieses ohne die Bonuspunkte "nicht bestanden" (5.0) lautet.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Hans Josef Allelein
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Reactor Safety (401435101)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Bonusveranstaltung Reaktorsicherheit	1st semester	no semester recommended	-	0
Vorlesung Reaktorsicherheit	1st semester	no semester recommended	-	2
Übung Reaktorsicherheit	1st semester	no semester recommended	-	1

Module titel	Safety Analyses, Repository Design and Processes (Compulsory elective subject)
Identifier	5126547
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	The module consists of three courses: *Safety Concepts and Long Term Safety Analysis, Repository Design and Operational Safety*, and *Simulation of Repository Related Processes*. The following subjects are taught in **Safety Concepts and Long Term Safety Analysis:** * Safety and verification concepts * Steps of a long-term analysis ; The following subjects are taught in **Repository Design and Operational Safety:** * Repository concepts * Logistics processes above and below ground, Industry 4.0, redundant systems * Barrier system and concepts * Operational safety ; The following subjects are taught in **Simulation of Repository Related Processes:** * Processes inside the repository * Processes and events external to the repository in the post-operational phase * Geohydraulic processes * Mass transport in fluids * Geomechanical Processes * State of the art of process simulation in computational models
Learning Objectives/ Learning Outcomes	The students * make themselves familiar with existing generic and site-specific national and international safety and demonstration concepts as well as their differences concerning systematics and structure for different host rocks * will gain comprehension of fundamental safety terminology and profound knowledge of the requirements for the operational and long-term safety case as stated by laws and regulations. Another objective is raising awareness about the impact that preliminary safety assessments in the site selection process exert on the optimization of the repository design and safety concept

	* are professionally enabled to design a safe repository operation and to plan measures for the prevention of accidents and their mitigation * get to know the codes used for numerical simulations in the long-term safety assessment such as TOUGH2 and MARNIE, PFLOTRAN * know the input parameters, data sources, and parameterization used in numerical simulations and have a qualitative understanding of their impact * understand the relationship between boundary conditions over time and model dimensions * can assess the impact of heterogeneities at different length scales and understand the role of “upscaling” * will be provided with a fundamental understanding of thermal, mechanical, hydraulic, and microbiological processes affecting the repository site during the operational and post-closure phase as well as their numerical simulation. Knowledge of the geochemistry and migration of radionuclides in time and space and long-term repository safety is conveyed * will get comprehensive knowledge about the scenario development methodology based on FEP catalogs to assess the future evolution of the repository system. These developments are covered in detail and comprise probable, less probable, hypothetical, and Human Intrusion (HI) scenarios. In this context, insight into the impact and assessment of uncertainties in numerical modeling is given * will be capable to interpret simulation results and draw a connection to natural analog studies that may increase the confidence in the results over large-scale timespans
(Study-Specific) Prerequisites	-
(recommended) Requirements	None required
References	See lecture hand-outs and online in RWTHmoodle *Fischer-Appelt, K., Baltes, B., Buhrmann, D., Larue, J., Mönig, J.: Synthesebericht für die VSG, Bericht zum Arbeitspaket 13 ; vorläufige Sicherheitsanalyse für den Standort Gorleben. GRS, Bd. 290, GRS-290, 424 S., ISBN 978-3-939355-66-3, GRS: Köln, 2* *Hoyer, E.-M., Luijendijk, E., Müller, P., Kreye, P., Panitz, F., Gawletta, D., Rühaak, W.: Preliminary safety analyses in the high-level radioactive waste site selection procedure in Germany. Advances in Geosciences, Bd. 56, S. 67–75, DOI 10.5194/adgeo-56-67-2021, 2021.* *Lersow, M.: Disposal of All Forms of Radioactive Waste and Residues, Long-Term Stable and Safe Storage in Geotechnical Environmental Structures. 449 S., ISBN 978-3-030-32910-5, Springer International Publishing AG: Cham, 2020.* *;Lersow, M.: Endlagerung aller Arten von radioaktiven Abfällen und Rückständen, Langzeitstabile, langzeitsichere Verwahrung in Geotechnischen Umweltbauwerken – Sachstand, Diskussion und Ausblick, Sachstand, Diskussion und Ausblick. 1. Aufl., 448 S., ISBN 9783662578223, Springer Berlin Heidelberg: Berlin, Heidelberg, 2018.*
Language	English
Examination Terms	Passing of module components is required to take the exam. The mark of the module is calculated from the examinations in the module which are weighted by their particular Credit Points (CP).
Miscellaneous	-
Module coordinator	-
ECTS Credits	10
Contact time (WSH)	7
Examination duration (min)	-

- Subsidiary Subjects
- Energy Technology
+ Safety Analyses, Repository Design and Processes (5126547)

Total hours (h)	300,0
Contact hours (h)	105,0
Self-study hours (h)	195,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Safety Concepts and Long Term Safety Analysis (512654701)	2nd semester	no semester recommended	4	-
Repository Design and Operational Safety (512654702)	2nd semester	no semester recommended	3	-
Simulation of Repository Related Processes (512654703)	2nd semester	no semester recommended	3	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Safety Concepts and Long Term Safety Analysis	2nd semester	no semester recommended	-	3
Repository Design and Operational Safety	2nd semester	no semester recommended	-	2
Simulation of Repository Related Processes	2nd semester	no semester recommended	-	2

Module titel	Silicon Photovoltaics Technology (Compulsory elective subject)
Identifier	6022696
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2022
Valid until	-
Module level	Master
Content	Introduction: 1. Structure of the lecture 2. Overview types of PV technologies 3. Current status of PV market and role of PV 4. Silicon as material Silicon PV: 1. Basic working process of a silicon solar cell 2. Production chain of silicon PV 3. Evolution of silicon PV 4. Current status of silicon PV Ingot and wafering: 1. From sand to wafer 2. Kerfless wafering Wetchemistry: 1. Cleaning/Oxidation 2. Texturing PERC: 1. PERC solar cell 2. MWT solar cell 3. IBC solar cell TOPCon: 1. Motivation for passivating contacts 2. Working principle 3. Implement of passivating contacts in high-efficiency solar cells HJT solar cell: 1. Motivation for HJT solar cells 2. Working principle 3. Process technologies Tandem PV: 1. Concept of multi-junctions/tandems4-terminal perovskite/silicon tandems 2. 2-terminal perovskite/silicon tandems 3. Current challenges and outlook 4. Other silicon-based tandems 5. Silicon based Tandem Silicon Module interconnection: 1. Standard module assembly 2. Advanced interconnection Silicon Module encapsulation: 1. Standard module encapsulation 2. Solar module glass 3. Solar module encapsulant

	4. Solar module backsheet Silicon Module reliability – LID: 1. Failure types of PV module 2. Light-induced degradation (LID) 3. Other field failures Silicon Module reliability – PID: 1. Failure types of PV module 2. Potential-induced degradation (PID) Balance of System Components: 1. Mounting 2. MPPT 3. DC-DC converter Agri-PV and Floating PV: 1. Applications for the Integration of Photovoltaics 2. Agricultural PV 3. Floating PV BIPV &; ;VIPV: 1. Building integrated PV 2. Vehicle integrated PV
Learning Objectives/ Learning Outcomes	After successful completion of the module, students will be able to distinguish and evaluate the different cell and module technologies, know their production, value chain and field of application, perform evaluation of photovoltaic systems from the ground up and recognize current challenges/opportunities of Si-photovoltaics.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge of semiconductor devices
References	Solar Energy: The Physics and Engineering of Photovoltaic Conversion, Technologies and Systems, UIT, Arno Smets, ISBN 978-1906860325, English Photovoltaik: Lehrbuch zu Grundlagen, Technologie und Praxis, HANSER, Konrad Mertens, ISBN: 978-3446464049; German
Language	German/English
Examination Terms	written or oral examination
Miscellaneous	-
Module coordinator	Prof. Uwe Rau
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90/30
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Silicon Photovoltaics Technology (602269601)	1st semester	no semester recommended	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Silicon Photovoltaics Technology	1st semester	no semester recommended	-	3

Module titel	Solar Technology (Compulsory elective subject)
Identifier	4014820
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Bachelor/Master
Content	Die Vorlesung gibt einen Einstieg in das Thema Solartechnik. Dabei vermittelt sie zunächst die notwendigen physikalischen Grundlagen und Begriffe bezüglich Sonnenstand, Helligkeitsverteilung, Spektrum, Exergie, Strahlungstransport in der Atmosphäre etc. Sie geht dann auf die unterschiedlichen Möglichkeiten von photothermischer, photoelektrischer und photochemischer Umwandlung der solaren Strahlung ein. Der Schwerpunkt der Vorlesung liegt auf der photothermischen Umwandlung. Dabei werden die Umwandlungs- und Verlustmechanismen von Strahlung bis zum Wärmeträger erläutert. Darüber hinaus werden die Grundlagen zur Konzentration von Solarstrahlung vermittelt und es wird auf die Bauweise unterschiedlicher Konzentratoren und Kollektoren eingegangen. Ausführlich werden die unterschiedlichen Nutzungsmöglichkeiten der Wärmeenergie auf unterschiedlichen Temperaturniveaus präsentiert. Diese reichen von der Beheizung von Schwimmbädern bis zur solarthermischen Stromerzeugung mit unterschiedlichen Technologien. Das letztere Thema wird dabei vertieft dargestellt. Die optimale Einkopplung in unterschiedliche Kreisprozesse, die Bau- und Betriebsweisen von Solarkraftwerken und die Bauweisen von thermischen Energiespeichern werden erläutert. Auf die Strategien zur Kostenoptimierung bei der Auslegung solcher Systeme wird eingegangen. Im Rahmen der Übung sollen die Studenten an Beispielen lernen, wie der Energieertrag insbesondere bei thermischen Solarsystemen bestimmt und optimiert werden kann. Insbesondere wird auf die Optimierung von Kraftwerksschaltungen eingegangen, in die die Solarenergie eingekoppelt wird. Im Rahmen der Übung erfolgt auch eine optionale Exkursion zum Standort des DLR-Instituts für Solarforschung in Köln-Porz.
Learning Objectives/ Learning Outcomes	With respect to the subject: • The students know the fundamental theories of heat transfer, fluid dynamis, thermodynamics , optics and semi conductor theory that are reelevant for the deisgn of solar systems. • They are able to explain the functionaliyt of these systems and can design them for different sites and operation boundary conditions. • They are able to develop mathematical modells to analyse and asses new concepts. • They are able to optimize solar systems and asses them according to their application potential. Not with respect to the subject (e.g. Team work, Presentation, Project Management, etc.): • They can use numerical tools on the PC efficiently. • They are able to document and ist solution in a readble way.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Reccommended Requirements (e.g.. other Modules, foreign languages, …): • Thermodynamics I/II • Heat and Masstransfer I • Energy Conversion
References	• Folien der Vorlesung (ca. 500) • J.A. Duffie, W.A. Beckmann Solar Engineering of Thermal Processes John Willey &; Sons, Inc, New York; ISBN 0471510564

	• C.J. Winter R.L. Sizmann, L.L. Vant-Hull Solar Power Plants, gebundene Ausgabe,; Springer Verlag; Berlin; 3-540-18897-5 • M. Kleemann, M. Meliß Regenerative Energiequellen, 2.Aufl, Springer, Berlin , ISBN 3-540-55085-2
Language	German
Examination Terms	Condition. Presence during 75 % of course hours, Passed if 75 %of questions in oral exam are correct
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Robert Pitz-Paal
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	120
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Solar Technology (401482001)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Solartechnik	1st semester	no semester recommended	-	2
Vorlesung Solartechnik	1st semester	no semester recommended	-	2

Module titel	Radiation Protection (Compulsory elective subject)
Identifier	4012541
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • Übersicht über den Strahlenschutz 2 • Strahlungsquellen • Radioaktivität, Zerfallsgesetz, Aktivität • Zerfallsarten, Röntgenstrahlung 3 • Wechselwirkung ionisierender Strahlung mit Materie • Strahlungsfeld • lineares Energieübertragungs-, Ionisierungsvermögen • Berechnung der Energieabsorption • Teilchenfluss, Reaktionsrate 4 • Dosisgrößen und –einheiten (Energiedosis, Kerma, Ionendosis, Äquivalentdosis) 5 • Biologische Wirkung ionisierender Strahlung • Dosis-Wirkungsbeziehung • stochastische und nicht stochastische Strahlenschäden 6 • Strahlungsmesstechnik • Nachweismethoden • Dosismessung, Ortsdosisleistung, Personendosis 7 • Berechnung der Strahlenexposition (äußere, innere, Inhalation, Ingestion) • Ableitung mit Lift und Wasser 8 • Abschirmung 9 • Schutzmaßnahmen • Dekontamination • Abfallbeseitigung • Emission mit Luft, Wasser 10 • Strahlenschutzregelungen (Atomgesetz, Strahlenschutzverordung, Röntgenverordnung) • Transportvorschriften 11 • Natürliche und zivilisatorische Strahlenexposition 12

	• Strahlenschutzprobleme nach Kernwaffeneinsatz 13 • Nichtionisierende Strahlung
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen die Schwierigkeiten beim Umgang mit radioaktiven Stoffen • Die Studierenden können die verschiedenen Strahlungsarten und ihre Wirkung bewerten • Die Studierenden können die verschiedenen Strahlenexposition von verschiedenen Strahlungsarten berechnen • Die Studierenden sind fähig die Wechselwirkung von Strahlung zu beschreiben und zu berechnen (biologische Aspekte, materialtechnische Aspekte, Risiko Aspekte, gesellschaftliche Gesichtspunkte) Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden können Problemstellungen analysieren und bewerten • Die Übung erfolgt in Kleingruppen so dass kollektive Lernprozesse gefördert werden (Teamarbeit)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	-
References	Vorlesungsskript
Language	German
Examination Terms	Eine mündliche Prüfung
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Hans Josef Allelein Dr.-Ing. Inga Maren Tragsdorf
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Radiation Protection (401254101)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Strahlenschutz	1st semester	no semester recommended	-	2
Übung Strahlenschutz	1st semester	no semester recommended	-	1

Module titel	Technology for the Nuclear Fusion (Compulsory elective subject)
Identifier	4013391
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	• Kernfusion als Energiequelle: - Prinzip der Kernfusion - Optionen für die technische Realisierung - Notwendige Bedingungen für die Kernfusion - Magnetischer Plasmaeinschluss • Motivation für die Nutzung der Kernfusion - Energiebedarf, Energieressourcen, Risiken - Vorteile der Kernfusion • Anlagen für magnetischen Plasmaeinschluss - Tokamak - Stellerator • Technologie für die Kernfusion - Belastungen: thermisch, elektromagnetisch, mechanisch, Neutronenfluss - Vakuum - Materialien - Supraleiter - Blanket - Divertor - Heizsysteme: NBI, ICRH, ECRH - Messung der Plasmaeigenschaften - Steuerung und Regelung - Ferngesteuerte Manipulation • Physik - Plasmainstabilitäten - Plasma-Wand-Wechselwirkung • Forschungsaktivitäten zur Kernfusion - Erreichte Ziele - Verbleibende Herausforderungen - Strategien für die Weiterentwicklung
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen die physikalischen Grundlagen der Kernfusion • Die Studierenden kennen und verstehen die technischen Voraussetzungen für eine kontrollierte Kernfusion • Die Studierenden sind mit den derzeitigen Forschungsaktivitäten zur Kernfusion vertraut Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Übung erfolgt in Kleingruppen so dass kollektive Lernprozesse gefördert werden (Teamarbeit)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.

(recommended) Requirements	-
References	Vorlesungsskript, Websites der Forschungseinrichtungen für Fusion
Language	German
Examination Terms	Eine schriftliche Klausur
Miscellaneous	-
Module coordinator	Dr.-Ing. Olaf ;Neubauer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Technology for the Nuclear Fusion (401339101)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Technologie für die Kernfusion	1st semester	no semester recommended	-	1
Vorlesung Technologie für die Kernfusion	1st semester	no semester recommended	-	2

Module titel	Climatology (Compulsory elective subject)
Identifier	5322584
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	This course deals with the following topics: Atmospheric composition, Energy budget and solar radiation, Air temperature, Moisture budget, Cloud formation and precipitation processes, Planetary-scale motions and the general circulation, Regional climatology, Classification patterns, Atmospheric trace gas composition, Measurements and data, Climate models and forecast, Extreme events, Teleconnections, Climate adaption strategies.
Learning Objectives/ Learning Outcomes	The module aims to introduce climatology with basics on solar radiation, energy and moisture budgets, atmospheric circulation patterns and spatiotemporal variabilities. Based on these foundations climate change is approached. Students will learn to understand the effects of determining climate factors on climate regions. In this context students will understand climate classification schemes as well as atmospheric trace gas compositions and interhemispheric transport. Students will be able to relate measurement of climate parameters and trace gases, and discuss examples of publicly available data. Students will be able to examine extreme events strengthened by climate change such as hurricanes and other tropical cyclones, tornados, changes in surface and sea surface temperatures, pressure patterns, ;droughts, flooding, and others, and analyze specific topics . ;Freely available data is analyzed with the help of tools e.g. in R, GIS, Python. Students learn to evaluate extreme events and their links in the context of climate change. The student will be able to analyze their effects on biotopes, megacities, and the anthroposphere, and identify strategies of adaption to cope with effects of climate on a global, regional, and local scale. **As successful students will apply the comprehensive knowledge on a specific topic within the final term paper**
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	• Barry, R. G., Chorley, R. J. (2009) Atmosphere, Weather and Climate. 9th ed., Routledge • Holton, J.R., Gregory, J.H. (2012) Introduction to Dynamic Meteorology. 5th ed. Academic Press • IPCC, 2013: Climate Change 2013: The Physical Science Basis. Contribution of WG I to the 5th Asssessment Report of the International Panel on Climate Change [T.F. Stocker, D. Quin, G.-K. • Plattner, M.Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)] Cambridge University Press • Schönwiese, C.-D. (2013) Klimatologie. 4th ed. UTB • Seinfeld, J.H., Pandis, S.N. (2006) Atmospheric Chemistry and Physics. 2nd ed. Wiley-Interscience • Wallace, J. W., Hobbs, P.V. (2006) Atmospheric Science. 2nd ed. Academic Press

Language	English
Examination Terms	The grade of the module results 100% from the final written term paper.
Miscellaneous	-
Module coordinator	Dr. rer. nat. Katja Petzoldt
ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Climatology (532258401)	1st semester	2nd semester	3	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Climatology	1st semester	2nd semester	-	-

Introduction to Physics of the Earth (5312570)

Module titel	Introduction to Physics of the Earth (Compulsory elective subject)
Identifier	5312570
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Dieser Kurs ist eine einsemestrige Einführung in die Physik des Erdkörpers als Ganzes. Es werden insbesondere die folgenden Themen behandelt: radiometrische Altersbestimmung; Seismologie, Erdbeben und Eigenschwingungen des Erdkörpers; Magnetfeld und Paläomagnetik; Figur und Schwerefeld sowie thermisches Regime der Erde.
Learning Objectives/ Learning Outcomes	Einführung in die Physik des Erdkörpers und physikalischer Prozesse in der Erde; Kompetenz: Lösen geophysikalischer Fragestellungen
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	-
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Christoph Clauser
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Introduction to Physics of the Earth (531257002)	1st semester	no semester recommended	0	4
Exam Introduction to Physics of the Earth (531257001)	1st semester	no semester recommended	4	0

Module titel	Geothermics (Compulsory elective subject)
Identifier	5311457
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2012
Valid until	-
Module level	Master
Content	The module offers a balanced and comprehensive treatment of geothermal methods. It comprises both (i) the basics of terrestrial heat transfer by heat conduction and advection and (ii) techniques for prospecting for and mining of geothermal heat. Subjects covered include: field and lab techniques for geothermal prospecting; thermophysical rock properties; thermal signatures of various transient and steady-state heat transfer processes; quantifying flow from its thermal signature; types of geothermal resources; assessment of geothermal potential and evaluation of corresponding heat mining techniques; design calculations for heat mining installations.
Learning Objectives/ Learning Outcomes	Successful students understand terrestrial heat transport and appreciate its thermal signatures. They can use this knowledge in tasks such as the detection of minute subsurface flow and the evaluation of the geothermal potential of a given region. They are acquainted with the different types of geothermal reservoirs, the corresponding heat mining strategies, and the different techniques available for designing suitable heat mining installations.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Mathematics and Physics
References	Lecture notes Anderson, G.M. (2005). Thermodynamics of Natural Systems. University Press, Cambridge. Beardsmore, G.R., Cull, J.P. (2001). Crustal heat flow - A guide to measurement and modelling. Cambridge Univ. Press. Clauser, C. (Ed.) (2003). Numerical simulation of reactive flow in hot aquifers. SHEMAT and processing SHEMAT. Springer, Berlin, 332 p.. Clauser, C.(Ed.) (1999). Thermal Signatures of Heat Transfer Processes in the Earth's Crust. In: Lecture notes in earth sciences 85, Springer, Berlin, 111 Dickson, M.H. (Ed.) (2003). Geothermal energy - Utilization and technology. In: Renewable energies series. UNESCO Publ , Paris.
Language	German
Examination Terms	The module grade is calculated from partial performances by weighting individual scores according to ECTS credits. Additional assignments provided and graded during the semester contribute up to 10% to the final course mark. At the beginning of a semester, but not later than the first date of the course, the exact criteria for the achievement of bonus credits is announced by the lecturer of the course via RWTH’s electronic information system. Written exam (90-120 min)
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Christoph Clauser
ECTS Credits	5
Contact time (WSH)	4

Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Written Exam Geothermics (531145701)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Geothermics	1st semester	no semester recommended	-	4

Module titel	Fundamentals of Applied Geophysics I - Seismics and Gravity (Compulsory elective subject)
Identifier	5311197
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2007
Valid until	Summer semester 2023
Module level	Bachelor/Master
Content	Dieser Kurs behandelt die geophysikalischen Methoden zur Erkundung des Untergrundes. Die Angewandte Geophysik hat als Ziel die Erkundung von Strukturen im Untergrund im Hinblick auf: (1) Lagerstätten (Kohlenwasserstoffe, Erze, Steine und Erden, Grundwasser, Erdwärme); (2) kontaminierten Altlasten; (3) Hohlräumen (z. B. aus historischem Bergbau); (4) Materialien im Allgemeinen, sowie speziell von Fundamenten, Abdichtungen, Dämmen etc. (z. B. auf Dichtigkeit). Gegenstand dieses Kurses sind sowohl die Erkundung von Strukturen in der Erdkruste als auch die physikalischen Eigenschaften verschiedener Bestandteile der Erdkruste. Es werden daher die zu diesem Zweck nützlichen geophysikalischen Methoden vorgestellt, insbesondere aus den Teilgebieten Seismik und Gravimetrie. Die Methoden Magnetik und Elektromagnetik werden im Modul „Grundlagen der Angewandten Geophysik II“ behandelt. Im Übungsteil werden Aufgaben gestellt, die selbständig (zu Hause) gelöst und in der darauf folgenden Übung durchgesprochen werden.
Learning Objectives/ Learning Outcomes	Vermittlung der geophysikalischen Verfahren Seismik und Gravimetrie zur Erkundung des Untergrundes; Kompetenz: selbständiges Lösen geophysikalischer Fragestellungen
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Modul „Mathematische Grundlagen“, Modul „Physikalische Grundlagen“, Modul „Einführung in die Geophysik und Geoingenieurwissenschaften“
References	• Berckhemer, H., 1997. Grundlagen der Geophysik, 2. Aufl., Inst. F. Geophysik und Meteorologie, Univ. Frankfurt, Frankfurt am Main. • Burger, H. R., 1992. Exploration Geophysics of the Shallow Subsurface, Prentice-Hall, Englewood Cliffs. • Fowler, C. M. R., 1990. The Solid Earth, Cambridge University Press, Cambridge . • Kertz, W., 1969. Einführung in die Geophysik I, Bibliographisches Institut, Darmstadt. • Lowrie, W., 1997. Fundamentals of Geophysics, Cambridge University Press, Cambridge. • Parasnis, D. S., 1997. Principles of Applied Geophysics, Chapman & Hall, London. • Sleep, N. H., & Fujita, K., 1997. Principles of Geophysics, Blackwell-Wiley, Hoboken NJ. • Telford, W. M., Geldart, L. P., & Sherriff, R. E., 1990. Applied Geophysics, Cambridge University Press, Cambridge.
Language	German
Examination Terms	Die Modulnote ergibt sich aus allen Teilprüfungen des Moduls, die mit ihren jeweiligen Credit Points (CP) gewichtet werden
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher:

	Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Christoph Clauser
ECTS Credits	6
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	90,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Fundamentals of Applied Geophysics I - Seismics and Gravity (531119701)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Grundlagen der angewandten Geophysik I - Seismik und Gravimetrie (GHI)	1st semester	no semester recommended	-	4
Übung Grundlagen der angewandten Geophysik I - Seismik und Gravimetrie (GHI)	1st semester	no semester recommended	-	2

Module titel	Fundamentals of Applied Geophysics II - Magnetics, Geoelectrics, and Electromagnetics (Compulsory elective subject)
Identifier	5311198
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2008
Valid until	Summer semester 2023
Module level	Bachelor/Master
Content	Dieser Kurs behandelt die geophysikalischen Methoden zur Erkundung des Untergrundes. Die Angewandte Geophysik hat als Ziel die Erkundung von Strukturen im Untergrund im Hinblick auf: (1) Lagerstätten (Kohlenwasserstoffe, Erze, Steine und Erden, Grundwasser, Erdwärme); (2) kontaminierten Altlasten; (3) Hohlräumen (z. B. aus historischem Bergbau); (4) Materialien im Allgemeinen, sowie speziell von Fundamenten, Abdichtungen, Dämmen etc. (z. B. auf Dichtigkeit). Gegenstand dieses Kurses sind sowohl die Erkundung von Strukturen in der Erdkruste als auch die physikalischen Eigenschaften verschiedener Bestandteile der Erdkruste. Es werden daher die zu diesem Zweck nützlichen geophysikalischen Methoden vorgestellt, insbesondere aus mit magnetischen, geoelektrischen und elektromagnetischen Verfahren. Die Methoden Seismik und Gravimetrie werden im Modul 1-3 (Grundlagen der Angewandten Geophysik I) behandelt. Im Übungsteil werden Aufgaben gestellt, die selbständig (zu Hause) gelöst und in der darauf folgenden Übung durchgesprochen werden.
Learning Objectives/ Learning Outcomes	Vermittlung der geophysikalischen Verfahren Magnetik, Geoelektrik und Elektromagnetik zur Erkundung des Untergrundes; Kompetenz: selbständiges Lösen geophysikalischer Fragestellungen
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Modul „Mathematische Grundlagen“, Modul „Physikalische Grundlagen“, Modul „Einführung in die Geophysik und Geoingenieurwissenschaften“, Modul „Angewandte Geophysik I – Seismik und Gravimetrie“
References	• Berckhemer, H., 1997. Grundlagen der Geophysik, 2. Aufl., Inst. F. Geophysik und Meteorologie, Univ. Frankfurt, Frankfurt am Main. • Burger, H. R., 1992. Exploration Geophysics of the Shallow Subsurface, Prentice-Hall, Englewood Cliffs. • Fowler, C. M. R., 1990. The Solid Earth, Cambridge University Press, Cambridge . • Kertz, W., 1969. Einführung in die Geophysik I, Bibliographisches Institut, Darmstadt. • Lowrie, W., 1997. Fundamentals of Geophysics, Cambridge University Press, Cambridge. • Parasnis, D. S., 1997. Principles of Applied Geophysics, Chapman & Hall, London. • Sleep, N. H., & Fujita, K., 1997. Principles of Geophysics, Blackwell-Wiley, Hoboken NJ. • Telford, W. M., Geldart, L. P., & Sherriff, R. E., 1990. Applied Geophysics, Cambridge University Press, Cambridge.
Language	German
Examination Terms	Die Modulnote ergibt sich aus allen Teilprüfungen des Moduls, die mit ihren jeweiligen Credit Points (CP) gewichtet werden
Miscellaneous	-

Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Christoph Clauser
ECTS Credits	6
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	90,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Fundamentals of Applied Geophysics II - Magnetics, Geoelectrics, and Electromagnetics (531119801)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Grundlagen der angewandten Geophysik II - Geoelektrik und Geomagnetik	2nd semester	no semester recommended	-	4
Übung Grundlagen der angewandten Geophysik II - Geoelektrik und Geomagnetik	2nd semester	no semester recommended	-	2

Module titel	Climate of the near-ground atmospheric layer (Compulsory elective subject)
Identifier	5312571
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	- Energie-, Strahlungs- und Massenflüsse sowie zugehörige Bilanzen an und über natürlichen und künstlichen Oberflächen sowie die Messung und Modellierung solcher Flüsse bzw. Bilanzen - Regionale Aspekte der Angewandten und synoptischen Klimatologie, sowie der raumzeitlichen Klimavariabilität - Klimatische Aspekte bei Stadtplanung und Luftreinhaltung
Learning Objectives/ Learning Outcomes	Die Vorlesung vermittelt ein grundlegendes Verständnis der Austauschbeziehungen von Impuls, Masse und Energie - insbesondere der Energie- und Strahlungsbilanz - zwischen Atmosphäre und Oberfläche in Abhängigkeit der Schichtung der Luft und der Bodenbeschaffenheit. Die Bedeutung dieser Zusammenhänge für Mensch und Landschaft werden herausgearbeitet. Dabei werden auch regionale und synoptische Aspekte der Angewandten Klimatologie und die Bedeutung der Verfahren für Stadtplanung und Luftreinhaltung thematisiert.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	-
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Christoph Schneider
ECTS Credits	2
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	60,0
Contact hours (h)	30,0
Self-study hours (h)	30,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Climate of the near-ground atmospheric layer: Classes (531257102)	1st semester	no semester recommended	0	2
Climate of the near-ground atmospheric layer: Module examination (531257101)	1st semester	no semester recommended	2	0

Module titel	Advanced Machine Learning (Compulsory elective subject)
Identifier	1211912
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	Regression techniques, Probabilistic Graphical Models, Exact Inference, Approximate Inference, Deep Generative Models, Deep Reinforcement Learning
Learning Objectives/ Learning Outcomes	Knowledge: On successful completion of this module, students should be able to recall and explain the theoretical foundations and concepts underlying advanced Machine Learning techniques, in particular * Linear regression * Regularization * Gaussian Processes * Bayesian Estimation * Probabilistic Graphical Models: Bayesian Networks, Markov Random Fields * Exact Inference: Belief Propagation, Junction Graphs * Approximate inference: Sampling techniques, MCMC, Variational Inference * Bayesian Non-Parametric Methods (Dirichlet Processes) * Deep Generative Models: Variational Auto-Encoders Skills: They should be able to derive, explain, and apply the following practical machine learning methods and algorithms: * Linear regression: Least-squares regression, Ridge regression, Kernel Ridge regression * Maximum Likelihood estimation, Maximum-A-Posteriori estimation, Bayesian estimation * Gaussian Process Regression * Sum-Product Belief Propagation, Max-Sum Belief Propagation * Rejection Sampling, Importance Sampling, Markov Chain Monte Carlo, Gibbs Sampling * Variational Inference * Dirichlet Processes: Stick-breaking construction Competences: Based on the knowledge and skills acquired, they should be able to * discuss the advantages and disadvantages of the covered machine learning techniques * find practical solutions to complex real-world machine learning problems * work on practical problems in a tea
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in Linear Algebra, Probability Theory, and Statistics is recommended. Successful completion of the lecture Machine Learning is recommended.

References	C.M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. | I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016. | R.S. Sutton, A.G. Barto, Reinforcement Learning: An Introduction, 2nd Edition, MIT Press, 2018.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. sc. techn. Bastian Leibe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Advanced Machine Learning (121191202)	1st semester	no semester recommended	0	1
Exam Advanced Machine Learning (121191201)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Advanced Machine Learning	1st semester	no semester recommended	-	3

Module titel	Computer Vision (Compulsory elective subject)
Identifier	1215724
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2018
Valid until	-
Module level	Bachelor/Master
Content	Image Processing Basics, Image Segmentation, Object Recognition, Object Categorization, 3D Reconstruction, Application of current Machine Learning methods to the above-mentioned problems.
Learning Objectives/ Learning Outcomes	Knowledge: On successful completion of this module, lecture participants should be able to recall and explain the theoretical foundations underlying Computer Vision techniques in the areas mentioned under “Content”. | Skills: Lecture participants can derive and explain methods and techniques that enable a machine to analyze the content of images and videos and to derive an understanding of the image content. They know the current research trends and developments. This enables them to select the basic Computer Vision techniques necessary for those capabilities. | Competences: Lecture participants are able to apply the covered methods to real problems on their own. They are able to implement the covered algorithms themselves in a language of their choice.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge in linear algebra, probability theory and statistics is recommended.
References	R. Szeliski, Computer Vision - Algorithms and Applications, Springer, 2010 | K. Grauman, B. Leibe, Visual Object Recognition, Morgan & Kaufman publishers, 2011 | I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016 | R. Hartley, A. Zisserman. Multiple View Geometry in Computer Vision, 2nd Edition, Cambridge University Press, 2004.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. sc. techn. Bastian Leibe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Computer Vision (121572402)	1st semester	no semester recommended	0	1
Exam Computer Vision (121572401)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Computer Vision	1st semester	no semester recommended	-	3

RWTH AACHEN UNIVERSITY

Module titel	Formal Systems, Automata, Processes (Compulsory elective subject)
Identifier	1214961
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Bachelor/Master
Content	1. Formal Systems: Terms, words, and languages as foundational concepts, introduced by representative examples (number expressions, arithmetic and Boolean expressions, while programs). Definition of languages by rule systems (term rewrite systems, grammars), derivation relations, method of structural induction. Classification of grammars (Chomsky hierarchy) and elementary facts about context-free grammars (normal forms, word problem (derivability test), non-emptiness problem). 2. Automata: Finite automata (deterministic and non-deterministic), closure properties (using product automata), regular expressions, non-emptiness and equivalence problem, proof of non-regularity of languages. Pushdown automata (deterministic and non-deterministic), translation of context-free grammars into pushdown automata as an example of implementing recursion by pushdown stores. 3. Processes: Foundational models of distributed and concurrent systems: example-oriented introduction of synchronized automata products, Petri nets, and Communicating Sequential Processes (CSP). Comparison with basic finite-automata model.
Learning Objectives/ Learning Outcomes	**Knowledge:** After successful completion of the module students know • finite automata and regular expressions • context-free grammars and pushdown automata • regular and context-free languages • concurrency models **Skills:** After successful completion of the module students will be able to • apply fundamental algorithms to finite automata and determine the computational complexity of the algorithms • investigate and use formal languages with different tools • analyze concurrent systems **Competencies:** Based on the knowledge and skills acquired in the module, students will be able to • transfer the learned contents to application areas such as compiler construction and verification • use formal models of computer science in a mathematically sound way
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Skript und Folien zur Vorlesung Standardbücher: • Hopcroft, Motwani, Ullman, Introducton to Automata, Theory, Languages, and Computation, Addison-Wesley 2001 (Ch.1-7) • M. Sipser, Introduction to the Theory of Computation, PWS Publ. Comp. 1997, Part 1.

+ Formal Systems, Automata, Processes (1214961)

Language	German
Examination Terms	Written Exam (100 %). Students must pass written homework to be admitted to the examination.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher InformatikModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessor Dr. ir. Dr. h. c. (AAU) Joost-Pieter KatoenUniversitätsprofessor Dr. rer. nat. Martin GroheUniversitätsprofessor Dr. rer. nat. Jürgen GieslUniversitätsprofessor Dr. rer. nat. Peter Rossmanith
ECTS Credits	6
Contact time (WSH)	-
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercises Formal Systems, Automata, Processes (121496102)	2nd semester	no semester recommended	0	2
Exam Formal Systems, Automata, Processes (121496101)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Formal Systems, Automata, Processes (2)	2nd semester	no semester recommended	-	3
Global Exercise Formal Systems, Automata, Processes (2)	no semester recommended	no semester recommended	-	-

Module titel	High-Performance Computing (Compulsory elective subject)
Identifier	1215720
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Bachelor/Master
Content	• Characteristics of micro architectures • Parallel computer architectures • Network topologies • Blocking algorithms to exploit data locality in deep memory hierarchies • Design principles of parallel algorithms • Modelling parallelism (speedup, efficiency, Amdahl) and performance • Introduction to parallel programming • Further selected topics
Learning Objectives/ Learning Outcomes	Acquisition of knowledge and skills as follows: • Comprehension of the main parallel computer architectures • Knowledge on basic design methodologies for data-local serial and parallel algorithms • Skills to apply basic methods for the analysis of runtime behavior of parallel algorithms • Comprehension of elementary operations in parallel programming
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Skills in the main concepts of imperative and object-oriented programming languages, as well as elementary programming techniques in these languages (Lecture on Programming)
References	PDF-Dateien der Folien und Übungen (zum Download), sowie: • G. Hager and G. Wellein: Introduction to High Performance Computing for Scientists and Engineers. CRC Computation Science Series, 2010. ISBN: 978-1-4398-1192-4. • J. Hennessy and D. Patterson: Computer Architecture. A Quantitative Approach. Morgan Kaufmann Publishers, Elsevier, 2011. ISBN: 978-0123838728.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher InformatikModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessor Dr. rer. nat. Matthias Müller
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0

Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam High-Performance Computing (121572001)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture + Exercise High-Performance Computing	1st semester	no semester recommended	-	3

Module titel	High-performance Matrix Computations (Compulsory elective subject)
Identifier	1211911
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	The course centers around the idea of developing efficient numerical algorithms for matrix computations through a synergy between mathematics and architectures. The focus is on the most common linear algebra operations: linear systems and eigenproblems. The objective is to attain high performance on a variety of parallel architectures: multi-core processors, GPUs, distributed and hybrid systems. Topics covered: generalized, standard and tridiagonal eigenproblems, matrix factorizations, linear systems. The students are expected to participate in practical programming exercises. The languages of choice are Matlab and C.
Learning Objectives/ Learning Outcomes	Knowledge: On successful completion of this module, students will have knowledge about efficient numerical algorithms for linear systems and eigenproblems parallel architectures standard numerical linear algebra libraries: BLAS, LAPACK, MKL, Elemental performance metrics: efficiency, strong &; weak scalability, time, space Skills: They should be able to write high-performance code for matrix operations in C design workqueue-based &; multi-threaded parallel algorithms design message-passing-based parallel algorithms Competences: Based on the knowledge and skills acquired, they should be able to identify opportunities for parallelism in matrix operations tailor algorithms for a specific target architecture (shared memory architectures, distributed memory architectures, accelerators)
(Study-Specific) Prerequisites	-
(recommended) Requirements	Voraussetzung: Knowledge from Numerical linear algebra.Principles of algorithms and Knowledge from programming.Familiarity with Matlab and C.
References	Lecture slides Diaries from the computer sessions G. Golub, C. van Loan. Matrix Computations. Third Edition, 1996. G. Meurant. Computer Solution of Large Linear Systems. North Holland, Amsterdam, 1999<
Language	English
Examination Terms	The grading results from 100% of the final exam of this module. The exam can be a written or an oral exam. The final form of the examination is announced at the beginning of the lecture. If it is intended that homework will count for the examination grade, the respective paragraphs of the examination regulations have to be followed. The exam is done at the end of the lecture period.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator:Modulangebotsverantwortlicher InformatikModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessor Paolo Bientinesi Ph. D.
ECTS Credits	6
Contact time (WSH)	-

- Subsidiary Subjects
- Computer Science
+ High-performance Matrix Computations (1211911)

Examination duration (min)	120
Total hours (h)	180,0
Contact hours (h)	-
Self-study hours (h)	-

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam High-performance Matrix Computations (121191101)	1st semester	no semester recommended	6	0
Exercise High-performance Matrix Computations (121191102)	no semester recommended	no semester recommended	0	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture High-performance Matrix Computations	1st semester	no semester recommended	-	4

Module titel	Introduction to Data Science (Compulsory elective subject)
Identifier	1216861
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	The course aims to provide a comprehensive overview of data science and expose students to real-life data sets and tools. The course provides three angles on data science: | Data science infrastructure concerned with volume and velocity. Topics include instrumentation, big data infrastructures, and distributed systems, databases and data management, and programming, and the main challenge is to make making things scalable and instant. | Data science analysis concerned with extracting knowledge from data. Topics include statistics, data|process mining, machine learning|artificial intelligence, operations research, algorithms, and visualization, and the main challenge is to provide answers to known and unknown unknowns. | Data science effects concerned with people, organizations, and society. Topics include ethics & privacy, IT law, human-technology interaction, operations management, business models, entrepreneurship, and the main challenge is to do all of the above in a responsible manner. The course will dive deeper into the following topics: | Data exploration | Data visualization | Data quality issues and preparation | Data types: from tables and event logs to unstructured data | Supervised learning | Decision tree learning | Unsupervised learning | Clustering | Pattern mining | Process mining | Text mining | Evaluation techniques | Distribution using MapReduce | Responsible data science: fairness, accuracy, confidentiality, and transparency | Discrimination-aware data mining | Anonymization versus encryption The above will be complemented with hands-on assignments using various datasets and software tools (still to be determined). Written homework (DS Assignment 1) includes an analysis of a real-life and/or synthetic data set using the techniques and tools provided in the course. This homework is used to test the understanding of the material. Written homework (DS Assignment 2) includes an analysis of more complex data sets using various data science techniques. This includes interpreting the results and creatively using multiple views of the data. The written exam or oral examination includes questions to test the theoretical knowledge of the algorithms and techniques learned.
Learning Objectives/ Learning Outcomes	Knowledge | After the course students should have a good overview of the broader field of data science. Through hands-on experience with real data sets, students will better understand the challenges in the different sub-areas of computer science. Students will understand visual analytics and advanced approaches to information visualization, the role of big data and data science in today's society, the limits of machine learning and data/process mining techniques. In addition, a few topics will be deepened and theoretical considerations will be made. | Skills | Students should be able to write small Python programs and apply existing programs, perform data visualization and exploration techniques, apply different classification methods from each data set and evaluate the results obtained through supervised learning, perform data pre-processing and identify data quality problems. | Skills | Based on the knowledge and skills acquired in this course, students should be able to apply common data science techniques and tools and be familiar with the major data challenges and technological approaches.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Recommended prior knowledge includes logic, programming, algorithms, and databases. The prerequisite for admission to the examination is the successful evaluation of the assignment. Details will be announced in the lecture.
References	Jawei Han, Micheline Kamber, Jian Pei, "Data Mining: Concepts and Techniques", third edition, Morgan Kaufmann Publishers. Some lectures have additional optional literature.
Language	English

Examination Terms	The module examination consists of the following partial examinations: Written homework (40 %); Written exam (60 %). Students must pass all parts of the examination individually to pass the module. It is not possible to transfer parts of the examinations in another semester.
Miscellaneous	-
Module coordinator	Universitätsprofessor Professor h. c. Dr. h. c. Dr. ir. Wil van der Aalst
ECTS Credits	6
Contact time (WSH)	6
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	90,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Assessment Introduction to Data Science (121686101)	no semester recommended	no semester recommended	6	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Introduction to Data Science	no semester recommended	no semester recommended	-	4
Tutorial Introduction to Data Science	no semester recommended	no semester recommended	-	2

Module titel	Machine Learning (Compulsory elective subject)
Identifier	1215744
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	Basic concepts: Introduction to Probability Theory, Bayes decision Theory | Probability Density Estimation | Discriminative Methods for Classification: Linear discriminants, Support Vector Machines, AdaBoost | Deep Learning: Multi-Layer Perceptrons, Convolutional Neural Networks, Recurrent Neural Networks
Learning Objectives/ Learning Outcomes	Kenntnisse: Nach erfolgreicher Teilnahme an den Modulveranstaltungen haben die Vorlesungsteilnehmer Kenntnisse und Fähigkeiten in den Themenfeldern, die unter Inhalt beschrieben werden, erworben. | Fertigkeiten: Vorlesungsteilnehmer können Methoden und Techniken, die es einer Maschine ermöglichen, aus Daten zu lernen, herleiten und erklären. Sie kennen die aktuellen Forschungstrends und -entwicklungen. Dadurch sind sie in der Lage, die grundlegenden Machine Learning Techniken, die für diese Fähigkeiten benötigt werden, auszuwählen. | Kompetenzen: Vorlesungsteilnehmer sind in der Lage, die behandelten Methoden selbstständig auf reale Probleme anzuwenden. Sie sind in der Lage, die vorgestellten Algorithmen selbst zu implementieren und diese in einer Programmiersprache ihrer Wahl umzusetzen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Basic knowledge in Linear Algebra, Probability Theory, and Statistics is recommended.
References	C.M. Bishop, Pattern Recognition and Machine Learning, Springer, 2006. | I. Goodfellow, Y. Bengio, A. Courville, Deep Learning, 2016.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. sc. techn. Bastian Leibe
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Machine Learning (121574402)	1st semester	no semester recommended	0	1
Exam Machine Learning (121574401)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Machine Learning	1st semester	no semester recommended	-	3

Module titel	Model Checking (Compulsory elective subject)
Identifier	1212328
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2018
Valid until	-
Module level	Bachelor/Master
Content	Main topics: • Transition systems • Concurrent and channel systems • Property classes: safety, liveness, invariants, and fairness • Linear Temporal Logic (LTL) • Computation Tree Logic (CTL) • Model Checking algorithms for LTL and (fair) CTL • Abstraction: (Bi)simulation
Learning Objectives/ Learning Outcomes	Acquisition of the following knowledge, skills and competences: • Modeling of (concurrent) programs • Knowledge of property classes • Understanding the construction and functioning of model-checking algorithms for LTL and CTL • Understanding of elementary abstraction mechanisms • Capability of employing Model Checkers (Spin)
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of fundamental automata models and regular languages. Knowledge of propositional logic. Knowledge of basic data structures such as stacks, trees, and graphs and related algorithms. Basic knowledge of complexity theory.
References	Folien zur Vorlesung sowie folgende Lehrbücher: • C. Baier, J.-P. Katoen: Principles of Model Checking, MIT Press, 2008. • M. Huth and M.D. Ryan: Logic in Computer Science, Modelling and Reasoning about Systems, Cambridge Univ. Press, 2004. • E.M. Clarke, O. Grumberg, D. Peled: Model Checking, MIT Press, 1999.
Language	English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the examination.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher InformatikModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessor i.R. Dr. rer. nat. Dr. h. c. Dr. h. c. Wolfgang ThomasUniversitätsprofessor Dr. ir. Dr. h. c. (AAU) Joost-Pieter Katoen
ECTS Credits	6
Contact time (WSH)	5

Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	75,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Model Checking (121232802)	1st semester	no semester recommended	0	2
Exam Model Checking (121232801)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Model Checking	1st semester	no semester recommended	-	3

Module titel	Semantics and Verification of Software (Compulsory elective subject)
Identifier	1212329
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	• Introduction of WHILE model language • Operational, denotational, and axiomatic semantics of WHILE • Equivalence of operational and denotational semantics • Dataflow analysis and abstract interpretation • Abstraction and refinement
Learning Objectives/ Learning Outcomes	**Knowledge** on successful completion of this module, students should be able to • illustrate the fundamental concepts of formal semantics for imperative programming languages • explain the differences between operational, denotational, and axiomatic semantics • describe connections between different kinds of formal semantics **Skills** on successful completion of this module, students should be able to • reason about the behaviour and correctness of programs using formal derivation and proof systems • apply formal concepts for proving the correctness of software, program analyses and optimisations, and compilers • develop semantic models for advanced programming language features such as procedures or threads **Competences** on successful completion of this module, students should be able to apply formal reasoning techniques in the development of computer software
(Study-Specific) Prerequisites	-
(recommended) Requirements	Understanding essential concepts of imperative and object-oriented programming languages and elementary programming techniques. Knowledge of foundations of formal systems and automata theory. Fundamental knowledge of mathematical logic.
References	Folien und Skripte zur Vorlesung sowie folgende Lehrbücher: • G. Winskel: The Formal Semantics of Programming Languages. MIT Press, 1993. • H.R. Nielson, F. Nielson: Semantics with Applications: A Formal Introduction, Wiley, 1992.
Language	German/English
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the examination.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator:

	Modulangebotsverantwortlicher Informatik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: apl. Professor Dr. rer. nat. Thomas Noll
ECTS Credits	6
Contact time (WSH)	5
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	75,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Semantics and Verification of Software (121232902)	1st semester	no semester recommended	0	2
Exam Semantics and Verification of Software (121232901)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Semantics and Verification of Software	1st semester	no semester recommended	-	3

Module titel	Statistical Classification and Machine Learning (Compulsory elective subject)
Identifier	1215840
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Bachelor/Master
Content	Introduction/motivation. | Bayes' decision rule. | Training and learning. | Model-free methods. | Neural networks. | Mixture densities and cluster analysis. | Stochastic finite automata (hidden Markov models). | Sequence classification (Master only). | Feature extraction (Maser only).
Learning Objectives/ Learning Outcomes	Knowledge: On successful completion of this module, students should be able to: develop intuition for statistical classification methods. | have command of algorithms and principles of statistical classification. | describe the various applications of state-of-the-art methods of statistical classification. | describe the fundamental properties and methods of statistical classification. | describe the methods for training a statistical classification system. | describe the trade-off between system complexity and performance in advanced statistical classification system. | describe methods for sequence classification (Master only). | describe methods for feature extraction (Master only). Skills: They should be able to: implement advanced methods of statistical classification (Master only: incl. sequence classification and feature extraction). | to train the parameters of a statistical classification system using appropriate training methods (Master only: incl. sequence classification and feature extraction). | apply methods of statistical classification (Master only: incl. sequence classification and feature extraction). | measure and analyze the performance of a statistical classification system in complex real-life applications (Master: incl. sequence classification and feature extraction). | have command over the contents and fundamental techniques of this module. | transfer the conveyed content by exemplary solution of special statistical classification problems (Master only: incl. sequence classification and feature extraction). Competences: Based on the knowledge and skills acquired they should: have an overview of advanced methods in statistical classification (Master only: incl. sequence classification and feature extraction). | be able to apply advanced methods of statistical classification (Master only: incl. sequence classification and feature extraction). | be in a position to analyze specific problems in a real-life application of a statistical classification system (Master only: incl. sequence classification and feature extraction).
(Study-Specific) Prerequisites	keine
(recommended) Requirements	None.
References	R. O. Duda, P. E. Hart, D. G. Storck: Pattern Classification. 2nd ed., J. Wiley, New York, NY, 2001. | K. Fukunaga: Introduction to Statistical Pattern Recognition. Academic Press, New York, NY, 1990.
Language	German
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Hermann Ney
ECTS Credits	6
Contact time (WSH)	5

- Subsidiary Subjects
- Computer Science
+ Statistical Classification and Machine Learning (1215840)

Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	75,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercises Statistical Classification and Machine Learning (121584002)	no semester recommended	no semester recommended	0	2
Exam Statistical Classification and Machine Learning (121584001)	no semester recommended	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Statistical Classification and Machine Learning	no semester recommended	no semester recommended	-	3

Module titel	Virtual Reality (Compulsory elective subject)
Identifier	1211909
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2021
Valid until	-
Module level	Master
Content	This course teaches the basic methods for a simulation of virtual environments and introduces to Virtual Reality applications in the fields of mechanical engineering, simulation science, and medicine. The course comes along with practical presentations and covers the following topics: The nature and history of VR, physiological aspects of 3-D visual perception, VR-related computer graphics, stereoscopic projections, projection and interaction hardware, VR displays, motion tracking, collision detection, 3D user interfaces, VR applications in research and industry.
Learning Objectives/ Learning Outcomes	Knowledge: After a successful completion of this module, students should have gained knowledge about the following topics: Characteristic features of Virtual Reality, Basic methods and algorithms of Virtual Reality, 3D interaction, Stereoscopic projections, Efficient methods of collision detection, Motion tracking | Skills: Students should be able to: Systematically evaluate and compare the quality of VR interfaces, Develop concepts of VR interfaces and applications | Competences: Based on the knowledge and the skills, students should be able to: Develop VR techniques and methods to solve technical and scientific problems, and work independently and scientifically in the discipline of Virtual Reality
(Study-Specific) Prerequisites	-
(recommended) Requirements	Basic knowledge of Linear Algebra.
References	D. Bowman et al. 3D User Interfaces. Addison-Wesley | K. M. Stanney. Handbook of Virtual Environments. Erlbaum | M.Slater et al. Computer Graphics & Virtual Environments. Addison-Wesley | G. Burdea, P. Coiffet. Virtual Reality Technology. John Wiley & Sons | K.-F. Kraiss (Ed.). Advanced Man Machine Interfaces. Springer | R.S. Kalawski. The Science of Virtual Reality and Virtual Environments. Addison Wesley
Language	German
Examination Terms	Written exam or oral examination (100 %). Students must pass written homework to be admitted to the module examination.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Torsten Wolfgang Kuhlen
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	15-45 (mündlich/oral) | 90-120 (schriftlich/written)
Total hours (h)	180,0
Contact hours (h)	60,0

Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Virtual Reality (121190902)	1st semester	no semester recommended	0	1
Exam Virtual Reality (121190901)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Virtual Reality	1st semester	no semester recommended	-	3

Module titel	Diffraction Methods (Compulsory elective subject)
Identifier	5313537
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2014
Valid until	-
Module level	Master
Content	Externes Modul: [MSAGW-303/15] a) Introduction into X-ray, Neutron and Electron Diffractometry Introduction to the concepts of X-ray, neutron and electron diffraction using powders and single-crystals: Sources, experimental equipment, detectors, interaction of radiation with matter, examples of typical applications, method-specific information content b) X-ray Course I Single-crystal X-ray diffraction course – structure determination: The crystallographic phase problem, structure factor equation, Fourier-transform, Patterson- and direct methods, sample selection, practical single crystal data collection, data correction, structure determination, structure refinement, structure evaluation
Learning Objectives/ Learning Outcomes	a) Introduction into X-ray, Neutron and Electron Diffractometry Basic knowledge of diffraction using neutrons, X-rays and electrons. b) X-ray Course I Obtain the ability to solve and refine crystal structures from single crystal X-ray-data
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	Leonid V. Azároff: Elements of x-ray crystallography. McGraw-Hill, 1968. ISBN: 0-07-002667-X George H. Stout; Lyle H. Jensen: X-ray structure determination: a practical guide. 2.ed. Wiley, 1989. ISBN 0-471-60711-8 Glusker, J. P. et al: Crystal structure analysis for chemists and biologists, 1994. Massa, W.: Kristallstrukturbestimmung, 2001. Schwarzenbach, D.: Kristallographie, Springer (2001); Giacovazzo, C. (ed): Fundamentals of Crystallography (1992).
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Georg Roth
ECTS Credits	4
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	30,0

Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Diffraction Methods: Lecture and Exercises (531353702)	1st semester	no semester recommended	0	2
Diffraction Methods: Examination (531353701)	1st semester	no semester recommended	4	0

Module titel	Introduction into xray, neutron and electron diffraction (Compulsory elective subject)
Identifier	5312572
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Externes Modul: [MSMatWis-202/11] 1. Eigenschaften von Röntgen-, Neutronen- und Elektronenstrahlen (Erzeugung, Detektion, vergleichende Einführung) 2. Wechselwirkung mit Materie I (Absorption, Brechungsindex, elastische Streuung von Röntgen-Strahlen, Elektronen und Neutronen) 3. Repetitorium kristallographischer Grundlagen 4. Beugung an kristalliner Materie (Beugungsgeometrien und experimentelle Verfahren; Laue-aufnahmen, Pulver- und Einkristalldiffraktometrie; reziprokes Gitter, Ewald-Konstruktion, Bragg- und Laue-Fall; Vergleich der Methoden bei der Verwendung von Röntgenstrahlen, Neutronen und Elektronen) 5. Elementare Analyse vom Beugungsexperimenten I: Lage und Form der Bragg-Reflexe (Charakterisierung der Probenqualität, Bestimmung der Gitterkonstanten) (Reziprokes Gitter, Ewald-Konstruktion f. alle Verfahren aus 4., Bragg- und Laue-Bedingungen) 6. Elementare Analyse von Beugungsexperimenten II: Intensitäten (kinematische Theorie, Strukturfaktor, systematische Auslöschungen, Bestimmung von Raumgruppen, experimentelle Bestimmung von Reflexintensitäten, Debye-Waller-Faktor, Vergleich für Röntgenstrahlen, Neutronen und Elektronen) 7. Dynamische Beugung (Extinktion, Breite eines Reflexes, dynamische Effekte, Zusammenhang mit kinematischer Beschreibung) 8. Beugung an realen Kristallen I: Einfluss der Mikrostruktur (statische Fehlordnung, Mosaizität, endliche Domänengröße, Zwillingsstrukturen) 9. Streuung an amorphen und stark fehlgeordneten Materialien (Bestimmung radialer Verteilungsfunktionen, Festkörper und. Flüssigkeiten) 10. Wechselwirkung mit Materie II (Röntgenstrahlen: Comptonstreuung, anomale Dispersion; Neutronen: elastische / inelastische Streuung; kohärente / inkohärente Streuung; magnetische Streuung) 11. Streifender Einfall (Fresnel-Formeln für Reflexion und Transmission, Reflektometrie an Oberflächen und dünnen Schichten, nicht- spekulare Reflektivität; Beugung unter streifenden Winkeln; Beschreibung mittels DWBA, Vergleich von Röntgenstrahlen und Neutronen) 12. Absorptionsspektroskopie (EXAFS-Prinzip und elementare Auswertung) Zusatzabschnitte (Teilauswahl nach Absprache): Z1. Fluoreszenzanalyse (Volumen und streifender Einfall; Nachweisgrenzen) Z2. Streuung an Inhomogenitäten (Kleinwinkelstreuung, experimenteller Aufbau, Porod- Gesetz) Z3. Magnetische Streuung (Wirkungsquerschnitte für Röntgen- und Neutronenstrahlen, experimentelle Aufbauten, Modellsysteme)

	Z4. Inelastische Streuung (Wirkungsquerschnitte für Röntgen- und Neutronenstrahlen, experimentelle Aufbauten, Bestimmung von Dispersionskurven von Elementaranregungen) Z5. Beugung an realen Kristallen II: Einfluss der Gitterschwingungen (thermisch-diffuse Streuung) Z6. Beugung an realen Kristallen III (Texturanalyse, Eigenspannungsanalyse, Phasenumwandlungen von Legierungen) Z7. Strahlungsquellen und Instrumentierung (Detaillierte Betrachtung der Erzeugung von Neutronen durch Reaktoren/Spallationsquellen und/oder Röntgenstrahlen an Speicherringen/Röntgenlasern; optische Komponenten (Spiegel, Linsen, Monochromatoren); Diffraktometerbauarten; Detektoren)
Learning Objectives/ Learning Outcomes	Wissen / Verstehen Die Studierende kennen verschiedene Beugungs- und Streuverfahren. Sie sind informiert über komplementäre Strahlungsarten (Röntgenstrahlung, Neutronen, Elektronen) sowie die dazugehörigen Methoden. Anwenden / Analyse Die erlernten Beugungs- und Streuverfahren werden zur Untersuchung der Struktur und Dynamik von kristalliner Materie angewandt. So erhalten die Studierenden einen Überblick über experimentelle Lösungen für wichtige Fragen der Materialwissenschaften. Synthese / Beurteilen Die Studierenden sind befähigt mithilfe der erlernten Methoden der Beugungs- und Streuverfahren experimentelle Lösungen zu finden, die Ergebnisse zu interpretieren und zu bewerten.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	-
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Georg Roth
ECTS Credits	4
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Introduction into xray, neutron and electron diffraction (531257202)	1st semester	no semester recommended	0	2

Exam Introduction into xray, neutron and electron diffraction (531257201)	1st semester	no semester recommended	4	0

RWTH AACHEN UNIVERSITY

Module titel	Principles of Crystallography (Compulsory elective subject)
Identifier	5314254
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2018
Valid until	Summer semester 2023
Module level	Bachelor
Content	Definitionen und Eigenschaften des kristallinen Zu- stands, Symmetrielehre und geometrische Kristallographie, Kristallchemie und Kristallstrukturen, Defekte und Fehlordnungen in Kristallen, physikalische Eigenschaften von Kristallen, Kristalloptik, Röntgenbeugung, Kristallwachstum und Kristallzüchtung, Anwendung von Kristallen in der Technik.
Learning Objectives/ Learning Outcomes	Wissen / Verstehen Die Studierenden lernen die Grundlagen der Kristallographie kennen. Sie können die Eigenschaften des kristallinen Zustandes definieren und kennen die physikalischen Eigenschaften von Kristallen. Anwenden / Analyse Das Wissen wird in einer angegliederten Übung angewendet und vertieft. Die Studierenden erwerben in den Übungen anhand von Modellen und Handstücken die Fähigkeit zum mehrdimensionalen Denken und sind in der Lage, komplexe räumliche Situationen zu analysieren und zu beschreiben. Synthese / Beurteilen Durch Verinnerlichung und Anwendung der Grundlagen der Kristallographie sind die Studierenden fähig, den Zusammenhang zwischen Kristallstruktur, Defekten, physikalischen Eigenschaften und technischer Anwendung zu erkennen und zu bewerten
(Study-Specific) Prerequisites	-
(recommended) Requirements	Keine Voraussetzungen für die Zulassung zum Modul.
References	-
Language	German
Examination Terms	Bewertung anhand des Klausurergebnisses (100% der Modulnote).
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Universitätsprofessor Dr. rer. nat. Georg Roth
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Principles of Crystallography (531425401)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Grundzüge der Kristallographie	1st semester	no semester recommended	-	2
Übung Grundzüge der Kristallographie	1st semester	no semester recommended	-	2

Module titel	Crystal Chemistry (Compulsory elective subject)
Identifier	5312573
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Der kristalline Festkörper: Aufbau, Bausteine, Bindungstypen, Strukturbeschreibung (Packungsmodelle, Koordinationssphären, Verknüpfungsprinzipien) Systematische Kristallchemie: Einfache Strukturtypen, Chemische Klassifizierung, Topologische Klassifizierung: Raumnetze, Schichtstrukturen, Ketten, isolierte Polyeder Wichtige Strukturtypen an Beispielen, Struktur und Eigenschaften
Learning Objectives/ Learning Outcomes	Grundwissen in Kristallchemie (chemische Bindung Strukturtypen, Struktursystematik, Eigenschaften)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	-
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Philipp Friedl M. A.Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Georg Roth
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Crystal Chemistry: Lecture and Exercises (531257301)	2nd semester	no semester recommended	0	3
Crystal Chemistry: Examination (531257302)	2nd semester	no semester recommended	4	0

Module titel	Applications of Laser Technology (Compulsory elective subject)
Identifier	4011686
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2008
Valid until	-
Module level	Master
Content	1 • Einführung: • Verbreitung der Lasertechnik/Markt • Überblick der verschiedenen Laserverfahren 2 • Werkzeug Laserstrahl: • Eigenschaften des Gaußschen Strahls • Strahlumformung und -transport 3 • Lasersysteme für die Materialbearbeitung: • Gas-/Excimer-Laser • Festkörper-/Diodenlaser 4 • Wechselwirkung von Laserstrahlung und Materie: • Fresnelsche Formeln • Inverse Bremsstrahlung 5 • Wärmeleitung im Werkstück: • Isolatoren/Metalle • Bsp.: Martensitisches Härten 6 • Oberflächentechnik: • Massentransport/Diffusion • Beschichten/Legieren/Dispergieren/Polieren 7 • Rapid Prototyping: • Lasergenerieren/Selective Lasermelting • Biegen 8 • Fügen: • Wärmeleitungsschweißen/Tiefschweißen • Löten 9 • Abtragen: • Bohren • Reinigen/Beschriften 10 • Schneiden: • Schmelzschneiden/Brennschneiden • Sublimierschneiden

	11 • Prozessüberwachung: • koaxiale Prozessüberwachung/akustische Prozessanalyse • Regelstrategien 12 • Messen: • Triangulation • Stoffanalyse 13 • Kommunikationstechnik und optische Datenspeicher: • Multiplexing/Glasfasernetze • CD/DVD/BlueRay 14 • Lebenswissenschaften und Medizintechnik: • Multiphotonenmikroskopie • Ophtalmologie 15 • Zusammenfassung: • neue Verfahren im Laborstadium • Ausblick
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen die für die Materialbearbeitung wesentlichen Eigenschaften von Laserstrahlung und können diese berechnen. • Die wesentlichen Wechselwirkungen von Laserstrahlung und Materie und Transportprozesse innerhalb eines Werkstücks sind qualitativ verstanden und können für praxisrelevante Spezialfälle berechnet werden. • Alle industriellen Anwendungen der Lasertechnik sind in ihren Mechanismen bekannt und können in ihren Systemparametern voneinander abgegrenzt werden. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden sind in der Lage, vorgegebene Fragestellungen in Gruppendiskussionen zu klären und selbstständig zu lösen sowie diese Lösungen vorzustellen und zu diskutieren.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Physik • Konstruktion und Anwendungen von Lasern und optischen Systemen
References	• Vorlesungsskript Lasertechnik II • CD Lasertechnik
Language	German
Examination Terms	Eine schriftliche Klausur
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. rer. nat. Constantin Häfner
ECTS Credits	6
Contact time (WSH)	4

Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Applications of Laser Technology (40116861)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Applications of Laser Technology	2nd semester	no semester recommended	-	2
Lecture Applications of Laser Technology	2nd semester	no semester recommended	-	2

Module titel	Computer-based Optics Design (Compulsory elective subject)
Identifier	4011489
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	1 • Einführung: • Gegenstand und Einordnung des Themas • Berufsbild des Optik-Ingenieurs • Trends im Optik-Design 2 • Ray-Tracing: • Prinzip des Ray-Tracing • Diagnosewerkzeuge • Bewertung der Abbildungsleistung optischer Systeme 3 • Optisches Layout und Optimierung: • Vorgehen beim Optik-Design • Optimierungsalgorithmen 4 • Grundformen optischer Systeme: • Ausführung • Anwendungsfelder 5 • Strahlführungssysteme: • Lichtleitfaserkopplung für Festkörperlaser • Spiegelsysteme für FIR-Laser 6 • Fokussiersysteme: • Transmissive Optiken • Spiegel-Fokussiersysteme 7 • Strahlablenksysteme: • Scanneroptiken und F-Theta-Objektive • Polygonsysteme 8 • Homogenisierungssysteme: • Wellenleiterelemente • Reflektive Systeme 9 • Mikrooptiken: • Kollimatoren für Hochleistungsdiodenlaser • miniaturisierte optische Systeme in Lasern 10 • Nichtrotationssysmmetrische optische Systeme:

	• Zylinderlinsensysteme • Prismensysteme 11 • Bildgebende optische Systeme: • optische Prozessüberwachungssysteme • optische Messsysteme 12 • Fertigungsgerechtes Design: • Berücksichtigung fertigungstechnischer Restriktionen • Verwendung von Standardkomponenten 13 • Toleranz- und Kostenanalyse für optische Systeme: • Einfluss von Fertigungs- und Montagetoleranzen auf die Leistungsfähigkeit optischer Systeme • Einfluss von Fertigungs- und Montagetoleranzen auf die Kosten optischer Systeme 14 • Zusammenfassung und Wiederholung der wichtigsten Lerninhalte Sonstiges: • Die Übungen werden mit einem kommerziell erhältlichen Ray-Tracing Programm im Rahmen einer Blockveranstaltung durchgeführt. Lizenzen sind am Lehrstuhl vorhanden. Eine Anmeldung ist erforderlich.
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen moderne Methoden des computergestützten Optikdesigns. • Die Studierenden sind in der Lage, optische Systeme mit Methoden des computergestützten Optikdesigns auszulegen und zu bewerten. • Die Studierenden kennen Möglichkeiten und Voraussetzungen des computergestützten Optik-Designs. • Die Studierenden sind in der Lage, optische Systeme für die Produktion fertigungsgerecht und kostenoptimiert auszulegen. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden werden in den Übungseinheiten befähigt, Problemstellungen zu analysieren, Lösungsvorschläge zu erarbeiten und zu bewerten (Methodenkompetenz) • Die Arbeit in der Übung erfolgt in Kleingruppen, so dass kollektive Lernprozesse gefördert werden (Teamarbeit) • Im Rahmen der Übungen werden von Studierenden Arbeitsergebnisse vorgestellt, so dass die Übungen dazu beitragen, kommunikative Fähigkeiten zu verbessern (Präsentation)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Vorlesung "Physik für Maschinenbauer" aus Bachelor-Studiengang • "Grundlagen und Ausführungen optischer Systeme"
References	Vorlesungsskript
Language	German
Examination Terms	• Eine mündliche Prüfung, • alternativ: Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Carlo Holly
ECTS Credits	6
Contact time (WSH)	4

Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Computer-based Optics Design (401148901)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Computer-based Optics Design	2nd semester	no semester recommended	-	4

Module titel	Fundamentals and Design of Optical Systems (Compulsory elective subject)
Identifier	4011510
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2008
Valid until	-
Module level	Master
Content	1 • Einführung: •Gegenstand und Einordnung des Themas • Vorstellung ausgewählte optische Systeme für die Produktion 2 • Elektromagnetische Wellen: • Analogie zwischen mechanischen und elektromagnetischen Wellen • Maxwellgleichungen, Wellengleichung, Superpositionsprinzip • Fourierzerlegung • Reflexion/Transmission, Polarisation 3 • Strahlenoptik (paraxiale Optik): • Abgrenzung: Beugungsoptik-Strahlenoptik • Konstruktion von Abbildungsstrahlengängen, Matrixformalismus • Kardinalpunkte und Hauptebenen • Helmholtz-Lagrange-Invariante, f/# - Zahl und numerische Apertur 4 • Aberrationen: • Aperturen und Pupillen • Optische Weglängendifferenz • Seidelsche Aberrationstheorie 5 • Korrektionsprinzipien: • Formfaktoren • Petzval-Summe • Symmetrisierung 6 • Ray-Tracing: • Prinzip des Ray-Tracing • Aberrationsdiagramme • Abbildungsleistung optischer Systeme 7 • Optisches Layout und Optimierung: • Vorgehen beim Optik Design • Optimierungsalgorithmen • Grundformen optischer System 8 • Optische Werkstoffe: • Grundlagen der linearen Dispersion • optische Gläser • Kristalloptiken • Metalloptiken

	• Kunststoffoptiken • GRIN-Werkstoffe 9 • Optische Komponenten: • Asphärische optische Komponenten • Lichtleitfasern • Doppelbrechung • Überblick: Fertigungsverfahren für optische Komponenten 10 • Interferenz und Beugung: • Zweistrahl- und Vielstrahlinterferenz • optische Schichten • Fresnelsches Beugungsintegral, Fern- und Nahfeld • beugungsbegrenzte Abbildung 11 • Der Gaußsche Strahl: • Wellengleichung in SVE-Näherung • Eigenschaften des Gaußschen Strahls • Transformation des Gaußschen Strahls, komplexer Strahlparameter 12 • Strahlqualität: • Beschreibung des Gauß-Mode und Erweiterung auf höhere Moden und Strahlverteilungen in der Praxis • Verfahren zur Definition von Strahlradien • Strahlqualität eines Arrays aus Einzelstrahlen • Nutzung der Strahlqualität bei Lasern 13 • Optische Systeme für Hochleistungsdiodenlaser: • Eigenschaften von Diodenlasern • Einflussfaktoren auf die Brillanz von Diodenlasermodulen • Auslegung von Fast-Axis-Collimatoren • inkohärente/kohärente Kopplung 14 • Zusammenfassung und Wiederholung der wichtigsten Lerninhalte
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen die grundlegenden Eigenschaften und Berechnungsverfahren der paraxialen Optik und die Abbildungsfehler bei nicht-paraxialer Optik und können diese Verfahren einsetzen. • Die Studierenden kennen das Ray-Tracing-Verfahren zum Entwurf und zur Optimierung technischer optischer Systeme. • Die Studierenden kennen Grundformen optischer Systeme und deren Anwendungsgebiete. • Die Studierenden können optische Systeme analysieren und deren Leistungsfähigkeit bewerten. • Die Studierenden sind in der Lage, strahlenoptische Verfahren abzugrenzen von wellenoptischen Verfahren. • Die Studierenden kennen die grundlegenden Eigenschaften und Berechnungsverfahren der Laseroptik und können diese anwenden. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden werden in den Übungseinheiten befähigt, Problemstellungen zu analysieren, Lösungsvorschläge zu erarbeiten und zu bewerten (Methodenkompetenz) • Die Arbeit in der Übung erfolgt auch in Klengruppen, so dass kollektive Lernprozesse gefördert werden (Teamarbeit) • Im Rahmen der Übungen werden von Studierenden Arbeitsergebnisse vorgestellt, so dass die Übungen dazu beitragen, kommunikative Fähigkeiten zu verbessern (Präsentation)
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.

(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Vorlesung "Physik für Maschinenbauer" aus Bachelor-Studiengang
References	• Vorlesungsskript • F. Pedrotti et al.: Optik für Ingenieure, Springer
Language	German
Examination Terms	• Eine mündliche Prüfung, • alternativ: eine schriftliche Prüfung
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Carlo Holly
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Fundamentals and Design of Optical Systems (401151001)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Fundamentals and Design of Optical Systems	2nd semester	no semester recommended	-	2
Lecture Fundamentals and Design of Optical Systems	2nd semester	no semester recommended	-	2

Module titel	Lasers in Biotechnology and Medical Technology (Compulsory elective subject)
Identifier	4011559
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	1 • Übersicht Laserverfahren in Medizin, Medizintechnik, Biotechnologie und Chemie • Verfahrenseinordnung zu alternativen Prozessen • Marktsituation 2 • Grundlagen Eigenschaften Licht - Wiederholung • Technologien zur Mikro- und Nanoskalierung von Licht • Optische Systeme zur Anregung und Detektion 3 • Grundlagen Wechselwirkung Licht Materie - Wiederholung • Strahlungstransport und Absorption in biologischen Materialien • Energietransport 4 • Wirkmechanismen in biologischen Materialien • Zellspezifische Wirkung von Laserstrahlung • Gewebespezifische Wirkung von Laserstrahlung 5 • Laserverfahren für medizintechnische Produkte • Lasergestützte generative Verfahren zur Implantatherstellung • Mikrostrukturierung für medizinische Instrumente 6 • Laser-Mikrofügetechnik für medizinische und biotechnische Produkte • Laserunterstützte Oberflächenmodifikation • Photochemische Funktionalisierung von Implantaten 7 • Laser in der Therapie • Laser in der Weichgewebechirurgie • Laser in der Hartgewebechirurgie 8 • Laser in der Ophtalmologie • Photodynamische Therapie • Laserinduzierte Thermotherapie 9 • Laserverfahren in der medizinischen Diagnostik • Fluoreszenzverfahren • Optische Kohärenztomographie 10 • Laserverfahren in der Biotechnologie • Verfahren zur Herstellung biotechnologischer Komponenten • Funktionalisierung von Biochips

Lasers in Biotechnology and Medical Technology (4011559)

	11 • Zellbasierte Laserverfahren • Zellmanipulation • Optische Pinzette 12 • Nanochirurgie in Zellen und Zellkompartimenten • Lasertranspektion und photonische Genmanipulation • Proteinmanipulation mit Laserstrahlung 13 • Laserverfahren in der Bioanalytik • Fluoreszenzspektroskopie • Oberflächen-Plasmonen-Resonanz- und Interferenzspektroskopie 14 • Laserverfahren in der Chemie • Photochemische Prozesse • Femtochemie 15 • Laborexkursion • Klinikumsexkursion
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen die wichtigen wesentlichen Eigenschaften von Laserstrahlung, deren Nutzung für Anwendungen in Medizin, Biotechnologie und Chemie und können diese berechnen. • Die unterschiedlichen Wechselwirkungsmechanismen von Laserstrahlung mit biologischen Materialien und Materie sowie in der Nutzung des Werkzeugs Photon für photochemische Verfahren sind qualitativ verstanden und können den verschiedenen Verfahren zugeordnet werden. • Wirkungsmechanismen für verschiedene Gewebetypen und Wechselwirkungen mit biologischen Medien und chemischen Verbindungen können für praxisrelevante Spezialfälle beschrieben und berechnet werden. • Wichtige Anwendungen von Lasern in der Medizin sind bekannt und können im Kontext einer Anwendung des Lasers in den Lebenswissenschaften eingeordnet werden. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden sind in der Lage, vorgegebene Fragestellungen in Gruppendiskussionen zu klären und selbstständig zu lösen sowie diese Lösungen vorzustellen und zu diskutieren.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Physik • Laser in der Mikrotechnik • Medizintechnik
References	• Skript • CD
Language	German
Examination Terms	Eine schriftliche Prüfung
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. rer. nat. Constantin Häfner Dr.-Ing. Arnold Gillner
ECTS Credits	6
Contact time (WSH)	4

Lasers in Biotechnology and Medical Technology (4011559)

Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Lasers in Biotechnology and Medical Technology (401155901)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Laser in Bio- und medizintechnik	2nd semester	no semester recommended	-	2
Vorlesung Laser in Bio- und Medizintechnik	2nd semester	no semester recommended	-	2

Module titel	Laser Measurement Technology (Compulsory elective subject)
Identifier	4011691
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2013
Valid until	-
Module level	Master
Content	1. Einführung in die Lasermesstechnik: Grundlagen, Anwendungen, Markt, Entwicklungstrends 2. Eigenschaften der Laserstrahlung: elektromagnetische Welle, Strahlparameter, Bestrahlungsstärke, Phase, Ausbreitung, Wellenlänge, Polarisation, Beugung, Kohärenz, Vergleich Laserstrahlung - thermisches Licht, Gaußscher Strahl 3. Wechselwirkung Laserstrahlung - Materie: Teilchencharakter, Reflexion, Brechung, Absorption; Lichtstreuung - Rayleigh, Mie, Raman; Frequenzverdopplung, Doppler-Effekt 4. Strahlformung und -führung: optische Elemente zur Strahlmodulation, Strahlablenkung und -teilung, Veränderung der Polarisation, Modulation der Intensität, Wellenlängenmodulation, Phasenschiebung, Ausbreitung Gaußscher Strahlen, optische Fasern 5. Detektion elektromagnetischer Strahlung: thermische Detektoren, photoelektrische Detektoren, Halbleiterdetektoren, ortsauflösende Detektoren, Messung von Detektorsignalen 6. Laser-Interferometrie: Grundlagen, Superpositionsprinzip und komplexe Schreibweise, Abstandsmessungen mit Laser-Interferometer, Polarisationsinterferometer, Doppelfrequenzinterferometer, Wellenlänge als Längenmaßstab, Messbereich und -genauigkeit, Winkelmessung, Geradheitsmessung, Twyman-Green-Interferometer, Anwendungsbeispiele 7. Holografische Interferometrie: Prinzip der Holografie und holografischen Interferometrie, Doppelbelichtungsverfahren, Echtzeitverfahren, Empfindlichkeitsvektor, Objekttranslation und -rotation, Phasenshiftverfahren, Messaufbau, Anwendungsbeispiele 8. Speckle-Messtechnik: Entstehung von Speckles, Speckle-Fotografie, abbildende Speckle-Fotografie, unfokussierte Speckle-Fotografie, Speckle-Interferometrie, Zeitmittelungsverfahren, Anwendungsbeispiele 9. Laser-Triangulation: Prinzip, Scheimpflug-Bedingung, Kennlinie eines Triangulationssensors, Einflussgrößen bei der Laser-Triangulation, Strahlverlauf, Eigenschaften der Objektoberfläche, Detektor und Signalauswertung, atmosphärische Einflüsse, Konturmessung, Anwendungsbeispiele 10. Laser-Doppler-Verfahren: Doppler-Effekt, Laser-Vibrometer, Laser-Doppler-Anemometer, Signalverarbeitung, Messbereich, Anwendungsbeispiele 11. Optische Kohärenztomographie (OCT): Time-Domain OCT, Fourier-Domain OCT, Signalauswertung, Auflösung und Messbereich, Anwendungsbeispiele 12. Laser-Spektroskopie I: Laser-Emissionsspektroskopie (LIBS), Verdampfung und Plasmabildung, zeitaufgelöste Spektroskopie, Spektrenauswertung, Messbereich, Anwendungsbeispiele 13. Laser-Spektroskopie II: Laser-induzierte Fluoreszenz (LIF), Light Detection and Ranging (LIDAR), differentielles Absorptions-LiDAR, Signalverarbeitung, Messbereich, Anwendungsbeispiele; Coherent Anti-Stokes Raman Spectroscopy (CARS), Messbereich, Anwendungsbeispiele 14. Laser, Laseranlagen, Begriffe, Sicherheit - Normen und Regelwerke
Learning Objectives/ Learning Outcomes	Fachbezogene Lernziele: • Die Studenten kennen die maßgeblichen Grundlagen für Lasermessverfahren: Eigenschaften der Laserstrahlung, Wechselwirkung Laserstrahlung mit Materie, Strahlformung und -führung sowie Detektion elektromagnetischer Strahlung. • Die Studenten können selbstständig Berechnungen zu Strahlformung, Interferenzerscheinungen, Beugungsphänomenen, Kohärenzeigenschaften, Reflexion und Brechung, Lichtstreuung, Polarisation, Ausbreitung Gaußscher Strahlen, optische Fasern, Detektion von Laserstrahlung sowie Sicherheit von Laserstrahlung durchführen. • Sie sind mit den Grundprinzipien und Eigenschaften der Lasermessverfahren vertraut: Interferometrie, Holografie, Speckle-Messtechnik, Laser-Triangulation, Laser-Dopplerverfahren, optische Kohärenztomographie, Laser-Spektroskopie. • Sie kennen die etablierten Einsatzgebiete und die Potentiale der Lasermesstechnik in der Produktionstechnik sowie in Forschung- und Entwicklung.

	Nicht fachbezogene Lernziele (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studenten sind in der Lage, vorgegebene Fragestellungen in Gruppendiskussionen zu erörtern und selbstständig zu lösen, diese Lösungen zu präsentieren und zu diskutieren.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	-
References	• Skript • A. Donges, R. Noll: Lasermesstechnik - Grundlagen und Anwendungen, Hüthig-Verlag (Neuauflage in engl. 2013, Springer-Verlag)
Language	German
Examination Terms	• 1 Klausur oder • 1 mündliche Prüfung Die Endnote ergibt sich aus der Note der Klausur oder der Note der mündlichen Prüfung.
Miscellaneous	-
Module coordinator	apl. Professor Dr. rer. nat. Reinhard Noll
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Laser Measurement Technology (401169101)	2nd semester	no semester recommended	6	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Lasermesstechnik	2nd semester	no semester recommended	-	2
Vorlesung Lasermesstechnik	2nd semester	no semester recommended	-	2

Module titel	Laser Beam Sources (Compulsory elective subject)
Identifier	4014348
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • Einführung: • Laser in 3 Bildern 2 • Laser Exkurs I: • Materie und aktives Medium 3 • Laser Exkurs II: • Licht und Resonator 4 • Licht: • Wellenoptik/SVE-Näherung • Geometrische Optik 5 • Gaußscher Strahl: • Strahlparameterprodukt/Strahlqualität • ABCD-Gesetz 6 • Resonatoren: • g-Parameter-Diagramm • Longitudinale/transversale Resonatormoden 7 • Materie: • Planck'scher Strahler • Atommodelle 8 • Aktives Medium: • Einsteinsche Ratengleichungen • Lichtwellenleiter 9 • Gaslaser: • Excimer-Laser • CO2-Laser 10 • Festkörperlaser: • Diodenpumpen • Nd:YAG-Laser 11 • Diodenlaser:

	• Halbleiterstrukturen • Stacks 12 • Modulation 1: • Gain-Switching • Q-Switching 13 • Modulation 2: • Modelocking • Chirped Pulse Amplification 14 • Unternehmerische Aspekte optischer Technologien: • VC/Netzwerke • Betriebswirtschaftliche Aspekte/ Bsp. Laser Job Shop 15 • Zusammenfassung: • neuartige Strahlquellen
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen die maßgeblichen Modellvorstellungen von Licht und deren mathematisches Gerüst. • Sie können selbstständig Propagation und Umformung durch optische Komponenten berechnen. • Die Eigenschaften von Atommodellen und deren für die Entstehung von Licht wichtigen Eigenschaften sind qualitativ verstanden. • Optische Resonatoren und deren Wechselwirkung mit dem aktiven Medium können mit Hilfe von ABCD-Gesetz bzw. den Ratengleichungen berechnet werden. • Auf Basis dieser allgemeinen physikalischen Grundlagen sind Komponenten und deren Funktionsweise aller industriell relvanten Gas-, Festkörper- und Dioden-Lasersysteme bekannt und können z.T. selbstständig ausgelegt werden. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden sind in der Lage, vorgegebene Fragestellungen in Gruppendiskussionen zu klären und selbstständig zu lösen sowie diese Lösungen vorzustellen und zu diskutieren.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Physik • Konstruktion und Anwendungen von Lasern und optischen Systemen
References	• Vorlesungsskript Lasertechnik I • CD Lasertechnik
Language	German
Examination Terms	Eine schriftliche Klausur
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. rer. nat. ;Constantin ;Häfner
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-

- Subsidiary Subjects
- Laser Technology
+ Laser Beam Sources (4014348)

Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Laser Beam Sources (401434801)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Laserstrahlquellen	1st semester	no semester recommended	-	2
Vorlesung Laserstrahlquellen	1st semester	no semester recommended	-	2

Module titel	Micro/Nano Manufacturing with Lasers (Compulsory elective subject)
Identifier	4011688
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • Übersicht Laserverfahren in Mikro-, Medizin- und Nanotechnologie • Verfahrenseinordnung zu alternativen Prozessen • Marktsituation 2 • Grundlagen Eigenschaften Licht - Wiederholung • Technologien zur Mikro- und Nanoskalierung von Licht • Abgrenzung Einsatzfelder Laserstrahlquellen für Mikro- und Nanotechnik 3 • Grundlagen Wechselwirkung Licht Materie - Wiederholung • Absorptionsprozesse: Metalle, Halbleiter, Keramik, Kunststoff • Photochemie Grundlagen 4 • Transportprozesse auf der Mikro- und Nanoskala • Kollektive Phänomene • Multiphasenprozesse 5 • Kurzpulswechselwirkung • Nichtlineare Wechselwirkungsprozesse • Selbstfokussierung 6 • Lithographieverfahren • Auflösungsgrenze - Grundlagen und Technologien • Technische Systeme 7 • Interferenzverfahren zur Nanostrukturierung • Laserinduzierte Photochemische und Photothermische Prozesse • Optische Nahfeldbearbeitung 8 • Mikroabtrag mit Laserstrahlung - Verfahrensvarianten • Mikrobohren • Photochemisch unterstützte Ätzverfahren 9 • Mikrofügen mit Laserstrahlung - Verfahrensvarianten • Mikroschweißen und Mikrolöten • Schmelzfreie Mikroverbindungstechnik 10 • Laserstützte Mikro- und Nanobeschichtung • Laser-CVD • Laser-PLD

	11 • Photochemische und Photothermische Mikro-Werkstoffmodifikation • Oberflächen-Photochemie • Bulk-Modifikation transparenter Werkstoffe 12 • Laser- und Laserverfahren für mikrooptische Bauelemente • Mikrosystemtechnische optische Komponenten • Photonische Kristalle - Grundlagen und Verfahren zur Herstellung 13 • Photopolymerisation • Nichtlineare Wechselwirkungen in Fluiden • Biotechnologische Anwendungen von Laserverfahren 14 • Maschinentechnik zur Laser-Mikrobearbeitung • Optische Systemtechnik zur Mikro- und Nanostrukturierung • Prozesskontrolle 15 • Anwendungsbeispiele • Laborexkursion
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studenten kennen die für die Mikrobearbeitung mit Laserstrahlung notwendigen und wichtigen wesentlichen Eigenschaften von Laserstrahlung, deren Nutzung für die Mikro- und Nanotechnik und können diese berechnen. • Die unterschiedlichen Wechsel-wirkungsmechanismen von Laserstrahlung und Materie bei der Mikro- und Nanobearbeitung sowie in der Nutzung des Werkzeugs Photon für photochemische Verfahren sind qualitativ verstanden und können den verschiedenen Verfahren zugeordnet werden. • Transportprozesse in der Festphase, der Flüssigphase und der Gasphase können für praxisrelevante Spezialfälle berechnet werden. • Wichtige Anwendungen von Lasern in der Mikrotechnik sind bekannt und können im Kontext einer Mikroproduktionstechnik eingeordnet werden. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studenten sind in der Lage, vorgegebene Fragestellungen in Gruppendiskussionen zu klären und selbstständig zu lösen sowie diese Lösungen vorzustellen und zu diskutieren.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Physik • Konstruktion und Anwendungen von Lasern und optischen Systemen
References	• Skript Laser in der Mikrotechnik • CD
Language	German
Examination Terms	Eine mündliche Prüfung
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. rer. nat. Constantin Häfner
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	-

Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Micro/Nano Manufacturing with Lasers (401168801)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Mikro-/ Nanofertigungstechnik mit Laserstrahlung	1st semester	no semester recommended	-	2
Übung Mikro-/Nanofertigungstechnik mit Laserstrahlung	1st semester	no semester recommended	-	2

Module titel	Technology of extreme ultraviolet radiation (Compulsory elective subject)
Identifier	4028589
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	1st Part (during semester): 1. lntroduction: Motivation: Application of EUV in semiconductor industry, introduction to Optics and EUV radiation, introduction to EUV lithography 2. Generation of EUV radiation (sources): Radiation generation principles, discharge- and laser-produced plasma EUV sources, high harmonic generation EUV sources, synchrotrons and free-electron lasers 3. EUV optics and optical components: Optics and physical principles, Optical properties in the EUV spectral range, multilayer mirrors, grazing-incidence optics, diffraction gratings, zone plates 4. EUV lithography: Principles of lithography, EUV lithography in the semiconductor industry 5. EUV metrology: Detectors for EUV (Photodiodes, Cameras), EUV metrology techniques (microscopy, retlectometry, scatterometry) 6. Challenges for EUV technology: EUV-Matter-lnteraction, EUV induced degradation, Precision in the nanoscale 2nd part (on-site course): 1. Optical component: Fabrication techniques, optical setup design 2. Application of lithography: Materials of EUV lithography, Calculation methods 3. EUV and Nanometrology: Applicability of methods, data interpretation and analysis 4. Vacuum technology: Technologies, materials, and classification, system design 5. Cleanroom technology: Technologies, materials, and classifications, behavior rules 6. System engineering: Integration of all technological aspects in a system, tolerancing of EUV systems 7. EUV technology at RWTH: Systemintegration at laboratory scale, demonstrations and usage of realized system at RWTH 8. Summary and repetition of most important topics
Learning Objectives/ Learning Outcomes	Wissen und Verstehen: Nach erfolgreicher Teilnahme an den Modulveranstaltungen haben die Studierenden und grundlegende und diverse Kenntnisse und Fähigkeiten in den umfangreichen Themenfeldern der EUV-Technologie erworben. Eine Aufstellung der wichtigsten Vorlesungsinhalte ist im Abschnitt „Inhalt" beschrieben. Insbesondere kennen und verstehen die Studierenden die Grundlagen der Optik mit Fokus auf die optischen Eigenschaften der EUV-Strahlung sowie die Prinzipien und Ausführungen von optischen Komponenten für EUV-Strahlung. Des Weiteren kennen sie die Grundlagen der Strahlungserzeugung und können die gängigsten Technologien zur Erzeugung von EUV-Strahlung sowie deren Eigenschaften einordnen und beschreiben. Die Studierenden entwickeln ein umfassendes Verständnis zu Prinzipen, Methoden und Anwendungen der zwei wichtigsten Anwendungsfelder der EUV-Strahlung: Photolithografie und Metrologie. Hierbei können sie die Bedeutung und Anwendung in Forschung und Industrie einordnen. Im Bereich des System-Engineerings für EUV-Anwendungen kennen die Studierenden die wichtigsten Einflüsse aufgrund der EUV-Strahlung und verstehen die

	wichtigsten unterstützenden Technologien darunter die Vakuum- und Reinraumtechnologie. <u>Fertigkeiten und Kompetenzen:</u> Die Studierenden erkennen Anwendungsgebiete der EUV-Technologie und sind in der Lage, ihr Wissen über die verschiedenen Teilaspekte der EUV-Technologie selbstständig und zielführend einzusetzen. Sie können optische Systeme für verschiedene EUV-Anwendungen unter Berücksichtigung der ausgewählten EUV-Strahlungsquellen und der Vakuumumgebung konzipieren. In Übungseinheiten werden die Studierenden befähigt Problemstellungen der EUV-Technologie zu analysieren, Lösungsvorschläge zu erarbeiten, zu bewerten und diese in schriftlicher und mündlicher Form klar und eindeutig darzustellen sowie wissenschaftlich fundiert zu verteidigen. Hierbei werden vor allem die Anwendungsbeispiele aus der EUV-Lithografie und EUV-Metrologie betrachtet. Die praktische Übungseinheiten geben eine Einführung in die Benutzung und anwendungsgerechte Auswahl von Standardbauteilen und Komponenten der EUV-Technologie, insbesondere der optischen Komponenten, sowie aus der Vakuum- und Reinraumtechnologie. <u>Sonstiges:</u> Durch die Nutzung einer MOOC für den ersten Vorlesung-Teil wird den Studierenden die selbstständige Nutzung von Online-Lehrmedien vermittelt. Im Rahmen der Online-Übungen führen die Studierenden selbständige Online-Recherchen durch und werden in den Gebrauch verschiedener Online-Datenbanken eingeführt. Die Studierenden können im Rahmen der praktischen Übungseinheiten im Team selbständig Aufgaben auf die Teammitglieder verteilen und Verantwortung für ihre Ergebnisse übernehmen. Sie können eine Präsentation ihrer Arbeitsergebnisse vorbereiten und diese frist- und formgerecht halten.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Physik für Maschinenbau
References	• D. Attwood, Soft X-rays and extreme ultraviolet radiation. Principles and applications, Cambridge, 2007 • V. Bakshi, EUV Lithography, SPIE Press, Bellingham WA, 2009 • V. Bakshi, EUV Sources for Lithography, SPIE Press, Bellingham WA, 2006 • E. Hecht, Optics, Pearson, 2017
Language	English
Examination Terms	A written exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Carlo Holly
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Technology of extreme ultraviolet radiation (4028589)	1st semester	2nd semester	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Technology of extreme ultraviolet radiation	1st semester	2nd semester	-	1
Exercise Technology of extreme ultraviolet radiation	1st semester	2nd semester	-	1
Seminar Technology of extreme ultraviolet radiation	1st semester	2nd semester	-	2

Module titel	Flight Dynamics (Compulsory elective subject)
Identifier	4013370
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2009
Valid until	-
Module level	Bachelor/Master
Content	1 • EINFÜHRUNG • Grundbegriffe 2 • GRUNDLAGEN • Bezeichnungen • Koordinatensysteme 3 • Luftkräfte, Luftkraftmomente 4 • STATIONÄRE LÄNGSBEWEGUNG • Statische Längsstabilität bei festem Ruder 5 • Ruderausschläge • Leitwerksauslegung 6 • Statische Längsstabilität bei freiem Ruder • Manöverstabilität 7 • Steuerung 8 • STATIONÄRE SEITENBEWEGUNG • Gier- und Rollbewegung • Steuerung 9 • Kopplungen • Stationäre Flugzustände 10 • BEWEGUNGSGLEICHUNGEN • Herleitungen 11 • Vereinfachungen • Linearisierung 12 • DYNAMIK DER LÄNGSBEWEGUNG • Eigenverhalten 13

	• Führungs- und Störverhalten 14 • DYNAMIK DER SEITENBEWEGUNG • Eigen-, Führungs- und Störverhalten 15 • FLUGEIGENSCHAFTSFORDERUNGEN • Längsbewegung • Seitenbewegung
Learning Objectives/ Learning Outcomes	Die Studierenden kennen und verstehen die Grundbegriffe und Grundgleichungen zur Untersuchung der Stabilität, Steuerbarkeit und Störanfälligkeit eines Flugzeugs (Flugeigenschaften, Flugdynamik) Sie sind in der Lage, diese Kenntnisse bei einfachen Aufgaben der Flugeigenschaftsanalyse oder des Flugzeugentwurfs bei vorgegebenen Flugeigenschafts-Anforderungen anzuwenden Die Studierenden können die Eigenschaften unterschiedlicher Flugzeugkonfigurationen bezüglich Stabilität und Manövrierfähigkeit beurteilen
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	notwendig: • Mechanik • Mathematik empfohlen: • Regelungstechnik • Grundlagen der Flugmechanik
References	Eigenes Skript "Flugdynamik" Etkin/Reid "Dynamics of Flight", John Wiley 1996, ISBN 0-471-03418-5Brockhaus, "Flugregelung", Springer 2001, ISBN 3-540-41890-3
Language	German
Examination Terms	Eine mündliche Prüfung oder eine schriftliche Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dieter Moormann
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Flight Dynamics (401337001)	2nd semester	no semester recommended	5	0

▲Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Flight Dynamics	2nd semester	no semester recommended	-	2
Lecture Flight Dynamics	2nd semester	no semester recommended	-	2

Module titel	Flight Control (Compulsory elective subject)
Identifier	4011707
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • EINFÜHRUNG • Zielsetzung • Historie • Quellen 2 • GRUNDLAGEN • Grundbegriffe • Beschreibungsformen • Der Regelkreis 3 • Auslegungsziele • Auslegungsverfahren 4 • ELEMENTE DER FLUGREGELKREISE • Regelstrecke • Bewegungsgleichungen • Dynamisches Verhalten 5 • Messgrößen, Stellgrößen, Störgrößen • Regelungsprinzipien 6 • AUFGABEN UND STRUKTUR DER FLUGREGELKREISE • Aufgaben • Auslegungsziele 7 • VERBESSERUNG DER FLUGEIGENSCHAFTEN • Eigenverhalten • Nickdämpfer • Phygoiddämpfung 8 • Eigenverhalten • Gierdämpfer • Rolldämpfer< 9 • Führungsverhalten • Lageregler • Kurvenkoordinierung • Kurvenkompensation 10 • Führungsverhalten • Vorgaberegler • Modellfolgeregler 11 • REGLER ZUR BAHNFÜHRUNG • Höhenregelung • Fahrtregelung • Kursregelung 12 • ERWEITERUNG DER EINSATZGRENZEN • Reduzierte Stabilität • Lastabminderung • Schwingungsdämpfung 13 • REALISIERUNGSGESICHTSPUNKTE • Strukturdynamik • Signalverarbeitung • Sicherheit 14 • REALISIERUNGSBEISPIELE • Do328 • A320 • ATTAS • VTOL-UAV
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen die grundlegenden Auslegungsziele und Auslegungsverfahren für Flugregelungssysteme und sie verstehen die Aufgaben und die Struktur der Flugregelkreise. • Sie sind in der Lage, diese Kenntnisse bei einfachen Aufgaben des Entwurfs von Systemen zur Modifikation der Flugeigenschaften, Reglern zur Bahnführung und zur Erweiterung der Einsatzgrenzen anzuwenden. • Die Studierenden können die Wirkungen unterschiedlicher Messgrößen und Stellgrößen in einem Gesamt-Flugführungssystem beurteilen. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • keine
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Flugdynamik • Regelungstechnik
References	• Skript "Flugregelung" • Brockhaus, "Flugregelung", Springer 2001, ISBN 3-540-41890-3
Language	German
Examination Terms	Eine mündliche Prüfung oder eine Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dieter Moormann

ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Flight Control (401170701)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Flight Control	1st semester	no semester recommended	-	2
Exercise Flight Control	1st semester	no semester recommended	-	2

Module titel	Aircraft Design I (Compulsory elective subject)
Identifier	4010860
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Bachelor/Master

Content	1
	• the situation of aircraft industry:
	  • passenger and cargo airtraffic
	  • existing companies, new airplanes' market
	2
	• typical procedures in aircraft design:
	  • description of the different development phases
	  • iterative process of aircraft design
	3
	• system-oriented concepts in aircraft engineering:
	  • description of different subsystems, their interdependence and influence on the complete system
	4
	• air traffic compared to other means of transport:
	  • accident statistics, accident causes, transport efficiency factors, payload factors
	5
	• costs:
	  • design and production costs of different types of aircraft
	  • calculation (computation) of direct operating costs
	6
	• mass:
	  • definition of mass distribution
	  • statistical data for several mass groups
	  • payload-range diagram
	7
	• influence of design and materials on weight:
	  • description of structural design of aircraft components
	8
	• description of the atmosphere:
	  • dependence of pressure, density, temperature, viscosity on height at standard conditions
	9
	• fundamentals of different propulsion types:
	  • definition of efficiency factors, derivation of major equations, and relevant comparative numerical values
	10
	• alternatives of propulsion integration in the airframe:
	  • advantages and disadvantages of different propulsion configurations
	  • installation losses when integrating propellers and jet engines into an aircraft
	11

	• coefficients, polars:
	  • definition, numerical values, dependences at take-off, cruise, landing (flap positions), flight polars
	12
	• flight performance at take-off and climb:
	  • equations of motion, take-off velocities, calculation of the FAR-take-off distance, equations for climb
	13
	• flight performances at cruise, descent , and landing:
	  • thrust / drag ratio, Breguet's range equation
	  • optimization of cruise, calculation of descent, landing distance
	14
	• limits of aerodynamic flight envelope:
	  • stall characteristics, flight altitudes, maximum velocities, Mach numbers and buffeting, g-values
	15
	• aircraft drag components:
	  • dependences of viscous drag, wave drag (impedance), pressure drag, induced drag on aircraft parameters and flight attitude

Learning Objectives/ Learning Outcomes	With respect to the subject: • survey of aircraft as a system • ability to analyse basic aircraft components and their interdependence • air traffic safety and profitability (cost effectiveness) • special procedures to calculate direct operating costs (DOC) • knowledge of aircraft structures, identification of advantages and disadvantages of different designs and use of different materials • description of power plant characteristics (propeller, jet engine) and demonstration of the efficiency factors' dependence on power plant parameters • perception and balance of advantages and disadvantages of different modes of power plant integration in the airframe • calculation of aircraft performance at take-off, climb, cruise, descent, and landing • limits of flight range due to physical conditions for different aircraft configurations • understanding of the different types of aircraft drag and statements on relative values of drag ratio Not with respect to the subject (e.g. Team work, Presentation, Project Management, etc.): • During the tutorials students learn to solve in team work subtasks in the field of aircraft design and flight performances • By our revision and evaluation of their homework the students learn to present fundamental results clearly
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Mandatory Requirements (e.g. other Modules): • Fluid Mechanics I Reccommended Requirements (e.g.. other Modules, foreign languages, …): • Materials Science I, II • English Required for (e.g. other Modules): • Aircraft Systems
References	Vorlesungsumdruck Flugzeugbau mit ca. 300 Seite Viel Sekundärliteratur vorhanden, aber für das Erreichen der Lernziele nicht notwendig
Language	German
Examination Terms	Eine schriftliche Klausur

Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Ing. Eike Stumpf
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Aircraft Design I (401086001)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Aircraft Design I	1st semester	no semester recommended	-	2
Lecture Aircraft Design I	1st semester	no semester recommended	-	2

Module titel	Aircraft Design II (Compulsory elective subject)
Identifier	4011700
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	1 • Berechnung der Widerstandsarten von Flugzeugen: Reibungswiderstand, • Formwiderstand mit und ohne Ablösung, Interferenzwiderstand, induzierter • Widerstand (mit Beschreibung der Wirbelmodelle). 2 • Berechnung des Wellenwiderstands im Trans- und im Überschallflug, • Beschreibung transsonischer Profile und der Flächenregel, Einfluss der Flügelpfeilung. 3 • Erklärung der unterschiedlichen Hochauftriebssysteme für Start und Landung (Spreizklappe, Wölbungsklappe, Spaltklappe, Fowlerklappe, Krügerklappe, Knicknase, Vorflügel), Darstellung der aerodynamischen Beiwerte. 4 • Behandlung der wichtigen Kriterien bei der Tragflügelauslegung (Flügelstreckung, Flügelfläche, Flügeldicke, Flügelzuspitzung, Verwindung, Pfeilung, Profilauswahl) und Diskussion der jeweiligen Auswirkungen auf die Flugleistungen und -eigenschaften. 5 • Darstellung der Beispiele zur Flügelauslegung anhand einiger • unterschiedlicher existierender Flugzeuge mit jeweiliger Bewertung. 6 • Darstellung der Fluglasten, Manöverlasten im v-n-Diagramm, • Lastverteilung beim Horizontalflug, Lasten beim Triebwerksausfall, Lasten bei schnellen Rudereingaben, Lasten infolge von Böen. 7 • Berechnung der instationären Lasten für die Stufenböe, Rampenböe und (1-cos)-Böe, Beschreibung des v-n-Diagramms für Böen. 8 • Behandlung der Bodenlasten beim Landestoß, der Energieaufnahme des Fahrwerks, der Kräfte auf die Räder (Andrehen und spring back). 9 • Beschreibung der dimensionierenden Lastannahmen bei unterschiedlichen Flugzeugtypen 10 • Behandlung der Strukturermüdung, Konstruktionsprinzipien, Beschreibung der Dauerfestigkeit im Zusammenhang mit Werkstoffwahl, wobei zunehmend auch Faserverbundwerstoffe zum Einsatz kommen. 11 • Erklärung des Begriffs der Lastkollektive und der Vorgehensweise zur Berechnung der Lebensdauer einzelner Flugzeugbauteile. 12

	• Beschreibung der Grundbegriffe der Aeroelastik und Behandlung der Problematik beim Flugzeugentwurf und bei Windkanalmessungen. 13 • Behandlung von wichtigen Fällen zur statischen Aeroelastik: • Torsionskippen beim Rechteckflügel, aeroelastische Verformung beim nach vorn bzw. nach hinten gepfeilten Flügel, Ruderumkehr. 14 • Behandlung der dynamischen Aeroelastik: Erklärung des Zustandekommens von Flatterzuständen und des Zusammenspiels von Bieg- und Torsionsschwingungen, Vorgehen bei der Flatteranalyse. 15 • Erklärung des strukturellen Aufbaus einzelner Flugzeugbauteile, insbesondere Bauelemente von Rumpf und Flügel (Holme, Stringer, Spante, Rippen, Beplankung/Haut).
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden sind in der Lage, das System "Flugzeug" zu überschauen und die gegenseitige Abhängigkeit der wesentlichen Flugzeugparameter systematisch zu analysieren. • Den Entwurf von Tragflügeln unter Berücksichtigung der vielseitigen Anforderungen haben sie verstanden. • Sie sind in der Lage, die Vor- und Nachteile der für Start und Landung notwendigen Hochauftriebssysteme zu beschreiben. • Die unterschiedlichen Lastfälle können sie erklären und die daraus entstehenden Strukturbelastungen der Flugzeugzelle ableiten. • Sie sind in der Lage, den strukturellen Aufbau von Rumpf und Flügel zu beschreiben, die verschiedenen Werkstoffe zu benennen und die Strukturermüdung zu erklären. • Sie haben gelernt, die zunehmend größeren Probleme der Aeroelastik zu überschauen und zu diskutieren. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): Im Rahmen der Übungen haben die Studierenden Fähigkeiten erworben, im Team einige Teilaufgaben aus dem Bereich des Flugzeugentwurfs und der Flugleistungen zu lösen. Durch Korrektur und Bewertung dieser Hausarbeiten lernen sie, die wesentlichen Ergebnisse in klarer Form darzustellen.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Flugzeugbau I • Gute Englischkenntnisse
References	• Umdruck zur Vorlesung Flugzeugbau II mit ca. 300 Seiten • Viel Sekundärliteratur vorhanden, aber für das Erreichen der Lernziele nicht notwendig
Language	German
Examination Terms	Eine schriftliche Klausur Bonuspunktregelung: Durch die Übungen können bis zu 10 % der max. Punkte der Klausur zusätzlich erworben werden. Die Endnote, unter Berücksichtigung der zusätzlich erzielten Punkte während der Übung, ergibt sich aus der Note der Klausur.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Ing. Eike Stumpf
ECTS Credits	5

Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Aircraft Design II (401170001)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Aircraft Design II	2nd semester	no semester recommended	-	2
Exercise Aircraft Design II	2nd semester	no semester recommended	-	2

Module titel	Fundamentals of Flight Mechanics (Compulsory elective subject)
Identifier	4010861
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Bachelor/Master
Content	1 • OVERVIEW • 1. Fundamentals • Terms, Coordinate Systems, basic equations 2 • 2. Flight Performance • Flight conditions, flight sections 3 • 3. Handling Qualities • Stability, controllability, susceptibility to disturbances, • automatic flight control
Learning Objectives/ Learning Outcomes	With respect to the subject: • The students know to specify the fundamental terms and equations to investigate the performance of flight and they can describe the correlation to the flying qualities requirements • They are able to apply the fundamental equations to basic problems, as: computing the flight performance parameters for a given aircraft, or: design of an aircraft for given mission requirements • Tey know to judge the interactive influence of the design parameters on flight performance and handling qualities
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Mandatory Requirements (e.g. other Modules): • Mechanics • Mathematics Recommended Requirements (e.g.. other Modules, foreign languages, …): • Aircraft Design I
References	• Zu erstellendes Skript "Grundlagen der Flugmechanik" • Brüning/Hafer/Sachs "Flugleistungen", Springer 1993, ISBN 3-540-56960-X • Etkin/Reid "Dynamics of Flight", John Wiley 1996, ISBN 0-471-03418-5 • Brockhaus, "Flugregelung", Springer 2001, ISBN 3-540-41890-3
Language	German
Examination Terms	Written exam
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dieter Moormann

+ Fundamentals of Flight Mechanics (4010861)

ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Fundamentals of Flight Mechanics (401086101)	1st semester	no semester recommended	3	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Fundamentals of Flight Mechanics	1st semester	no semester recommended	-	1
Exercise Fundamentals of Flight Mechanics	1st semester	no semester recommended	-	1

RWTH AACHEN UNIVERSITY

Module titel	Aircraft Propulsion II (Compulsory elective subject)
Identifier	4011608
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	Moderne Luftfahrtantriebe spielen im weltweiten Personen- und Warenverkehr eine bedeutende Rolle. Flugzeuge sind fester Bestandteil unserer modernen Infrastruktur und benötigen für einen profitablen Einsatz hoch effiziente und leistungsstarke Triebwerke. Um diese Anforderungen erfüllen zu können, ist ein tiefes Verständnis der Aero- und Thermodynamik in den unterschiedlichen Luftfahrtantrieben erforderlich. Die Vorlesung Luftfahrtantriebe II baut auf der Vorlesung Luftfahrtantriebe I auf. Die Grundlegenden Erkenntnisse aus Luftfahrtantriebe I werden auf aktuelle Triebwerkskonzepte, wie z.B. das Zweistrom-Turbinen-Luftstrahl-Triebwerk (Turbofan) und das Propeller-Turbinen-Luftstrahl-Triebwerk (Turboprop), angewendet. Dabei orientiert sich das Vorlesungskonzept weiter an dem analytischen Charakter der vorangegangenen Vorlesung. Alle Zusammenhänge werden nachvollziehbar analytisch hergeleitet und wichtige Auslegungs- und Betriebsparameter abgeleitet. Ebenso ist der Vergleich der vermittelten Berechnungsmethoden mit gängiger Performance Software Inhalt der Vorlesung. Neben den Gesamtsystembetrachtungen werden im Rahmen von Luftfahrtantriebe II ; auch die einzelnen Komponenten der verschiedenen Triebwerkskonzepte im Detail betrachtet. Dabei stehen die Funktionsweisen und wichtigsten Betriebsparameter der Komponenten im Fokus.
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen den Aufbau und die Funktionsweise der unterschiedlichen Triebwerksbauarten • Sie sind in der Lage die aerothermodynamischen Zusammenhänge zu erkennen und zu erklären • Sie können die aerothermodynamischen Gesetze auf die Problemstellungen bei der Nachrechnung von Triebwerken anwenden Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studierenden können Probleme eigenständig erkennen und formulieren • Sie sind in der Lage, geeignete Lösungsmöglichkeiten zu entwickeln und gegenüberzustellen.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Thermodynamik • Strömungsmechanik I • Grundlagen der Turbomaschinen • Luftfahrtantriebe I
References	• Koschel, W. und Niehuis, R.: Luftfahrtantriebe II, Vorlesungsumdruck • Münzberg, H.G.: Flugantriebe, Springer Verlag Berlin 1972
Language	German
Examination Terms	Eine schriftliche Klausur. Die Endnote setzt sich zu 100% aus der Klausurnote zusammen.

	Bonuspunktregelung: Durch erfolgreiches Bearbeiten der Zwischenprüfung können bis zu 5% Bonuspunkte bezogen auf die reguläre Klausur erreicht werden.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Peter Jeschke
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Aircraft Propulsion II (401160801)	3rd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Aircraft Propulsion II	3rd semester	no semester recommended	-	2
Exercise Aircraft Propulsion II	3rd semester	no semester recommended	-	2
Bonuspunkteprüfung Luftfahrtantriebe II	3rd semester	no semester recommended	-	0

Module titel	Spacecraft Design I (Compulsory elective subject)
Identifier	4013371
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2009
Valid until	-
Module level	Bachelor/Master
Content	1 • Überblick und historische Entwicklung • Industrie, Forschung und Institutionen in der Raumfahrt 2 • Raumfahrtantriebe: Physikalische Größen und Definitionen • Funktionsweisen und Charakteristika der verschiedenen Antriebsarten 3 • Bauweisen von Feststofftriebwerken • Zyklen der Flüssigkeitstriebwerke • Leistungs- und Energiebetrachtung an elektrischen Antrieben 4 • Herleitung der Schubgleichung • Definition und Betrachtung unterschiedlicher Wirkungsgrade 5 • Definitionen und Prozesse bzgl. Düsenströmung • Düsenauslegung • Triebwerkskühlung 6 • Ziolkowsky-Gleichung (Tsiolkovsky) • Betrachtung der Massen • Stufungsprinzip und -optimierung 7 • Aufbau der Atmosphäre • Modellatmosphäre: Annahmen und Berechnung • Fluktuationen 8 • Dichtemessung mittels Satellit • Ionosphäre • Magnetosphäre 9 • Bahntypen • Zweikörperproblem • LEO, GEO, GTO, SSO 10 • koplanare Bahnübergänge unter kontinuierlichem Schub • Hohmann-Transfer • Änderung der Bahnebene 11 • Bewegungsgleichung für Aufstiegsbahnen • Gravity loss

	• Widerstandsverluste 12 • Ariane 5 • Space Shuttle • Sojus 13 • Ballistischer Wiedereintritt: Bewegungsgleichung, Berechnung von Trajektorie und Verzögerungsbelastung
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studenten kennen die Funktionsweisen sowie die damit verbundenen Vor- und Nachteile der unterschiedlichen Triebwerkstypen und sind in der Lage, sie verschiedenen Missionsanforderungen zuzuordnen. • Sie sind in der Lage, Düsenströmungen und die daraus resultierenden Schübe zu berechnen und verstehen die Zusammenhänge der ausschlaggebenden Parameter und Kennzahlen. • Die Studenten sind fähig, Antriebsvermögen und Treibstoffverbrauch einer Rakete sowie deren Optimierung mittels Stufung zu berechnen. • Sie kennen den Aufbau der Atmosphäre sowie übliche Standardmodelle und begreifen die Auswirkungen auf Aufstiegsbahnen von Trägersystemen. • Sie beherrschen das Zweikörperproblem und können Raumflugbahnen auslegen sowie energetisch günstige Bahnänderungen berechnen. • Die Studenten kennen die wichtigsten derzeitigen Raumtransportsysteme sowie die entsprechenden Standardorbits. • Sie verstehen die Zusammenhänge und Einflüsse der unterschiedlichen Parameter für den ; Wiedereintritt von Raumkapseln. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Die Studenten werden befähigt, eine systemische Betrachtung von Raumfahrzeugen zu vollziehen. • Sie haben gelernt, Lösungsvorschläge zur Missionsauslegung von Raumfahrzeugen zu erarbeiten und zu bewerten (Methodenkompetenz).
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	empfohlen: Englisch
References	Vorlesungsumdruck Raumfahrzeugbau I, ca. 370 Seiten
Language	German
Examination Terms	Eine Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Ing. Eike Stumpf
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Spacecraft Design I (401337101)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Raumfahrzeugbau	2nd semester	no semester recommended	-	2
Vorlesung Raumfahrzeugbau	2nd semester	no semester recommended	-	2

Module titel	Spacecraft Design II (Compulsory elective subject)
Identifier	4011710
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • Wiedereintritt mit Auftrieb • aerodynamische Beiwerte in hypersonischer Kontinuumsströmung 2 • Aerothermodynamik des Wiedereintritts: Wärmefluss, Aufheizrate, integrale Last, Stanton-Zahl • Hochtemperatureffekte und deren Auswirkung auf den Wiedereintritt • Thermalschutz 3 • kinetische Gastheorie • Bestimmung und Bedeutung der Knudsen-Zahlen • Strömungbereiche und deren Auswirkungen auf den Wiedereintritt 4 • Wiedereintrittssimulation: Definition und Verlauf von Kennzahlen • Funktionsweisen und Messbereiche von Hyperschallkanälen • Überblick über das System Satellit und die Subsysteme 5 • Aufgaben und Arten der Lagestabilisierung • Schwingung im Gravitationsfeld • Einfluss von Magnetfeld und Solardruck auf einen Satelliten 6 • Präzession und Nutation: Phänomene und Formeln • energetische Betrachtung eines Kreisels • Funktionsweise und Berechnung eines Jo-Jo-Systems 7 • Aktive Lageregelung: geeignete Antriebe • stetige und unstetige Regelung • Reaktionsrad und Momentenkreisel 8 • Funktionsweise und Vergleich von optischen sowie Inertial-Sensoren • mathematische Beschreibung eines integrierenden Wendekreisels 9 • Energie- und Leistungsbereiche von Solar- und Brennstoffzellen, Batterien, Radioisotopengeneratoren und solardynamischen Systemen • Funktionsweise und Vergleich der Energiequellen 10 • Telemetrie und Telekommando • Berechnung von Sende- und Empfangsleistung des Hornstrahlers • Übertragungsverluste und Antennengewinn 11

	• Strahlungsgesetze: Planck, Wien, Stefan-Boltzmann, Kirchhoff, Lambert • Eigenschaften des schwarzen Strahlers 12 • Strahlungseigenschaften realer Körper • Oberflächeneigenschaften und deren Degradation • Bestimmung der Gleichgewichtstemperatur 13 • Temperaturgrenzschichten und Thermalkontrolle • Aufbau von Raumfahrzeugen anhand konkreter Beispiele: Giotto, STS, ISS • Struktur: mechanische Lasten, Kollisionswahrscheinlichkeit und -schutz 14 • Massen und Kosten • Wiederverwendbare Raumfahrzeuge: Auslegung, bisherige und zukünftige Konzepte 15 • Bemannte Raumfahrt: Historie, Aufgaben, Anforderungen • menschliche Physiologie in Mikrogravitation • Beispiele
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden sind mit der Aerothermodynamik und Simulation des Wiedereintritts vertraut. • Sie haben Kenntnis von verdünnten Gasen und freimolekularen Strömungen erlangt. • Den Studierenden wurde ein systemisches Verständnis für Satelliten sowie deren Subsysteme und Strukturen vermittelt. • Sie sind in der Lage, die Interaktion von Raumfahrzeugen mit ihrer Umgebung abzuschätzen sowie Lagestabilisierungs- und -regelungsmechanismen auszulegen. • Sie kennen die Charakteristika der verschiedenen Energieversorgungs- und Kommunikationssysteme. • Die Studierenden sind befähigt, die thermischen Prozesse an Bord eines Satelliten zu interpretieren und geeignete Maßnahmen zu konzipieren. • Sie kennen die Herausforderungen bemannter Raumfahrt und zukünftiger Raumfahrzeuge. • Die Studenten können die Vor- und Nachteile der bemannten bzw. unbenannten Raumfahrt im Vergleich bewerten Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • Den Studierenden wird der Satellit als System nahegebracht (systemisches Denken). • Sie haben gelernt, Lösungsvorschläge zur Missionsauslegung von Satelliten zu erarbeiten und zu bewerten (Methodenkompetenz).
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Raumfahrzeugbau I • Englisch
References	Vorlesungsumdruck Raumfahrzeugbau II, ca. 340 Seiten
Language	German
Examination Terms	Eine Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Ing. Eike Stumpf
ECTS Credits	4
Contact time (WSH)	4

Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Spacecraft Design II (401171001)	3rd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Raumfahrzeugbau II	3rd semester	no semester recommended	-	2
Vorlesung Raumfahrzeugbau II	3rd semester	no semester recommended	-	2

Module titel	Space Flight Dynamics I (Compulsory elective subject)
Identifier	4011701
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	1 • SONNENSYSTEM 2 • ALLGEMEINE DEFINITIONEN • Maßsysteme • Koordinatensysteme • Zeitdefinitionen 3 • ZWEI-KÖRPER-PROBLEM • Kepler • Newton 4 • BEWEGUNGSGLEICHUNGEN 5 • LÖSUNG DER RELATIVBEWEGUNG 6 • KEGELSCHNITTE • Grundaufgaben 7 • SCHWEREFELD DER ERDE 8 • BALLISTISCHE BAHNEN 9 • FLUCHT- UND EINFANGBAHNEN 10 • ÜBERGANGANGSBAHNEN • Hohmann-Transfer 11 • BI-Elliptische Übergangsbahnen • Räumliche Übergangsbahnen 12 • GESCHWINDIGKEITSTRANSFORMATIONEN • Swing-By 13 • LAMBERT´S THEOREM 14

	• Anwendung Lambert´sches Theorem
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen die Grundbegriffe und Grundgleichungen zur Berechnung von Raumflugbahnen unter dem Einfluss von zwei gravitationsbehafteten Körpern • Sie sind in der Lage, diese Kenntnisse bei einfachen Aufgaben der Auslegung von ballistischen Bahnen, Flucht- und Einfangbahnen und Übergangsbahnen anzuwenden • Die Studierenden können die Anwendbarkeit und die Grenzen der hergeleiteten Methoden beurteilen Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • keine
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Raumfahrzeugbau I
References	• Skript "Raumfflugmechanik I" • W. Steiner, M. Schagerl "Raumflugmechanik", Springer, ISBN 3-540-20761-9
Language	German
Examination Terms	Eine mündliche Prüfung
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dieter Moormann
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Space Flight Dynamics I (401170101)	2nd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Raumflugmechanik I	2nd semester	no semester recommended	-	2
Vorlesung Raumflugmechanik I	2nd semester	no semester recommended	-	2

Module titel	Space Flight Dynamics II (Compulsory elective subject)
Identifier	4011709
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	1 • MEHRKÖRPERPROBLEM • Bewegungsgleichungen 2 • MEHRKÖRPERPROBLEM • Erhaltungssätze • Relativbewegung • Einflusssphäre 3 • DREI-KÖRPER-PROBLEM • Librationspunkte • Zirkular-restringiertes Dreikörperproblem 4 • Jacobi-Integral • Nullgeschwindigkeitsflächen 5 • BERECHNUNG VON RAUMFLUGBAHNEN • Encke´sche Methode 6 • BERECHNUNG VON RAUMFLUGBAHNEN • Änderung der Bahnelemente • Einfluss der Erdabplattung 7 • BERECHNUNG VON RAUMFLUGBAHNEN • Patched-Conic Methode • Multi-Conic Methode 8 • Flugbahnen Erde-Mond • Interplanetere Bahnen 9 • LEISTUNGSRECHNUNG • Raketen-Grundgleichung • Antriebe • Geräteparameter 10 • Stufungsprinzip • Apollo-Mondflüge 11 • AUFSTIEGSBAHNEN UND STARTFENSTER

	• Bahnen • Segmente 12 • EBENE ZWEIKÖRPERBAHNEN BEI KONSTANTEM SCHUB • Grundgleichungen • Kleine Schübe 13 • DREHBEWEGUNGEN • Bewegungsgleichungen • Stabilität • Näherungen 14 • LAGEREGELUNG • Methoden • Kontinuierliche Regelung • Diskontinuierliche Regelung
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen und verstehen die Grundbegriffe und Grundgleichungen zur Berechnung von Raumflugbahnen unter dem Einfluss von mehreren gravitationsbehafteten Körpern und zusätzlicher Kräfte. Die Studierenden kennen und verstehen die Grundbegriffe und Grundgleichungen zur Beschreibung der rotatorischen Freitheitsgrade und der Methoden zur Stabilisierung. • Sie sind in der Lage, diese Kenntnisse bei einfachen Aufgaben der Auslegung von von Raumflugbahnen und Lageregelung anzuwenden. • Die Studierenden können die Anwendbarkeit und die Grenzen der hergeleiteten Methoden beurteilen. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • keine
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Raumfahrzeugbau I, II • Raumflugmechanik I
References	• Skript "Raumfflugmechanik II" • W. Steiner, M. Schagerl "Raumflugmechanik", Springer, ISBN 3-540-20761-9
Language	German
Examination Terms	Eine mündliche Prüfung
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Dieter Moormann
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Space Flight Dynamics II (401170901)	3rd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Raumflugmechanik II	3rd semester	no semester recommended	-	2
Vorlesung Raumflugmechanik II	3rd semester	no semester recommended	-	2

Module titel	Aircraft Propulsion I (Compulsory elective subject)
Identifier	4013365
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2018
Valid until	-
Module level	Bachelor/Master
Content	Moderne Luftfahrtantriebe spielen im weltweiten Personen- und Warenverkehr eine bedeutende Rolle. Flugzeuge sind fester Bestandteil unserer modernen Infrastruktur und benötigen für einen profitablen Einsatz hoch effiziente und leistungsstarke Triebwerke. Um diese Anforderungen erfüllen zu können, ist ein tiefes Verständnis der Aero- und Thermodynamik in den unterschiedlichen Luftfahrtantrieben erforderlich. Die Vorlesung Luftfahrtantriebe I gibt einen ersten Einblick in das Thema Luftfahrtantriebe. Im Fokus stehen die grundlegende Funktionsweise und der Aufbau des Einwellen-Turbinen-Luftstrahl-Triebwerks und seiner Komponenten. Durch den analytischen Charakter der Vorlesung werden die physikalischen Abhängigkeiten zwischen den einzelnen Triebwerkskomponenten nachvollziehbar aufgezeigt und die wichtigsten Parameter der Triebwerksauslegung und Triebwerksnachrechnung abgeleitet. Dabei kommen vereinfachte analytische Berechnungsmethoden zum Einsatz um für das Triebwerk wichtige Zielgrößen, wie den Schub oder den spezifischen Brennstoffverbrauch in erster Größenordnung zu bestimmen. Neben den analytischen Methoden werden auch numerische Rechenmethoden vorgestellt, wie sie aktuell in der Industrie Anwendung finden. Im Rahmen der Vorlesung werden Sie sich zudem erste Fähigkeiten im Umgang mit der gängigen Gasturbinen Performance Software GasTurb aneignen.
Learning Objectives/ Learning Outcomes	With respect to the subject: • The students know the assembly and the operantional processes of jet engines • They are able to apply the aero/thermodynamic equations for process calculations • They know the task and function of the different components of a jet engine • The students can explain the operating behavior of jet engines on the basis of the operating maps • They are able to calculate and anylyze the thrust of a jet engine and its fuel consumption Not with respect to the subject (e.g. Team work, Presentation, Project Management, etc.): • The students are able to recognize and to formulate independently • They are able to develop and to judge suitable solutions
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	Recommended Requirements (e.g. other Modules): • Thermodynamics • Fluid Dynamics • Energy Conversion Machinery
References	• Koschel, W. und Niehuis, R.: Luftfahrtantriebe, Vorlesungsumdruck • Münzberg, H.G.: Flugantriebe, Springer Verlag Berlin 1972
Language	German

+ Aircraft Propulsion I (4013365)

Examination Terms	Assigned marks / ranking
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Peter Jeschke
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Aircraft Propulsion I (401336501)	2nd semester	no semester recommended	5	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Aircraft Propulsion I	2nd semester	no semester recommended	-	2
Exercise Aircraft Propulsion I	2nd semester	no semester recommended	-	2
Bonuspunkteprüfung Luftfahrtantriebe I	2nd semester	no semester recommended	-	0

Module titel	Space Propulsion I (Compulsory elective subject)
Identifier	4011703
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	1. Funktionsweise und Aufbau eines Raketentriebwerks 2. Einführung der charakteristischen Kenngrößen 3. Übersicht der Bauarten von Raketentriebwerken (chemisch, nuklear, elektrisch) 4. Gasdynamische Grundlagen der Düsenströmung 5. Düsenauslegung 6. Flüssigkeitstriebwerke: Verbrennungsgüte, Treibstoffe, Basiszyklen, Brennkammer (Geometrie, Injektorelemente, Treibstoffaufbereitung, Kühlkonzepte, Pumpensysteme) 7. Feststofftriebwerke: Komponenten, Treibstoffarten, innere Ballistik, Gestaltung der Abbrandfläche bezüglich des Schubes, Treibstoffherstellungsprozess
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden kennen die Funktionsweise und den Aufbau eines Raketentriebwerks und seine charakteristischen Kenngrößen. • Sie können verschiedene Bauarten von Raketentriebwerken erläutern. • Sie beherrschen die gasdynamischen Grundlagen der Düsenströmung und können auf dieser Basis Düsen für Raketentriebwerke auslegen. • Sie kennen die Elemente von Flüssigkeits- und Feststofftriebwerken und können zugehörige Prozesse beschreiben. Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • keine
(Study-Specific) Prerequisites	keine
(recommended) Requirements	Empfohlene Voraussetzungen (z.B. andere Module, Fremdsprachenkenntnisse, …): • Thermodynamik • Strömungsmechanik • Grundlagen der Turbomaschinen
References	-
Language	German
Examination Terms	schriftlich oder mündlich
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Peter Jeschke
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-

Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Space Propulsion I (401170301)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Übung Raumfahrtantriebe I	1st semester	no semester recommended	-	2
Vorlesung Raumfahrtantriebe I	1st semester	no semester recommended	-	2

Module titel	Space Propulsion II (Compulsory elective subject)
Identifier	4011712
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	1. Treibstoffaufbereitung und Verbrennungsprozess bei Flüssigkeitstriebwerken 2. Auslegung von Treibstoffpumpen und Turbinen 3. Schubvektorsteuerung 4. Verbrennungsinstabilitäten 5. Auslegung und Betrieb von Testanlagen 6. Antriebe für Satelliten und Orbitalsysteme 7. Luftatmende Antriebe und Kombinationstriebwerke für wieder verwendbare Raumtransportsysteme
Learning Objectives/ Learning Outcomes	Fachbezogen: • Die Studierenden können die Treibstoffaufbereitung und den Verbrennungsprozess bei Flüssigtriebwerken beschreiben. • Sie wissen, wie Treibstoffpumpen und Turbinen auszulegen sind. • Sie verstehen das Prinzip der Schubvektorsteuerung. • Sie können mögliche Verbrennungsinstabilitäten beschreiben. • Sie wissen, wie Testanlagen auszulegen und zu betreiben sind. • Sie kennen die speziellen Antriebe für Satelliten und Orbitalsysteme sowie für wieder verwendbare Raumtransportsysteme Nicht fachbezogen (z.B. Teamarbeit, Präsentation, Projektmanagement, etc.): • keine
(Study-Specific) Prerequisites	keine
(recommended) Requirements	Empfohlene Voraussetzungen: • Thermodynamik • Strömungsmechanik • Raumfahrtantriebe I
References	Koschel, W.: Raumfahrttantriebe II, Vorlesungsmanuskript
Language	German
Examination Terms	schriftlich oder mündlich
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Peter Jeschke
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-

Space Propulsion II (4011712)

Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Space Propulsion II (401171201)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Raumfahrtantriebe II	2nd semester	no semester recommended	-	2
Übung Raumfahrtantriebe II	2nd semester	no semester recommended	-	2

Module titel	Computeralgebra (Compulsory elective subject)
Identifier	1113549
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2007
Valid until	-
Module level	Bachelor/Master
Content	Operation endlich erzeugter Gruppen auf Mengen, Homomorphiesatz für Gruppen, freie Gruppen, Homomorphiesatz für Ringe und Moduln, Teilbarkeitstheorie und Faktorisierungsalgorithmen, insbesondere endliche Körper und p-adische Zahlen, konstruktive Behandlung von endlich erzeugten Moduln über Polynomalgebren: Rechnen in Restklassenringen, Präsentationen von Moduln, Anwendungen auf algebraische Gleichungssysteme
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Verständnis für Homomorphiekonzepte am Beispiel grundlegender algebraischer Strukturen entwickeln, algebraische Begriffsbildungen zusammen mit algorithmischen Konzepten einüben, formale Rechenmethoden und ihre Anwendbarkeit kennenlernen, strukturelles und algorithmisches Denken in grundlegenden Situationen verinnerlichen, diverse Computeralgebrasysteme benutzen sowie Basiswissen und Fertigkeiten für das weitere Studium erwerben.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	M. Artin: Algebra, Birkhäuser 1993; S. Lang: Algebra (third edition), Addison Wesley 1995; W.W. Adams, P. Loustaunau: An Introduction to Gröbner Bases, AMS 1994; D.F. Holt et al.: Handbook Of Computational Group Theory, Chapman &; Hall 2005
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung (benotet); Prüfungsdauer und -art werden zu Beginn der Lehrveranstaltung bekannt gegeben.
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr. rer. nat. Eva Zerz Universitätsprofessorin Dr. Alice Niemeyer
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0

Contact hours (h)	90,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Computeralgebra (111354902)	1st semester	no semester recommended	0	2
Exam Computeralgebra (111354901)	1st semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Computeralgebra	1st semester	no semester recommended	-	4
Globalübung Computeralgebra	1st semester	no semester recommended	-	-

Module titel	Introduction to Applied Statistics (Compulsory elective subject)
Identifier	1112714
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Bachelor/Master
Content	Grundlegende Methoden der Beschreibenden Statistik (Merkmale, Datentypen, graphische und tabellarische Darstellungen, empirische Verteilungsfunktion, Histogramm, Lage-, Streuungs- und Zusammenhangsmaße, Regressionsrechnung), Wiederholung stochastischer Grundbegriffe und Erweiterungen (stetige Wahrscheinlichkeitsverteilungen, Grenzwertsätze), stochastische Modellierung, Verfahren der Inferenzstatistik (Punktschätzung, Intervallschätzung und Statistische Tests für Binomial- und Normalverteilung, Regressionsmodelle)
Learning Objectives/ Learning Outcomes	Die Studierenden erlernen und beherrschen die Grundzüge der angewandten Statistik, sind sicher im Umgang mit grundlegenden Begriffen und Verfahren und sind in der Lage, die Gemeinsamkeiten und Unterschiede zwischen Beschreibender und Schließender Statistik zu verstehen und zu reflektieren. Sie können diese Sachverhalte schriftlich und mündlich in sachlich wie formal adäquater Weise darstellen, sind in der Lage, sie auch in komplexen anwendungsorientierten wie innermathematischen Problemstellungen anzuwenden und können Fragestellungen und Argumente eigenständig bearbeiten. Sie wissen um die Bedeutung und den Nutzen der Stochastik und Statistik für die Modellierung und Analyse zufallsabhängiger Vorgänge und können ihre Kenntnisse in konkreten Problemstellungen umsetzen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	-
References	Literatur: Cramer, E., Kamps, U. (2029) Grundlagen der Wahrscheinlichkeitsrechnung und Statistik. 5. Aufl. Springer, Berlin. Cramer, E., Kamps, U. (2020) Statistik griffbereit. Formelsammlung zur Wahrscheinlichkeitsrechnung und Statistik.6. Aufl. ISW, Aachen.
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben und/oder Programmieraufgaben mit einer statistischen Programmiersprache Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung (benotet); Prüfungsdauer und -art werden zu Beginn der Lehrveranstaltung bekannt gegeben.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Erhard Cramer Universitätsprofessor Dr. rer. nat. Udo Kamps Universitätsprofessorin ; Dr. rer. nat.Maria Kateri
ECTS Credits	6
Contact time (WSH)	4

Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Introduction to Applied Statistics (111271402)	1st semester	no semester recommended	0	1
Exam Introduction to Applied Statistics (111271401)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Einführung in die Angewandte Statistik	1st semester	no semester recommended	-	3

Module titel	Functional Analysis (Compulsory elective subject)
Identifier	1113551
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2010
Valid until	-
Module level	Bachelor/Master
Content	Funktionenräume und ihre Topologien, Vollständigkeit, Konvexe Mengen, Projektionen, Kompaktheit, Satz von Riesz, Lineare Operatoren, Lineare Funktionale, Rieszscher Darstellungssatz, Satz von Hahn-Banach, Prinzip der gleichmäßigen Beschränktheit, Schwache Konvergenz, Endlich dimensionale Approximation, Kompakte Operatoren, Spektrum kompakter Operatoren, Spektralsatz für kompakte und normale Operatoren.
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Techniken der Analysis I - III und der Linearen Algebra I - II in einem Teilgebiet der Mathematik kennenlernen, das vielen Gebieten in der Mathematik und der Theoretischen Physik zugrunde liegt.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse des Moduls Analysis III und Lineare Algebra II
References	W. Alt, Lineare Funktionalanalysis, Springer Verlag 2002; D. Werner, Funktionalanalysis, Springer Verlag 2000; H. Heuser, Funktionalanalysis, Teubner Verlag 1992; G. Bachman, L. Narici, Functional Analysis, Dover 2000; W. Rudin, Functional Analysis, Mc Graw Hill 1973; Z. Wloka, Funktionalanalysis und ihre Anwendungen, De Gruyter 1971
Language	German
Examination Terms	Zulassungsvoraussetzungen: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Sebastian Noelle Universitätsprofessor Dr. rer. nat. Christof Erich Melcher
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0

Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Functional Analysis (111355102)	1st semester	no semester recommended	0	2
Exam Functional Analysis (111355101)	1st semester	no semester recommended	9	0

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Funktionalanalysis	1st semester	no semester recommended	-	4

Module titel	Complex Analysis I (Compulsory elective subject)
Identifier	1113550
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2017
Valid until	-
Module level	Bachelor/Master
Content	Komplexe Differenzierbarkeit und Cauchy-Riemannsche Differentialgleichungen, Kurvenintegrale, Cauchysche Theorie, Abbildungsverhalten holomorpher Funktionen, einfach zusammenhängende Gebiete, isolierte Singularitäten, Residuensatz mit Anwendungen auf reelle Integrale, Produktdarstellungen, Gamma-Funktion, Riemannscher Abbildungssatz.
Learning Objectives/ Learning Outcomes	Die Studierenden sollen die Grundzüge der komplexen Analysis beherrschen und ihre Bedeutung für die reelle Analysis kennenlernen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	W. Fischer, I. Lieb: Funktionentheorie, Vieweg 2005; E. Freitag, W. Busam: Funktionentheorie, Springer-Verlag, Berlin 2000; A. Krieg: Funktionentheorie I, Skript, RWTH Aachen 2010; R. Remmert, G. Schumacher: Funktionentheorie, Springer-Verlag, Berlin 2002
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung (benotet); Prüfungsdauer und -art werden zu Beginn der Lehrveranstaltung bekannt gegeben.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Hartmut Führ
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

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Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Complex Analysis I (111355002)	2nd semester	no semester recommended	0	2
Exam Complex Analysis I (111355001)	2nd semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Funktionentheorie I	2nd semester	no semester recommended	-	4

Module titel	Complex Analysis II (Compulsory elective subject)
Identifier	1113590
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	-
Valid until	-
Module level	Master
Content	Analytische Fortsetzung, Harmonische Funktionen, Partialbruchentwicklungen, Elliptische Funktionen, Elliptische Modulformen
Learning Objectives/ Learning Outcomes	Die Studierenden sollen die Methoden der komplexen Analysis vertiefen und Anwendungen auf die Zahlentheorie kennenlernen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Keine
References	W. Fischer, I. Lieb, Funktionentheorie, Vieweg 2005; E. Freitag, R. Busam, Funktionentheorie I, Springer-Verlag, Berlin 2000; M. Koecher, A. Krieg, Elliptische Funktionen und Modulformen, Springer-Verlag, Berlin 1998
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	N.N.
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Complex Analysis II (111359002)	3rd semester	no semester recommended	0	2
Exam Complex Analysis II (111359001)	3rd semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Funktionentheorie II	3rd semester	no semester recommended	-	4

RWTH AACHEN UNIVERSITY

Module titel	Geometric Analysis II (Compulsory elective subject)
Identifier	1113623
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	-
Valid until	-
Module level	Master
Content	Es werden ausgewählte und der aktuellen Forschungssituation angepasste Fragestellungen aus den folgenden Bereichen behandelt: nichtlineare partielle Differentialgleichungen in der konformen Geometrie, geometrische Maßtheorie, geometrische Randwert- und Hindernisprobleme, Analysis freier Ränder, optimale Lösungen geometrischer Variationsprobleme, geometrische Evolutionsgleichungen, harmonische Analysis und Geometrie, analytische Methoden in der Riemannschen Geometrie und Finslergeometrie
Learning Objectives/ Learning Outcomes	Die Studierenden werden die hinter geometrischen Problemen liegenden analytischen Schwierigkeiten untersuchen, das Zusammenspiel verschiedener analytischer Techniken bei der Bearbeitung geometrisch motivierter Fragestellungen erarbeiten und moderne analytische Techniken für gegebene differentialgeometrische Probleme modifizieren und weiterentwickeln.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Keine
References	Originalarbeiten
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Dr. rer. nat. Alfred Wagner Universitätsprofessor Dr. rer. nat. Heiko von der Mosel
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Geometric Analysis II (111362302)	2nd semester	no semester recommended	0	1
Exam Geometric Analysis II (111362301)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Geometrische Analysis II	2nd semester	no semester recommended	-	2

Module titel	High-dimensional Probability for Mathematicians and Data Scientists (Compulsory elective subject)
Identifier	1117182
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	Concentration inequalities, random matrices, matrix concentration inequalities, chaining methods, selected applications in data science including machine learning, signal processing and random matrix theory
Learning Objectives/ Learning Outcomes	Goal of the course is to gain understanding of high-dimensional probability theory, in particular methods to establish concentration inequalities and chaining methods, and to develop the ability to apply techniques from high-dimensional probability to problems in data science.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Recent literature
Language	English
Examination Terms	To participate in the examination the solution of selected exercise is required Written or oral examination at the end of the term
Miscellaneous	-
Module coordinator	Holger Rauhut, Ulrich Terstiege
ECTS Credits	9
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	270,0
Contact hours (h)	15,0
Self-study hours (h)	255,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Assessment High-dimensional Probability for Mathematicians and Data Scientists (111718201)	1st semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture High-dimensional Probability for Mathematicians and Data Scientists	1st semester	no semester recommended	-	4
Tutorial High-dimensional Probability for Mathematicians and Data Scientists	1st semester	no semester recommended	-	2

RWTH AACHEN UNIVERSITY

Module titel	Lie Algebras (Compulsory elective subject)
Identifier	1113597
Version	-
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2021
Valid until	-
Module level	Bachelor/Master
Content	Lie-Algebren und ihre universell Einhüllenden, endlich-dimensionale nilpotente, auflösbare und halbeinfache Lie-Algebren über den komplexen Zahlen, Wurzelsysteme, Klassifikation der endlich-dimensionalen komplexen halbeinfachen Lie-Algebren, Beispiele für deformierte universell Einhüllende (Quantengruppen), Einführung in die Darstellungstheorie der endlich-dimensionalen komplexen halbeinfachen Lie-Algebren
Learning Objectives/ Learning Outcomes	Die Studierenden sollen in die Strukturtheorie der Lie-Algebren eingeführt werden, die Klassifikation der einfachen, endlich-dimensionalen, komplexen Lie-Algebren kennenlernen sowie Basiswissen und Fertigkeiten für das weitere Studium und die Abschlussarbeit erlangen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Keine
References	W.A. de Graaf, Lie algebras, theory and algorithms, North-Holland Publishing Co. 2000; J.E. Humphreys, Introduction to Lie algebras and representation theory, Springer 1972; N. Jacobson, Lie algebras, Dover Publications 1979
Language	German/English
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Prof. Dr. G. Fourier Prof. Dr. A. Niemeyer
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Lie Algebras (111359702)	1st semester	no semester recommended	0	2
Exam Lie Algebras (111359701)	1st semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Lie-Algebren	1st semester	no semester recommended	-	4

Module titel	High-dimensional Probability Theory (Compulsory elective subject)
Identifier	1113571
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2015
Valid until	-
Module level	Master
Content	Chernoff, Hoeffding and Bernstein inequalities, Stein's method, variance bounds, Poincaré inequalities, Martingale method, entropy method, log-Sobolev inequalities, connections to information theory and transportation cost inequalities, convex distance inequality, chaining, generic chaining, selected applications, for instance in random matrix theory or statistical learning
Learning Objectives/ Learning Outcomes	Goal of the course is to gain understanding of high-dimensional probability theory, in particular methods to establish concentration inequalities and chaining methods, and to develop the ability to apply techniques from high-dimensional probability to practical problems.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Current Literature
Language	English
Examination Terms	Homework Written or oral examination. Type and length of the exam will be announced in the beginning of the semester.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Ansgar Steland
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise High-dimensional Probability Theory (111357102)	1st semester	no semester recommended	0	2
Exam High-dimensional Probability Theory (111357101)	1st semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung High-dimensional Probability Theory	1st semester	no semester recommended	-	4

Module titel	Mathematical Foundations of Machine Learning (Compulsory elective subject)
Identifier	1114996
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2022
Valid until	-
Module level	Master
Content	Bayesian learning, principal component analysis,neural networks, support vector machines, kernel methods, reproducing kernel Hilbert spaces, clustering
Learning Objectives/ Learning Outcomes	The goal of the course is to gain basic understanding of the theoretical foundations of machine learning. In particular, the course will emphasize on the mathematical formulation of machine learning concepts and algorithms as well as their rigorous analysis.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None
References	Aktuelle Literatur
Language	English
Examination Terms	Homework Written or oral examination. Type and length of the exam will be announced in the beginning of the semester.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Holger Rauhut
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Mathematical Foundations of Machine Learning (111499602)	1st semester	no semester recommended	0	2
Exam Mathematical Foundations of Machine Learning (111499601)	1st semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Mathematical Foundations of Machine Learning	1st semester	no semester recommended	-	4

Module titel	Mathematical Models in Science and Engineering (Part 2, PDEs) (Compulsory elective subject)
Identifier	1114969
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Bachelor/Master
Content	1. Mathematische Grundlagen 2. Kinematik 3. Feldgleichungen 4. Festkörpermechanik 5. Thermodynamik 6. Strömungslehre 7. Kinetische Gastheorie 8. Elektrodynamik 9. Magnetohydrodynamik
Learning Objectives/ Learning Outcomes	Technisch-physikalische Prozesse, die kontinuierlich in Raum und Zeit sind, werden mit partiellen Differentialgleichungen (PDEs) beschrieben. Ziel der Vorlesung ist es die Zusammenhänge der relevanten partiellen Differentialgleichungen der angewandten Mathematik aufzuzeigen und den Prozess der Modellierung vom physikalischen Konzept über die mathematischen Gleichungen bis zum konkreten Resultat zu beherrschen. Die Vorlesung präsentiert eine zusammenhängende mathematische Herleitung und Diskussion verschiedener partieller Differentialgleichungen als Modelle für technische und naturwissenschaftliche Prozesse.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	(Kenntnisse) Mathematische Grundlagen I-III Erfahrung mit Matlab/Maple/Mathematica nützlich
References	• teilweise: R. Temam, A. Miranville, Mathematical Modeling in Continuum Mechanics, Cambridge University Press, 2000
Language	German
Examination Terms	Eine mündliche Prüfung und Bearbeitung von Hausaufgaben
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher MathematikModellierungsteamverantwortlicher: Dr. rer. nat. Katja PetzoldtModulverantworlicher: Universitätsprofessor Dr. rer. nat. Martin FrankUniversitätsprofessor Dr. Manuel Torrilhon
ECTS Credits	5
Contact time (WSH)	5
Examination duration (min)	0

Total hours (h)	150,0
Contact hours (h)	75,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Mathematical Models in Science and Engineering (Part 2, PDEs) (111496902)	1st semester	no semester recommended	0	5
Exam Mathematical Models in Science and Engineering (Part 2, PDEs) (111496901)	1st semester	no semester recommended	5	0

Module titel	Mathematical Models in Ordinary Differential Equations (Compulsory elective subject)
Identifier	1113517
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2011
Valid until	-
Module level	Bachelor/Master
Content	Gewöhnliche Differentialgleichungen (ODEs) bilden die Grundlagen von vielen zeitabhängigen Prozessen in den Natur- und Ingenieurwissenschaften. Anhand verschiedener Anwendungsbeispiele wird in der Vorlesung gezeigt wie sich die mathematischen Eigenschaften von ODEs in der Modellierung wiederfinden. Mögliche Themen sind: Multi-Skalen Relaxation, Populationsmodelle, Räuber-Beute-Interaktion, Chemische Reaktionen, Newton-Mechanik, Wärmeleitung, etc.
Learning Objectives/ Learning Outcomes	Ziel der Vorlesung ist es die qualitativen Eigenschaften von Lösungen von ODEs in der angewandten Mathematik zu verstehen und den Prozess der Modellierung vom physikalischen Konzept über die mathematischen Gleichungen bis zum konkreten Resultat zu beherrschen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Keine
References	teilweise: K.K.Tung, Topics in Mathematical Modeling, Princeton University Press, 2007
Language	German/English
Examination Terms	Prüfungsleistung: Projektarbeit, mündliche Prüfung, Hausaufgaben; Prüfungsdauer wird am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. Manuel Torrilhon
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Mathematical Models in Ordinary Differential Equations (111351702)	1st semester	no semester recommended	0	2
Exam Mathematical Models in Ordinary Differential Equations (111351701)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Mathematische Modelle (ODEs)	1st semester	no semester recommended	-	2

Module titel	Numerical Analysis I (Compulsory elective subject)
Identifier	1114980
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2006
Valid until	-
Module level	Bachelor/Master
Content	Fehleranalyse, Kondition, Rundungsfehler, Stabilität, Direkte Lösungsverfahren für lineare Gleichungssysteme, Lineare Ausgleichsrechnung, Iteratives Lösen nichtlinearer Gleichungssysteme, Nichtlineare Ausgleichsrechnung, Lösen von Eigenwertproblemen
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Verständnis für grundlegende Begriffe der numerischen Analysis, insbesondere der Kondition eines Problems und Stabilität eines Algorithmus und der darauf basierenden Fehleranalyse, entwickeln, die Fähigkeit erwerben, grundlegende numerische Methoden in ihrer Funktionsweise zu verstehen, die durch sie erreichbaren Ergebnisse einzuschätzen und darauf aufbauend in flexibler Anpassung an neue Aufgabenstellungen die Methode weiter zu entwickeln, die Grundbegriffe und Konzepte wie Matrixfaktorisierungen, Projektionen und iterative Lösungsansätze sicher beherrschen und die Fähigkeit zum aktiven Umgang mit den Gegenständen der Lehrveranstaltung erwerben und aufbauend auf diesen methodischen Werkzeugen erste grundlegende Konzepte für das approximative Lösen wissenschaftlicher und technischer Probleme aneignen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse der Module Analysis I, Lineare Algebra I
References	W. Dahmen, A. Reusken, Numerik für Ingenieure und Naturwissenschaftler, Springer 2006; P. Deuflhard, A. Hohmann, Numerische Mathematik I, de Gruyter 2002; A. Reusken, Numerische Analysis I (Skript)
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Sebastian Noelle Universitätsprofessor Dr. rer. nat. Arnold Reusken
ECTS Credits	6
Contact time (WSH)	6
Examination duration (min)	0

Physics MSPhy
–
Elective Courses

– Subsidiary Subjects
– Mathematics
+ Numerical Analysis I (1114980)

Total hours (h)	180,0
Contact hours (h)	90,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Numerical Analysis (111498002)	1st semester	no semester recommended	0	3
Exam Numerical Analysis I (111498001)	1st semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Numerical Analysis	1st semester	no semester recommended	-	3

Module titel	Numerical Analysis II (Compulsory elective subject)
Identifier	1114981
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2007
Valid until	-
Module level	Bachelor/Master
Content	Approximation und Interpolation mit Polynomen, Spline-Funktionen, schnelle Fourier-Transformation, Numerische Integration
Learning Objectives/ Learning Outcomes	Die Studierenden sollen das Verständnis für grundlegende Begriffe der numerischen Analysis, insbesondere Kondition eines Problems und Stabilität eines Algorithmus sowie der darauf basierenden Fehleranalyse, vertiefen, die Fähigkeit erwerben, grundlegende numerische Methoden in ihrer Funktionsweise zu verstehen, die durch sie erreichbaren Ergebnisse einzuschätzen und darauf aufbauend in flexibler Anpassung an neue Aufgabenstellungen die Methode weiterzuentwickeln, Grundbegriffe und -techniken wie Interpolation, Glattheits-Eigenschaften und Approximationsgüte sicher beherrschen und die Fähigkeit zum aktiven Umgang mit den Gegenständen der Lehrveranstaltung erwerben und aufbauend auf diesen methodischen Werkzeugen erste grundlegende Konzepte für das approximative Lösen wissenschaftlicher und technischer Probleme aneignen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse der Module Analysis I, Lineare Algebra I, Numerische Analysis I
References	W. Dahmen, A. Reusken, Numerik für Ingenieure und Naturwissenschaftler, Springer 2006; P. Deuflhard, A. Hohmann, Numerische Mathematik I, de Gruyter 2002; A. Reusken, Numerische Analysis II (Skript)
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Sebastian Noelle Universitätsprofessor Dr. rer. nat. Arnold Reusken
ECTS Credits	6
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	180,0

Contact hours (h)	90,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Numerical Analysis (111498102)	2nd semester	no semester recommended	0	3
Exam Numerical Analysis II (111498101)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Numerical Analysis II	2nd semester	no semester recommended	-	3

Module titel	Mathematical Lab (Compulsory elective subject)
Identifier	1114983
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2007
Valid until	-
Module level	Bachelor/Master
Content	Wechselnde Fragestellungen und Algorithmen aus der diskreten Optimierung, Gruppentheorie, Zahlentheorie, linearen Algebra, Bildverarbeitung, Datenkompression, Numerik etc.
Learning Objectives/ Learning Outcomes	Die Studierenden sollen lernen, für Probleme aus verschiedenen Gebieten der Mathematik effiziente algorithmische Lösungen zu entwickeln. Sie sollen die Fähigkeit zur Umsetzung abstrakter Algorithmen in C++ Programme erwerben, Grundlagen erarbeiten, um Programmieraufgaben für andere mathematische Veranstaltungen des Bachelor-Studiums zu lösen, und Voraussetzungen schaffen, um später bei der mathematischen Simulation naturwissenschaftlicher und technischer Probleme mitzuwirken.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse der Module Analysis I, II, Lineare Algebra I, Numerische Analysis I
References	Wechselnd, je nach behandelten Themen
Language	German
Examination Terms	Zulassungsvoraussetzung: Regelmäßige Teilnahme und Testate für Programmieraufgaben Prüfungsleistung: Bestehen einer mündlichen Prüfung; Prüfungsdauer wird am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Sebastian Noelle
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Mathematical Lab (111498302)	2nd semester	no semester recommended	0	4
Exam Mathematical Lab (111498301)	2nd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Numerisches Praktikum	2nd semester	no semester recommended	-	0

Module titel	Partial Differential Equations I (Compulsory elective subject)
Identifier	1113553
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2007
Valid until	-
Module level	Bachelor/Master
Content	Typeneinteilung partieller Differentialgleichungen, Einführung in die Potentialtheorie, Hilbertraum-Methoden: Darstellungssatz von Riesz, Lemma von Lax-Milgram, Sobolev Räume, Fourier-Transformation, Spursätze, H-Regularität schwacher Lösungen, Eigenwertprobleme für elliptische Operatoren
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Techniken der Analysis I-III in einem Kerngebiet der modernen Mathematik anwenden. Es wird die Fähigkeit vermittelt, sich eigenständig in einen Themenbereich der aktuellen Forschung einzuarbeiten. Die Studierenden sollen die zentrale Rolle der Partiellen Differentialgleichungen in Natur- und Ingenieurwissenschaften kennenlernen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Keine
References	M. Renardy, R. Rogers: An Introduction to Partial Differential Equations, Springer Verlag 2004; L.C. Evans: Partial Differential Equations, AMS 1998; D. Gilbarg, N. Trudinger: Partial Differential Operations of Second Order, Springer Verlag 2001; L.C. Evans, R.F. Gariepy: Measure Theory and Fine Properties of Functions, CRC Press 1992
Language	German/English
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Christof Erich Melcher Dr. rer. nat. Alfred Wagner
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0

Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Partial Differential Equations I (111355302)	2nd semester	no semester recommended	0	2
Exam Partial Differential Equations I (111355301)	2nd semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Partielle Differentialgleichungen I	2nd semester	no semester recommended	-	4

Module titel	Partial Differential Equations II (Compulsory elective subject)
Identifier	1113633
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2008
Valid until	-
Module level	Master
Content	Evolutionsgleichungen: Spezielle Gleichungen, Maximum-Prinzipien, schwache Formulierung, Existenztheorie, Regularität, Nichtlineare Gleichungen, Qualitative Theorie
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Techniken der Analysis I - III und der Partiellen Differentialgleichungen I in einem Kerngebiet der modernen Mathematik anwenden. Es wird die Fähigkeit vermittelt, sich eigenständig in einen Themenbereich der aktuellen Forschung einzuarbeiten. Die Studierenden sollen die zentrale Rolle der Partiellen Differentialgleichungen in Natur- und Ingenieurwissenschaften kennen lernen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Grundkenntnisse des Moduls Partielle Differentialgleichungen I
References	L.C. Evans: Partial Differential Equations, AMS 1998; M. Renardy, R. Rogers: An Introduction to Partial Differential Equations, Springer-Verlag 2004; E. Di Benedetto: Partial Differential Equations, Birkhäuser 1995; D. Henry: Geometric Theory of Semilinear Parabolic Equations, Springer-Verlag 1981; J. Smoller: Stock Waves and Reaction Diffusion Equations, Springer-Verlag 1983; G.R. Sell, Y. You: Dynamics of Evolutionary Equations, Springer-Verlag 2002
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Christof Erich Melcher Dr. rer. nat. Alfred Wagner
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0
Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Partial Differential Equations II (111363302)	3rd semester	no semester recommended	0	2
Exam Partial Differential Equations II (111363301)	3rd semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Partielle Differentialgleichungen II	3rd semester	no semester recommended	-	4

Module titel	Stochastics I (Compulsory elective subject)
Identifier	1114978
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2007
Valid until	-
Module level	Bachelor/Master
Content	Diskreter Wahrscheinlichkeitsraum, Grundformeln der Kombinatorik, Eigenschaften von Wahrscheinlichkeitsräumen, bedingte Wahrscheinlichkeit, stochastische Unabhängigkeit, Zufallsvariablen, Erwartungswerte, elementare Grenzwertsätze, Borelmengen und Maße, Maße mit Riemann-Dichten.
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Kenntnis und Verständnis der grundlegenden Begriffe und Prinzipien der Stochastik, insbesondere in diskreten Wahrscheinlichkeitsräumen, erwerben. Sie sollen lernen, die elementaren Konzepte und Methoden der Stochastik zielgerichtet und sicher anzuwenden, Aussagen der Wahrscheinlichkeitsrechnung zu bewerten und interpretieren zu können, Wesen und Zielsetzung von (stochastischen) Modellen zu verstehen, einfache stochastische Modelle nachzuvollziehen und selbst zu entwickeln. Sie sollen das Arbeiten in einem Modell lernen, Lösungsstrategien für gestellte Aufgaben und praktische Anforderungen entwickeln und umsetzen können, mit dieser Veranstaltung ein sicheres Fundament für nachfolgende Lehrveranstaltungen zur Stochastik erwerben.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse des Moduls Analysis I
References	Skript und Bereitstellung von Lerninhalten, Aufgaben und Lösungen in der Lehr- und Lernumgebung EMILeA-stat (http://emilea-stat.rwth-aachen.de). Weitere Literatur wird in der Vorlesung bekannt gegeben.
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung (benotet); Prüfungsdauer und -art werden zu Beginn der Lehrveranstaltung bekannt gegeben.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Udo Kamps
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Stochastics I (111497802)	2nd semester	no semester recommended	0	2
Exam Stochastics I (111497801)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Stochastics I	2nd semester	no semester recommended	-	2
Discussion Stochastics I	2nd semester	no semester recommended	-	-

Module titel	Stochastics II (Compulsory elective subject)
Identifier	1114979
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2006
Valid until	-
Module level	Bachelor/Master
Content	Messbare Abbildungen, Integral bezüglich eines Maßes, Wahrscheinlichkeitsmaße mit Dichten, Produktmaß und stochastische Unabhängigkeit, Grenzwertsätze, charakteristische Funktionen, Anwendung charakteristischer Funktionen und Verteilungskonvergenz , Einblick in die Statistik.
Learning Objectives/ Learning Outcomes	Die Studierenden sollen Kenntnis und Verständnis der grundlegenden Begriffe und Prinzipien der Stochastik erwerben. Sie sollen lernen, die elementaren Konzepte und Methoden der Stochastik zielgerichtet und sicher anzuwenden, Aussagen der Wahrscheinlichkeitsrechnung zu bewerten und interpretieren zu können, Wesen und Zielsetzung von (stochastischen) Modellen zu verstehen, einfache stochastische Modelle nachzuvollziehen und selbst zu entwickeln. Sie sollen das Arbeiten in einem Modell lernen, Lösungsstrategien für gestellte Aufgaben und praktische Anforderungen entwickeln und umsetzen können, mit dieser Veranstaltung ein sicheres Fundament für nachfolgende Lehrveranstaltungen zur Stochastik erwerben.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse der Module Analysis I, II, Stochastik I
References	Skript und Bereitstellung von Lerninhalten, Aufgaben und Lösungen in der Lehr- und Lernumgebung EMILeA-stat (http://emilea-stat.rwth-aachen.de). Weitere Literatur wird in der Vorlesung bekannt gegeben.
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Udo Kamps
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Stochastics II (111497902)	3rd semester	no semester recommended	0	2
Exam Stochastics II (111497901)	3rd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Stochastics II	3rd semester	no semester recommended	-	2
Discussion Stochastics II	3rd semester	no semester recommended	-	-

Module titel	Calculus of Variations I (Compulsory elective subject)
Identifier	1113554
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2006
Valid until	-
Module level	Bachelor/Master
Content	Euler-Lagrange-Gleichungen, eindimensionaler Variationsintegrale, Sobolev-Funktionen auf beschränkten Gebieten, Dirichlet-Prinzip, Kompaktheitskriterien, Unterhalbstetigkeit, Existenzsätze, Regularität schwacher Lösungen
Learning Objectives/ Learning Outcomes	Die Studierenden sollen in ein klassisches Teilgebiet der Mathematik eingeführt werden. Dazu werden Begriffe wie Minimum, Maximum und kritischer Punkt, die aus der Analysis I, II bekannt sind, erweitert und klassische eindimensionale Minimierungsaufgaben vorgestellt. Die Studierenden sollen befähigt werden, eigenständig Minimierungsprobleme zu formulieren und zu bearbeiten.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Keine
References	G. Buttazzo, M. Giaquinta, S. Hildebrandt: One Dimensional Variational Problems, Oxford University Press 1988; U. Brechtken-Manderscheid: Einführung in die Variationsrechnung, Wissenschaftliche Buchgesellschaft 1983; W. Rudin: Reelle und Komplexe Analysis, Oldenbourg Verlag 1999;
Language	German/English
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder mündlichen Prüfung; Prüfungsdauer und -art werden am Anfang des Semesters bekannt gegeben
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Christof Erich Melcher Dr. rer. nat. Alfred Wagner
ECTS Credits	9
Contact time (WSH)	6
Examination duration (min)	0
Total hours (h)	270,0
Contact hours (h)	90,0

Self-study hours (h)	180,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Calculus of Variations I (111355402)	1st semester	no semester recommended	0	2
Exam Calculus of Variations I (111355401)	1st semester	no semester recommended	9	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Variationsrechnung I	1st semester	no semester recommended	-	4

Module titel	Number Theory (Compulsory elective subject)
Identifier	1110927
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	-
Valid until	-
Module level	Bachelor/Master
Content	Arithmetik, elementare Primzahlverteilung, Kongruenzen, prime Restklassen, Summen von Quadraten, pythagoräische Tripel, Irrationalität und Transzendenz, Algorithmische Zahlentheorie
Learning Objectives/ Learning Outcomes	Die Studierenden sollen algebraische Methoden am Beispiel des Ringes Z der ganzen Zahlen kennenlernen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Kenntnisse des Moduls Lineare Algebra II
References	T.M. Apostol: Introduction to analytic number theory, Springer-Verlag, New York 1976; F. Ischebeck: Einladung zur Zahlentheorie; B-I, Mannheim 1992; A. Krieg: Elementare Zahlentheorie, Skript, RWTH Aachen 2005; A. Leutbecher: Zahlentheorie, Springer-Verlag, Berlin 1996; R. Remmert, P. Ullrich: Elementare Zahlentheorie, Birkhäuser, Basel 1995; H. Scheid: Zahlentheorie, Spektrum-Verlag, Heidelberg 2003
Language	German
Examination Terms	Zulassungsvoraussetzung: Lösen von Übungsaufgaben Prüfungsleistung: Bestehen einer Klausur oder einer mündlichen Prüfung (benotet); Prüfungsdauer und -art werden zu Beginn der Lehrveranstaltung bekannt gegeben.
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr. Alice Niemeyer Universitätsprofessorin Dr. rer. nat. Eva Zerz
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0
Contact hours (h)	60,0

Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Number Theory (111092702)	2nd semester	no semester recommended	0	1
Exam Number Theory (111092701)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Zahlentheorie	2nd semester	no semester recommended	-	3

Module titel	Employee Inventions Law (Compulsory elective subject)
Identifier	5212575
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	- Wem gehören Arbeitnehmererfindungen? - Welche Vergütung erhalten Arbeitnehmererfinder? - Hochschulerfindungen - Know-how-Schutz für Betriebsgeheimnisse
Learning Objectives/ Learning Outcomes	Grundlegende Kenntnisse im Arbeitnehmererfinderrecht
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	none
References	-
Language	German
Examination Terms	Written examination, oral examination or presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator:FB5 Modul-AVModellierungsteamverantwortlicher:Kimberly Meyer B. A. RWTHModulverantworlicher:Honorarprofessor Dr.iur. Michael Trimborn
ECTS Credits	3
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	90,0
Contact hours (h)	30,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture/Exercise Employee Inventions Law (521257502)	2nd semester	no semester recommended	0	2
Exam Employee Inventions Law (521257501)	2nd semester	no semester recommended	3	0

Module titel	Introduction to the Patent Law and National Patent Law (Compulsory elective subject)
Identifier	6015524
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	Topics of lecture: The lecture deals with the protection of intellectual property in the field of engineering. The subject matter contains the registration, the granting and the implementation of property rights in the field of engineering, particularly relating to patents. Structure of lecture: # History of patent law # Material patent law: innovation, inventive step # Selection of lawful, technical and economical suitable inventions
Learning Objectives/ Learning Outcomes	The students shall obtain an appropriate and advanced comprehension regarding the basic principles of patent law. Furthermore the assessment skills for the evaluation of the technological, economical and strategical virtue of patents shall be created. This performance of the bachelor study course focuses on the national law.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	will be announced in the lecture.
Language	German/English
Examination Terms	oral examination (30 min) or written examination (90min)
Miscellaneous	-
Module coordinator	Dr. Hans-Dieter Jostarndt
ECTS Credits	6
Contact time (WSH)	6
Examination duration (min)	90 oder 30
Total hours (h)	180,0
Contact hours (h)	90,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Introduction to the Patent Law and National Patent Law (601552401)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Introduction to the Patent Law and National Patent Law	2nd semester	no semester recommended	-	6

Module titel	International Patent Law (Compulsory elective subject)
Identifier	6010424
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2012
Valid until	-
Module level	Master
Content	Topics: The lecture addresses the protection of intellectual property in a technical context. The processes of application, granting and the enforcement of protective rights, especially patents are part of the lecture. Outline oft he Lecture: # History of patent law # Substantial Patent Law: Novelty, Inventive Step # How to assess patentability # technically, economically and legally # Procedural law using the European grant procedure as an example # Grounds for revocation of European patents (missing patentability, inadequate disclosure, inadmissible extension) # Opposition proceedings before the European Patent Office # Actions for annulment # Strategies to enforce protective rights by envoking infigement proceedings
Learning Objectives/ Learning Outcomes	The students are taught a deeper understanding of international patent law. Furthermore the competences to evaluate the technological, economical and strategical value of patents shall be trained.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Gewerbliche Schutzrechte in Russland und den GUS-Staaten und Einführung in das Eurasische Patentübereinkommen 1. Aufl. 2003 (Blinnikow/Zellentin), Verlag: Heymanns # Intellectual Property Issues in Commercial Transactions 1. Aufl. 2008 (Demetriades, Christina), Verlag Sweet & Maxwell # European National Patent Decisions Report 2004, published by the European Patent Office # Guidelines for examination in the European patent office 2010; published by the European Patent Office # The Economics of the European Patent System, IP Policy for Innovation and Competition", First published 2007 (Dominique Guellec and Bruno van Pottelsberghe de la Potterie); published in the United States by Oxford University Press Inc., New York # PCT Procedures and Passage into the European Phase, Peter Watchorn & Andrea Veronese; 2nd Edition 2010, published Medienhaus Kastner AG
Language	German/English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Dr. Hans-Dieter Jostarndt
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90 oder 30

Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam International Patent Law (601042401)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise International Patent Law	1st semester	no semester recommended	-	3

Module titel	Patent Law (Compulsory elective subject)
Identifier	5212574
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	- Patentschutz: Neuheit, Erfindungshöhe - Patentschrift: Aufbau, praktische Beispiele - Patentverletzung: Schadensersatz, Vorgehen gegen Verletzer - Lizensierung von Patenten u. Know-how-Schutz für Betriebsgeheimnisse
Learning Objectives/ Learning Outcomes	Grundlegende Kenntnisse im Patentrecht
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	none
References	-
Language	German
Examination Terms	Written examination, oral examination or presentation
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: FB5 Modul-AVModellierungsteamverantwortlicher: Kimberly Meyer B. A. RWTHModulverantworlicher: Honorarprofessor Dr.iur. Michael Trimborn
ECTS Credits	4
Contact time (WSH)	2
Examination duration (min)	0
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Patent Law: Lecture and Exercise (521257402)	1st semester	no semester recommended	0	2
Exam Patent Law (521257401)	1st semester	no semester recommended	4	0

Module titel	Introduction to epistomology (Compulsory elective subject)
Identifier	7014106
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2007
Valid until	-
Module level	Master
Content	Das Seminar ist eine einführende Lehrveranstaltung zur Erkenntnistheorie, deren Ziel es ist, die Teilnehmer mit den wichtigsten Grundbegriffen dieser zentralen philosophischen Disziplin vertraut zu machen. Die Fragen „Was ist Wissen?“ und „Wann sind wir berechtigt zu sagen, dass wir etwas wissen?“ sollen dabei sowohl von einer historischen als auch von einer systematischen Perspektive her beleuchtet werden. Die historische Betrachtung sieht den Erkenntnistheoretiker seit den Anfängen der Philosophie in einen Disput mit dem Skeptiker verstrickt. Letzterer geht davon aus, dass es kein Wissen gibt, wobei Skeptiker mit dieser Behauptung verschiedene Ziele verfolgen: Für Sokrates war der Skeptizismus ein Schritt auf dem Weg zum Wissen, pyrrhonische Skeptiker versuchten durch Einnahme einer skeptischen Position die Ataraxie zu erreichen, während die akademische Skepsis einfach den Standpunkt vertrat, dass es kein Wissen gibt. Diese Ziele werden bei vielen Philosophien offenkundig: René Descartes geht von einem methodischen Skeptizismus aus, um zu unbezweifelbaren Sätzen zu gelangen. David Hume weist auf das Induktionsproblem hin und vertritt damit einen theoretischen, partiellen Skeptizismus. In einer systematischen Betrachtung zeigen sich Fragen und Standpunkte, welche die Epistemologie immer wieder bzw. gegenwärtig beschäftigen: Quellen unserer Erkenntnis, Wissen und Wahrheit, synthetisches Wissen a ariori, Realismus und Idealismus, Quines naturalisierte Erkenntnistheorie.
Learning Objectives/ Learning Outcomes	Nach erfolgreicher Absolvierung der Lehrveranstaltung sollen die Teilnehmerinnen und Teilnehmer: - Grundbegriffe der Erkenntnistheorie nennen und erklären können. - Grundprobleme der Erkenntnistheorie nennen und erklären können. - verschiedene erkenntnistheoretische Positionen nennen, deren Thesen erklären und kritisch hinterfragen können. - sich eine fundierte Meinung bezüglich erkenntnistheoretischer Fragestellungen gebildet haben und diese ausdrücken können. - den eigenen Standpunkt bezüglich erkenntnistheoretischer Positionen darlegen, begründen und verteidigen können. - an einem fachlichen Diskurs bezüglich erkenntnistheoretischer Fragestellungen teilnehmen können.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	-
Language	German
Examination Terms	Graded Task(s)
Miscellaneous	-
Module coordinator	• Modulangebotsorganisation: LeMa-Team Philosophische Fakultät, modulangebotsorganisation@fb7.rwth-aachen.de • Modulverantung: Univ.-Prof. Dr. phil. Gabriele Gramelsberger
ECTS Credits	4

Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	30,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to epistomology: Module examination (701410601)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to epistomology: Classes	1st semester	no semester recommended	-	2

Module titel	Introduction to the philosophy of science (Compulsory elective subject)
Identifier	7014105
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2007
Valid until	-
Module level	-
Content	Gegenstand des Seminars werden die Grundbegriffe, die zentralen Fragestellungen sowie wichtige Positionen der Wissenschaftstheorie sein, die wir uns anhand klassischer Texte erarbeiten wollen. Dabei werden wir unter anderem eingehen auf Versuche der Abgrenzung der Wissenschaft von Pseudowissenschaften, auf die Duhem-Quine-These und die empirische Unterbestimmtheit von wissenschaftlichen Theorien, auf das Induktionsproblem sowie Poppers Falsifikationismus, auf Theorien der wissenschaftlichen Bestätigung und der wissenschaftlichen Erklärung, auf die Rolle von Beobachtung und Experiment, auf den Status von Naturgesetzen, auf die Theorie der wissenschaftlichen Revolutionen Kuhns, auf Feyerabends Argumentation wider den Methodenzwang sowie auf die Frage des wissenschaftlichen Realismus.
Learning Objectives/ Learning Outcomes	Grundkenntnisse im Bereich der Wissenschaftstheorie
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	-
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	• Modulangebotsorganisation: LeMa-Team Philosophische Fakultät, modulangebotsorganisation@fb7.rwth-aachen.de • Modulverantwortliche: Univ.-Prof Dr. phil. Gabriele Gramelsberger
ECTS Credits	6
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	180,0
Contact hours (h)	30,0
Self-study hours (h)	150,0

Introduction to the philosophy of science (7014105)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to the philosophy of science: Module examination (701410501)	2nd semester	no semester recommended	6	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to the philosophy of science: Classes	2nd semester	no semester recommended	-	2

Module titel	Approaches to Current Arms Control Challenges (Compulsory elective subject)
Identifier	1320692
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2019
Valid until	-
Module level	Master
Content	Bilateral or multilateral arms control agreements are restrictions on weapon systems to increase stability. They exist both for weapons of mass destruction and conventional weapons, which will be discussed. By examining the strengths and weaknesses of exist-ing arms control agreements, this seminar addresses the challenges they face in today's international security environment. This includes both policy topics as well as technical aspects. The latter includes evaluating the verifiability of agreements by examining moni-toring technologies and concepts. Furthermore, the seminar will explore arms control measures for the future that are being discussed today, in particular to address emerging military technologies or to enable future aims such as nuclear disarmament that require new measures.
Learning Objectives/ Learning Outcomes	After the seminar, students will know technical and policy aspects of weapon systems. They will be able to understand and compare the strengths and weaknesses of arms control measures and their verification. Students will be able to describe today's state of arms control as well as future prospects and analyze related developments with regard to international security.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Written exam, oral exam or student's presentation. he admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
Miscellaneous	-
Module coordinator	-
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Approaches to Current Arms Control Challenges (132069201)	2nd semester	no semester recommended	5	2

Module titel	Science for Nuclear Arms Control (Compulsory elective subject)
Identifier	1319147
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Winter semester 2018
Valid until	-
Module level	Master
Content	This module introduces scientific contributions to nuclear arms control with an emphasis on physics. It addresses the two main aspects that science plays here. First, the role of science and technology in nuclear proliferation is studied. This includes for instance the production of uranium and plutonium, as well as studying the physics principles behind nuclear warheads and missiles. Second, verification tools to assess compliance with nonproliferation and disarmament agreements are examined. In addition to general verification approaches, various detection techniques are studied in this context, for example gamma and neutron measurements or satellite imagery. Furthermore, relevant computer simulations are introduced.
Learning Objectives/ Learning Outcomes	This module enables students to understand the role of science and technology in nuclear arms control. Based on scientific knowledge, mostly in physics, they learn to assess the military potential of nuclear programs. By studying verification approaches and techniques, students will be able to make informed judgments on the technical verifiability of nuclear nonproliferation and disarmament agreements.
(Study-Specific) Prerequisites	None
(recommended) Requirements	None
References	-
Language	English
Examination Terms	Admission to module examination: Written homework, practical exercises or oral presentation. Module examination: Written exam, oral exam or oral presentation
Miscellaneous	-
Module coordinator	Göttsche, Malte
ECTS Credits	5
Contact time (WSH)	3
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	45,0
Self-study hours (h)	105,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Science for Nuclear Arms Control (Examination) (131914701)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Science for Nuclear Arms Control (Lecture/Exercises)	1st semester	no semester recommended	-	3

Module titel	Introduction to Acoustics (Compulsory elective subject)
Identifier	6011253
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2013
Valid until	-
Module level	Bachelor
Content	Introduction into the fundamentals of sound propagation and sound field modelling, acoustic measurementsm recording and reproduction technology, anatomy and physiology of human hearing psychoacoustics, 3D sound
Learning Objectives/ Learning Outcomes	The students should get a fundamtental understanding of acoustics in various areas: # Acoustics and interaction with human perception # Acoustics in engineering sciences (electrical, automotive, architecture) # Acoustics in measurement in audio and media technology
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	will be announced in the lecture.
Language	German
Examination Terms	written examination (90min) or oral examination (30min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Michael Vorländer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Introduction to Acoustics (601125301)	2nd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Introduction to Acoustics	2nd semester	no semester recommended	-	3

Module titel	Electroacoustics (Compulsory elective subject)
Identifier	6017140
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	• Basics of Electroacoustic: Principle of sound radiation, electroacoustic analogies, equivalent circuits, electroacoustic transducers (M-transducer, N-transducer), passive electric networks • Acoustic Measuring Technique: Sound Level Meter, 1/3 octave and octave-filter, frequency analysis, 2-channel FFT and correlation measuring techniques for LTI-systems, impulse measuring methods in room- and building acoustic, standard methods of signal analysis in room and building acoustics • Applications: Loudspeaker systems and loudspeaker cabinets (i.e. bass reflex and bandpass type cabinets), passive and active electric networks (crossover networks), microphones for measuring and recording applications, measuring technique for sound reinforcement systems Measurement and analysis of impulse responses in room and building acoustics, derivation of reverberation times and sound insulation
Learning Objectives/ Learning Outcomes	After participating in the lecture the student will be able understanding and analyzing electroacoustic transducers in a way that the development of real world systems will be feasible. To describe electroacoustic systems by using the equivalent circuit concept is used as an integral method that can connect both the acoustic and the electric domain of any system. Two-port theory is introduced and applied for the connection between different parts of the circuit. With respect to acoustic measurement tasks different solutions are known and may be selected applied accordingly. In the laboratory course several methods have been taught and exercised by the students themselves. Knowledge about the influence of uncertainties and errors in the measurement chain enables the student to critically question the achieved results.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification.
References	• Skript zur Vorlesung Einführung in die Akustik • Zollner, Zwicker, Elektroakustik, Springer Verlag, 3. Auflage 1983
Language	English
Examination Terms	Oral examination or written examination
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Michael Vorländer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90 oder 30
Total hours (h)	120,0

Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Electroacoustics (601714001)	1st semester	no semester recommended	4	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Electroacoustics	1st semester	no semester recommended	-	3

Module titel	Intensive Course on Room Acoustics (Compulsory elective subject)
Identifier	6015567
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2013
Valid until	-
Module level	Master
Content	In diesem Intensivkurs werden die Grundlagen der Raumakustik systematisch behandelt. Die Thematik der Schallausbreitung in Konzertsälen wird dabei generell aus zwei Blickwinkeln betrachtet. Zum einen werden die Grundlagen der Erzeugung und der Ausbreitung von Schall in geschlossenen Räumen betrachtet, zum anderen die psychologischen Faktoren, die sich selbst mit dem heutigen Kenntnisstand nicht bis zum Letzten exakt beschrieben lassen. Die Zusammenhänge und die Gleichberechtigung dieser Aspekte machen den Charakter der Raumakustik aus. Im ersten Teil des Intensivkurses werden die physikalischen Eigenschaften von Schallfeldern in Räumen beschrieben. Dies geschieht allerdings nicht ohne der menschlichen Wahrnehmung Rechnung zu tragen. Themen des ersten Teils: - Grundlagen - Reflexion &; Streuung - Wellentheorie von Schallfeldern in geschlossenen Räumen - Geometrische Raumakustik - Nachhall und Statistische Raumakustik - Schallabsorption und Schallabsorber - Messtechnik in der Raumakustik Im zweiten Teil werden die Aspekte der Schallwahrnehmung in Räumen dargestellt, die bei der Planung von Konzertsälen, Theatern, Opernhäuser oder Hörsälen berücksichtigt werden. Anhand von zahlreichen Beispielen werden die vorgenannten Aspekte verdeutlicht. Themen des zweiten Teils: - Subjektive Wahrnehmung von Schallfeldern in Räumen - Beschallungsanlagen in Raumen - Musik und Akustik - Planung von Räumen (Konzertsäle, Sprachtheater, Opernhäuser, Hörsäle, Multi-Purpose Auditorien) - Fallbeispiele Im dritten Teil des Intensivkurses steht die praktische Anwendung der ersten zwei Teile im Vordergrund. In raumakustischen Messungen soll die Akustik der Aula der RWTH quantitativ bestimmt werden. Mit Hilfe von raumakustischen Simulationen sollen Maßnahmen entwickelt werden, die die Akustik der Aula für Konzerte verbessern würde. Themen des dritten Teils: - Raumakustische Messungen in der Aula - Analyse der Messergebnisse - Erstellen eines Raytracing Modells der Aula - Optimierung der Aula für konzertante Aufführungen - Darstellung der Ergebnisse
Learning Objectives/ Learning Outcomes	Grundkenntnisse im Bereich der Raumakustik
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	No prerequisite for admission to the module. The admission to the module examination is acquired by written homework, practical exercises or a student's presentation.
References	-
Language	German
Examination Terms	Written exam, oral exam or student's presentation
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Michael Vorländer
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	-

Subsidiary Subjects
Technical Acoustics
Intensive Course on Room Acoustics (6015567)

Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Intensive Course on Room Acoustics: Classes (601556702)	1st semester	no semester recommended	0	4
Intensive Course on Room Acoustics: Module examination (601556701)	1st semester	no semester recommended	4	0

Module titel	Medical Acoustics: Technologies for Hearing Systems and Ultrasound (Compulsory elective subject)
Identifier	6015522
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	Summer semester 2023
Module level	Master
Content	Fundamentals of Acoustics # Resonators / Modes # Fundamentals of Acoustic Measurement Techniques # Hearing and Binaural Technology # Physiology of Hearing # Hearing Aids and Cochlea Implants # Noise: Sources and Effects # Ultrasound
Learning Objectives/ Learning Outcomes	After attending the course, students are able to understand and apply acoustic methods for diagnosis and therapy. The students are supposed to gain advanced knowledge of the principles of physiology of hearing and binaural technology. The students are able to analyze and evaluate complex processes in binaural hearing. The students are able to understand and apply the methods of medical applications in acoustics, such as hearing aid technology and ultrasound diagnosis and therapy. Current issues (impact of noise) can be evaluated and further developed by the students.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Akustik, Eine Einführung, Kuttruff, Heinrich, Verlag Hirzel, Erscheinungsjahr 2004, ISBN 10: 3-7776-1244-8 # Lehrbuch der Phoniatrie und Pädaudiologie Wendler, Jürgen, Verlag Thieme, Erscheinungsjahr 2005, ISBN 10: 3-13-102294-9 # Physik und Technik des Ultraschalls Kuttruff, Heinrich, Verlag Hirzel, Erscheinungsjahr 1988, ISBN 10: 3-7776-0427-5 # Bildgebende Systeme für die medizinische Diagnostik, Morneburg, Heinz; Alexandrescu, Mirca; Verlag Publicis-MCD-Verlag, Erscheinungsjahr 1995, ISBN 10: 3-89578-002-2
Language	English
Examination Terms	Written examination
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr.-Ing. Janina Fels
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0

Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Medical Acoustics: Technologies for Hearing Systems and Ultrasound (601552201)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Medical Acoustics 1	1st semester	no semester recommended	-	3

Module titel	Medical Acoustics: Audiology and Voice (Compulsory elective subject)
Identifier	6015509
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2020
Valid until	Summer semester 2023
Module level	Master
Content	Anatomy and Function of the Hearing System and Voice # Fundamentals of Acoustics # Resonators / Modes # Hearing System # Audiology # Psychoacoustics # Diagnosis of hearing impairment # Vocal tract # Disorders of voice # Musical Acoustics # Singing voice
Learning Objectives/ Learning Outcomes	After attending the course, students are able to understand and apply acoustic methods for diagnosis and therapy. Students are supposed to gain advanced understanding of the function of the hearing system and voice and of voice and speech disorders. The students can also apply this knowledge to analyze and further develop acoustic systems for diagnosis and treatment of the hearing system, voice and speech
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Akustik, Eine Einführung, Kuttruff, Heinrich, Verlag Hirzel, Erscheinungsjahr 2004, ISBN 10: 3-7776-1244-8 # Lehrbuch der Phoniatrie und Pädaudiologie Wendler, Jürgen, Verlag Thieme, Erscheinungsjahr 2005, ISBN 10: 3-13-102294-9
Language	German/English
Examination Terms	Written examination
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr.-Ing. Janina Fels
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0

Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Medical Acoustics: Audiology and Voice (601550901)	2nd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Medical Acoustics: Audiology and Voice	2nd semester	no semester recommended	-	3

Module titel	Laboratory: Hearing Technology and Acoustics (Compulsory elective subject)
Identifier	6020883
Version	v1_neu
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2023
Valid until	-
Module level	Master
Content	Technical Acoustics: Measurement of LTI systems Reverberation room Airborne sound insulation Impedance tube Dynamic loudspeaker Acoustical modes Medical Acoustics: Psychoacoustic effects and illusions Experiment design in listening tests Binaural technology - measurement and equalization Individual features of Head-Related Transfer Functions Speech-in-noise perception with hearing loss
Learning Objectives/ Learning Outcomes	-
(Study-Specific) Prerequisites	-
(recommended) Requirements	none
References	Lab Instructions, further literature will be announced
Language	German
Examination Terms	These lab courses are ungraded. The result of a successful participation is "passed". The performance of individual participants of a training group (usually 3-6 people) will be evaluated by a colloquium before and after each experiment. • Colloquia on each experiment • Execution of experiments • Written presentation of results According to § 5 para. 2 of ÜPO the learning outcome of these lab courses could not be achieved without active participation of the students. Therefore, a regular presence of the student is mandatory.
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Janina Fels
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	60,0

Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory: Hearing Technology and Acoustics (602088301)	1st semester	no semester recommended	4	4

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Module titel	Technical Acoustics (Compulsory elective subject)
Identifier	6010950
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Basic oscillations and vibrations theory, • sound field parameters, wave equation in for gases or liquids, • plane waves, spherical waves, • reflection, • refraction, • diffraction, • Doppler effect, • generation of waves, • sound propagation in tubes, • tubes with non-continuous sections, • sound waves in closed cavities, • sound propagation in isotropic bodies, • bending and flexural waves and perception properties of the ear. • Electromechanical transducers, • different types of transducers, • electroacoustic receiver (microphone), • electroacoustic transmitters (loudspeaker), • digital sound recording, • room acoustics, • sound reinforcement systems, • building acoustics, • noise generation and noise control, • acoustic measurement techniques, • music and speech, • under water acoustics and ultrasound.
Learning Objectives/ Learning Outcomes	After successful completion of the module, students know the fundamentals of theoretical acoustics and the acoustic phenomena in technology and the environment. They have a clear idea about the most important technological fields such as electroacoustics, room acoustics, architectural acoustics, noise suppression and hearing research and are able to carry out calculations, planning, analyses and evaluations in these fields as well as contribute to research and developments in electroacoustics, audio technology, hearing acoustics and virtual acoustics.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	Skript zur Vorlesung Technische Akustik • Kuttruff, "Akustik: Eine Einführung", 1. Auflage, Hirzel, Stuttgart, 2004
Language	English
Examination Terms	Written examination
Miscellaneous	-

Module coordinator	Universitätsprofessor Dr. rer. nat. Michael Vorländer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Technical Acoustics (601095001)	2nd semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Technical Acoustics	2nd semester	no semester recommended	-	3

Module titel	Psychoacoustics and Methods for Listening Experiments (Compulsory elective subject)
Identifier	6015551
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	# Human senses: Human Hearing System # Human Perception of Sound: Critical Bands, Pitch and Frequency , JNDs, Auditory Filtering, Masking, Informational Masking, Role of Memory in Perception, Auditory Attention, Loudness Perception # Binaural Hearing: Fundamentals, binaural masking, localization, motion detection, precedence effect, binaural models # Speech perception: Fundamentals, Models (Articulation Index, Speech Intelligibility Index, etc.), Influence of Room Acoustics and Noise on Speech perception # Auditory Scene Analysis # Psychophysics: Scales, Methods, Signal Detection Theory (Yes/No, Rating, Forced Choice) # Research Methods: Hypotheses (H0 and H1), p-value, Type 1 &; 2 errors, Variables, Definition # Experimental Design: within-subjects / between-subjects, Power analysis, T-test / ANOVA # Psychoacoustic Measures: Loudness, Sharpness, Tonality, Roughness, etc. # Ethics
Learning Objectives/ Learning Outcomes	After successful participation, the students are able to describe and characterize an advanced understanding of the ear and the fundamentals of physical and physiological processes in the human perception of sound. In addition, the student are able to understand and apply independently the most important steps in design, realization and evaluation of listening experiments
(Study-Specific) Prerequisites	keine
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	# Zwicker, E., & Fastl, H. (2013). Psychoacoustics: Facts and models (Vol. 22). Springer Science & Business Media. # Bregman, A. S. (1994). Auditory scene analysis: The perceptual organization of sound. MIT press. # Bech, S., & Zacharov, N. (2007). Perceptual audio evaluation-Theory, method and application. John Wiley & Sons.
Language	German/English
Examination Terms	Oral exam (30min) or written exam (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessorin Dr.-Ing. Janina Fels
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	30 oder 90
Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Psychoacoustics and Methods for Listening Experiments (601555101)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Excercise Psychoacoustics and Methods for Listening Experiments	1st semester	no semester recommended	-	3

Module titel	Acoustic Virtual Reality (Compulsory elective subject)
Identifier	6010401
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	INHALT: • Basics, • Sound field and wave equations, • sound sources, • sound fields in rooms, • geometrical acoustics, • psychological room acoustics, • binaural hearing, • binaural technique, • acoustical computer simulations, • Ray Tracing, mirror image sources, • auralisation, • real-time auralisation, • binaural synthesis, • room acoustical real-time auralisation,
Learning Objectives/ Learning Outcomes	At the end of the module the students have basic knowledge about the theory of acoustic virtual reality for modeling of virtual reality and virtual prototyping scenes. This includes skills in acoustic field theory, signal processing and audio technology. They can apply the theory in development and implementation of software for rendering and audio reproduction of auditory virtual environments. With these skills they can contribute in teams working on complex Virtual Reality systems in research and engineering and in virtual prototyping in industry.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Knowledge of an appropriate degree program with professional qualification
References	• Skript zur Vorlesung Acoustic Virtual Reality • Vorländer, Springer RWTH Edition 2007
Language	English
Examination Terms	oral examination (30min) or written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Michael Vorländer
ECTS Credits	4
Contact time (WSH)	3
Examination duration (min)	90 or 30

Total hours (h)	120,0
Contact hours (h)	45,0
Self-study hours (h)	75,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Acoustic Virtual Reality (601040101)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Acoustic Virtual Reality	1st semester	no semester recommended	-	3

Module titel	Laboratory: Acoustic Virtual Reality (Compulsory elective subject)
Identifier	6016865
Version	v1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Master
Content	Spatial Hearing Spatial Audio Synthesis Room Acoustics Room Acoustic Simulation Spatial Audio Reproduction: Binaural Methods Spatial Audio Reproduction: Panning Methods Real Time Signal Processing Virtual Reality Scene Design
Learning Objectives/ Learning Outcomes	The students should get basic understanding of signal processing and its application in acoustic real-time simulations and gain experience in listening tests in order to evaluate the simulation quality.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Lecture „Acoustic Virtual Reality“
References	• Vorländer, „Auralization“, Springer 2008
Language	English
Examination Terms	The lab course is ungraded. The result of a successful participation is "passed". The performance of individual participants of a training group (usually 3-6 people) will be evaluated by a colloquium before and after each experiment. • Colloquia on each experiment • Execution of experiments • Written presentation of results According to § 5 para. 2 of ÜPO the learning outcome of these lab courses could not be achieved without active participation of the students. Therefore, a regular presence of the student is mandatory.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. nat. Michael Vorländer
ECTS Credits	4
Contact time (WSH)	4
Examination duration (min)	_
Total hours (h)	120,0
Contact hours (h)	60,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Laboratory: Acoustic Virtual Reality (601686501)	1st semester	no semester recommended	4	4

Module titel	Unit Operations in Process Engineering (Compulsory elective subject)
Identifier	4010854
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2009
Valid until	-
Module level	Bachelor/Master
Content	1 • General fundamentals • Dimensional analysis, dimensionless numbers 2 • Mechanical process engineering, comminution: • Power demand of comminution processes - semi-empirical comminution laws and dimensional analysis • Energy efficiency • Comminution machinery 3 • Mechanical process engineering, sieving • Ideal and real separation of particles • Calculation and application of the Tromp-curve 4 • Mechanical process engineering, sedimentation • Application fields of sedimentation • Definition of separation conditions, terminal settling velocity 5 • Mechanical process engineering, filtration • Filtration categories: deep bed filtration, surface filtration • Filtration devices • Filter equations: Darcy´s law, capillary model, Carman-Kozeny equation, empirical models 6 • Mechanical process engineering, mixing and stirring • Fields of application • Power characteristics of different mixer types • Dimensional analysis 7 • Chemical process engineering, chemical reactions • Stoichiometric reaction equation, concentrations • Characteristic numbers of chemical reactors 8 • Chemical process engineering, reaction kinetics of homogeneous reactions • Reaction rate, equation of reaction kinetics • Equilibrium reactions and equilibrium constants • Effects of temperature on reaction rate 9 • Chemical engineering, composed reactions: • Parallel reactions, successive reactions, chain reactions 10

	• Chemical engineering, ideal reactors • Stirred tank reactor, plug flow reactor • Cascade of ideal reactors • Comparison of ideal reactors 11 • Chemical engineering, residence time distribution • Measurement methods for residence time distribution • Residence time distributions of ideal reactors • Residence time distributions of real reactors • Effects of residence time distribution und mixture on conversion rate 12 • Thermal process engineering, absorption • Fundamentals: absorption equilibrium, mass transfer models 13 • Calculation of tray and packed columns • Material balance, McCabe-Thiele-diagram, HTU-concept, NTU 14 • Thermal process engineering, vapour/liquid equilibria of mixtures • Binary systems • Representation of vapour/liquid-equilibria 15 • Thermal process engineering, distillation and rectification • Discontinuous simple distillation • Continuous simple distillation • Cascade cycle, rectification
Learning Objectives/ Learning Outcomes	With respect to the subject: • The students are familiar with the main unit operations in mechanical, chemical and thermal process engineering. • They know the basic methods and approaches to solve process engineering tasks. On the basis of the learned methodologies the students are able to perform on their own design calculations for process engineering unit operations and to interlink them to complex processes.
(Study-Specific) Prerequisites	Keine Voraussetzungen für die Zulassung zum Modul. Die Zulassung zur Modulprüfung wird durch schriftliche Hausaufgaben, praktische Übungen oder ein Referat erworben.
(recommended) Requirements	-
References	• Vorlesungsumdruck (erhältlich am IVT), 120 Seiten. zahlreiche Abbildungen und graphische Darstellungen
Language	German
Examination Terms	Eine schriftliche Klausur
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Matthias Wessling
ECTS Credits	4
Contact time (WSH)	5
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	75,0

Self-study hours (h)	45,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Unit Operations in Process Engineering (401085401)	1st semester	no semester recommended	4	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exercise Unit Operations in Process Engineering	1st semester	no semester recommended	-	3
Lecture Unit Operations in Process Engineering	1st semester	no semester recommended	-	2

Module titel	Sensors (Compulsory elective subject)
Identifier	6011248
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2010
Valid until	-
Module level	Bachelor/Master
Content	# Functionality and application of the relevant sensor classes; # Temperature sensors, # Force and pressure sensors, # Magnetic field sensors, # Optical Sensors, # Chemical Sensors;
Learning Objectives/ Learning Outcomes	After successful participation in the class, the students are able to # understand the physical principles and technical fundamentals of different sensor systems # apply the learned fundamentals to develop sensors for industrial, household and automotive applications # evaluate sensor systems concerning their technical characteristics and optimize them for required applications.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	-
References	# Skript zur Vorlesung Sensoren und Sensormesstechnik 1, Sekr. IWE 2, WSH 24A010 # Sensoren, H.Schaumburg, B.G. Teubner Verlag # Sensoranwendungen, H.Schaumburg, B.G. Teubner Verlag # Sensortechnik, H.-R. Tränkler, E.Obermeier (Hrsg.), Springer Verlag # Mikrosensorik, Thomas Elbel, Vieweg- Verlag # Sensors, W. Göpel, J. Hesse und J.N. Zemel, VCH Verlag # Sensoren, G. Schanz, Hüthig-Verlag # Halbleiter-Elektronik-Sensorik, W.Heywang, Springer-Verlag # Halbleiter-Schaltungstechnik, U. Tietze u. Ch. Schenk, Springer Verlag # H. Xiao, "Introduction to Semiconductor Manufacturing Technology", Prentice Hall
Language	German
Examination Terms	Written examination (90min)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr.-Ing. Rainer Waser
ECTS Credits	5
Contact time (WSH)	2
Examination duration (min)	90
Total hours (h)	150,0

Sensors (6011248)

Contact hours (h)	30,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Sensors (601124801)	2nd semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture and Exercise Sensors	2nd semester	no semester recommended	-	2

Module titel	Application-oriented Development and Testing of PVD High Performance Coatings (Compulsory elective subject)
Identifier	4021492
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2019
Valid until	-
Module level	Master
Content	1. Einsatzgebiete und Potenziale der PVD-Dünnschichttechnologie • Wirtschaftliche Bedeutung und Anwendungsbeispiele von PVD-Dünnschichten 2. Prozess- und plasmatechnische Grundlagen der PVD-Dünnschichttechnologie 3. Prozessvariante Magnetron Sputtering (MS) • Gleichstrom-Variante (dcMS) und gepulste Varianten (mfMS; HPPMS; dcMS/HPPMS) 4. Prozessvariante Lichtbogenverdampfung (Arc) • Laserstrahlverdampfung und (gepulste) Lichtbogenverdampfung 5. Prozessvarianten Gasflusssputtern (GFS) und Elektronenstrahlverdampfen (EB-PVD) 6. Diamantähnliche amorphe Kohlenstoffschichten (Diamond-like Carbon) • Grundlagen, Varianten, Herstellung, Anwendungsbeispiele aus Forschung und Industrie 7. Nitridische und oxinitridische Hartstoffschichten • Grundlagen, Varianten, Herstellung, Anwendungsbeispiele aus Forschung und Industrie 8. Oxidische Schutzschichten • Grundlagen, Varianten, Herstellung, Anwendungsbeispiele aus Forschung und Industrie 9. Anwendungsorientierte Schichtentwicklung, Schichtherstellung und praxisnahe Prüfung • Mechanische und chemische Substratvorbehandlung, Probenchargierung, Abschei-dung • Methoden moderner Oberflächenanalytik 10. Prüfung der grundlegenden Schichteigenschaften u.a. Schichtdicke, Topographie, mechanische Eigenschaften, Phasenzusammensetzung 11. Prüfung der Haftung zwischen Schicht und Grundwerkstoff • Rockwell-lndentation, Scratchtest, lmpacttest 12. Erprobung und Bewertung der Leistungseigenschaften u.a. tribologische Prüfstände, Benetzungsverhalten, Raman-Spektroskopie
Learning Objectives/ Learning Outcomes	Wissen und Verstehen: Die Studierenden kennen insbesondere: • die Grundlagen der Physical Vapour Deposition (PVD)-Dünnschichttechnologie mit Blick auf die Schichtabscheidung und Schichtcharakteristika • prozessspezifische Merkmale und Unterschiede sowie prozessbedingte Schichteigen-schaften • die innovativen und industriell etablierten Analysemethoden von der Plasmadiagnostik bis zur tribologischen Erprobung • die anwendungsorientierte Prozess- und Schichtwerkstoffauswahl sowie Schichtabscheidung Nach erfolgreicher Teilnahme an der Modulveranstaltung sind die Studierenden in der Lage, typische Beschichtungsprozesse der PVD-Dünnschichttechnologie zu beschreiben, die prozessspezifischen Vor- und Nachteile sowie die Grenzen der Prozesse und Schichtsysteme zu erläutern, die Einsatzgebiete unterschiedlicher Schichtsysteme und -werkstoffe darzustellen und typische Anwendungsbeispiele aufzuzählen. Fertigkeiten und Kompetenzen: Die Studierenden können den Einsatz und die Auswahl unterschiedlicher PVD-Beschichtungsprozesse und Schichtwerkstoffe mit Blick auf die Anwendungsgebiete, allgemeiner Maschinenbau, Produktions- und Fertigungstechnik, Energietechnik, Auto-mobil- und Luftfahrttechnik sowie Medizintechnik nachvollziehen.
(Study-Specific) Prerequisites	-

(recommended) Requirements	Empfohlene Voraussetzungen: • "Hochleistungswerkstoffe" (Bobzin) In den Masterstudlengangen: Produktionstechnik, Energietechnik, Allgemeiner Maschinenbau • Kenntnisse der Gebiete Tribologie und Korrosion aus der "Oberflachentechnik Teil 1" (Bobzin) im Bachelorstudiengang Maschinenbau innerhalb des Berufsfelds Produktions-technik • Kenntnisse der Gebiete Tribologie und Korrosion aus der "Oberflächentechnik Tell 1" (Bobzin) in den Masterstudien
References	• Veranstaltungsliteratur: Foliensatz zur Vorlesung am Institut für Oberflächentechnik erhältlich • K. Bobzin: Oberflächentechnik für den Maschinenbau, Weinheim: Wiley-VCH, 1. Auflage, 2013, ISBN 978-3-527-33018-8
Language	German
Examination Terms	Die Endnote ergibt sich aus der Note der Klausur.
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr.-Ing. Kirsten Bobzin Dr.-lng. Tobias Brögelmann
ECTS Credits	4
Contact time (WSH)	1
Examination duration (min)	-
Total hours (h)	120,0
Contact hours (h)	15,0
Self-study hours (h)	105,0

● Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Application-oriented Development and Testing of PVD High Performance Coatings (402149201)	1st semester	no semester recommended	4	-

▲ Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Application-oriented Development and Testing of PVD High Performance Coatings	1st semester	no semester recommended	-	1
Exercise Application-oriented Development and Testing of PVD High Performance Coatings	1st semester	no semester recommended	-	1

Laboratory Application-oriented Development and Testing of PVD High Performance Coatings	1st semester	no semester recommended	-	1

Module titel	Material Physics (Compulsory elective subject)
Identifier	5212493
Version	Angelegt über RWTH API als 1_neu
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Summer semester 2021
Valid until	-
Module level	Bachelor
Content	* Atomistischer Aufbau des Festkörpers * Kristallbaufehler * Legierungen * Diffusion * Mechanische Eigenschaften * Erholung, Rekristallisation, Kornvergrößerung * Erstarrung von Schmelzen * Umwandlung im festen Zustand * Physikalische Eigenschaften
Learning Objectives/ Learning Outcomes	**Wissen / Verstehen** Die Studierenden sollen mit den physikalischen Grundlagen der Werkstoffe vertraut gemacht werden. Sie sind in der Lage, diese Grundlagen wiederzugeben und vergleichend zu betrachten. **Analyse / Anwendung** Konzepte und Methoden werden von den Studierenden eigenständig und in Übungen umgesetzt. **Synthese / Beurteilen** Nach der Umsetzung folgt eine Beurteilung der Konzepte und Methoden und eine Überprüfung auf deren Relevanz in der Anwendung, sowie der Transfer des Erlernten auf andere materialphysikalische Fragestellungen.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlen: Veranstaltungen des 1. und 2. Semesters (Mathe, Chemie, Mechanik, Kristallographie)
References	-
Language	German
Examination Terms	* Schriftliche Klausur * Gewichtung 100% * freiwillige Lernfortschrittskontrolle: Bewertung: Verbesserung um eine Notenstufe durch Erreichen von 80% der Punkte; Verbesserung um zwei Notenstufen durch Erreichen von 90% der Punkte 3. Verbesserung gilt nur für Klausuren, die innerhalb eines Jahres nach der Lernfortschrittskontrolle geschrieben werden und unter der Voraussetzung, dass die Klausur mit einer Note von 4,0 oder besser bewertet wurde. Eine bessere Gesamtnote als 1,0 ist in jedem Fall ausgeschlossen.
Miscellaneous	-
Module coordinator	-
ECTS Credits	8
Contact time (WSH)	6
Examination duration (min)	150
Total hours (h)	240,0
Contact hours (h)	90,0
Self-study hours (h)	150,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Materials physics - exam (521249301)	3rd semester	no semester recommended	8	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar materials physics	3rd semester	no semester recommended	-	0
Materials physics - exercise	3rd semester	no semester recommended	-	2
Materials physics - lecture	3rd semester	no semester recommended	-	4

Module titel	Introduction to Business Administration (Compulsory elective subject)
Identifier	8015068
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2008
Valid until	-
Module level	Bachelor
Content	Die Veranstaltung bietet eine Einführung in die wesentlichen Aspekte der Betriebswirtschaftslehre. Der Inhalt der Vorlesung gliedert sich in sechs Themenblöcke (Grundlagen und Grundbegriffe; Rechnungswesen; Investition und Finanzierung; Produktion und Logistik; Marketing und Vertrieb; Unternehmensführung), die zur Verdeutlichung der praktischen Relevanz durch Gastvorträge ergänzt werden.
Learning Objectives/ Learning Outcomes	Die Studierenden technisch und naturwissenschaftlich orientierter Studiengänge kennen die grundlegenden Denkweisen der Betriebswirtschaftslehre. Sie können wesentliche Fachbegriffe ebenso wie grundlegende Konzepte auf aktuelle Fragestellungen übertragen und sind fähig, einen Bezug zwischen den theoretisch vermittelten Kursinhalten und der unternehmerischen Praxis herzustellen.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	None
References	• Hutzschenreuter, Thomas, 2007: Allgemeine Betriebswirtschaftslehre. Grundlagen mit zahlreichen Praxisbeispielen, Lehrbuch, Gabler Verlag. ISBN: 8349-052-5 • Schreyögg, Georg; Koch, Jochen, 2007: Grundlagen des Managements. Basiswissen für Studium und Praxis, Lehrbuch, Gabler Verlag. ISBN: 978-3-8349-0376-1 • Picot, Arnold; Reichwald, Ralf; Wigand, Rolf, T., 2001: Die grenzenlose Unternehmung. Information, Organisation und Management. 4. Aufl., Gabler Verlag, Lehrbuch. ISBN: 3-409-42214-5 • Reichwald, Ralf; Piller, Frank, 2006: Open Innovation, Individualisierung und neue Formen der Arbeitsteilung, Gabler Verlag. ISBN: 978-3834901064
Language	German
Examination Terms	Klausur (60%, benotet, 60min.) Die Klausur und Wiederholungsklausur werden zu Beginn bzw. Ende des auf das jeweilige Wintersemester folgenden Prüfungszeitraums angeboten., Planspiel (20%, benotet), Referat (20%, benotet) Es werden online Fallstudien gestellt, die jede Woche bearbeitet werden sollen.
Miscellaneous	-
Module coordinator	Modulverantworlicher: Universitätsprofessor Dr. rer. pol. Malte Brettel
ECTS Credits	6
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	180,0

Contact hours (h)	60,0
Self-study hours (h)	120,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Introduction to Business Administration (Exam) (801506802)	2nd semester	no semester recommended	6	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Einführung in die Betriebswirtschaftslehre (Vorlesung)	2nd semester	no semester recommended	-	2
Einführung in die Betriebswirtschaftslehre (Übung)	2nd semester	no semester recommended	-	2

Module titel	Foundations of Entrepreneurship (Compulsory elective subject)
Identifier	8014854
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	This course provides an introduction into the topic of entrepreneurship. Central focus of this course is to explain how ideas are translated into marketable business opportunities. Theoretical core concepts such as innovation management and opportunity recognition are presented. These are complemented by guest lectures in order to connect theory and practice. The practice session is closely connected to the lecture. Within this sesscion, participants develop new product ideas based on real technologies.
Learning Objectives/ Learning Outcomes	The objective of this course is to gain deeper un-derstanding of entrepreneurship, both – as science and in practice. Next to basic theoretical insights related to this topic such as opportunity recognition or innovation management, this course is closely connected to business practice. Course participants will develop an understanding for entrepreneurial thinking and acting. Further, participants will work on real business ideas for a presentation at the end of the course.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Introduction to Business Administration (EBWL) or basic knowledge of business administration, interest in entrepreneurship topics This course is an open online course. That means the content of the course will be delivered in videos and in class we will discuss the content further.
References	Smith, David: Exploring Innovation Birley, Sue / Muzyka, Daniel F.: Mastering Entrepreneurship Hisrich, Robert D. / Peters, Michael P.: Entrepreneurship Dorf Richard C. / Byers, Thomas H.:Technology Ventures
Language	English
Examination Terms	Paper (20%, graded), Presentation (20%, graded), Examination (60%, graded, 60min.)
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. pol. Malte Brettel
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Foundations of Entrepreneurship (Exam) (801485401)	1st semester	no semester recommended	5	0
Foundations of Entrepreneurship (Practice Section) (801485402)	1st semester	no semester recommended	0	2

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Foundations of Entrepreneurship	1st semester	no semester recommended	-	2

Module titel	Start-up and Growth Management (Compulsory elective subject)
Identifier	8014017
Version	Angelegt über RWTH API als 1
Duration (Semester)	one semester
Cycle (Semester)	winter semester
Valid from	Winter semester 2011
Valid until	-
Module level	Master
Content	Aufbauend auf der Veranstaltung "Foundations of Entrepreneurship" gewährt der Kurs "Gründungs- und Wachstumsmanagement" einen tiefergehenden Einblick in das breite Themenspektrum des Entre- und Intrapreneurship. Gründungstheorien und Wachstumsmodelle werden vorgestellt und interaktiv mit den Studierenden besprochen. Im Vordergrund stehen dabei die Chancen und Herausforderungen junger Unternehmen. Ausgewählte praktische Problemstellungen werden vorgestellt, im Team diskutiert und gelöst. Die Vorlesung wird durch eine Übung ergänzt, in der die Studierenden mit der Relevanz und dem Inhalt eines Business Plans vertraut gemacht werden und schließlich selbst in Zusammenarbeit mit einem Gründer einen Business Plan ausarbeiten.
Learning Objectives/ Learning Outcomes	Gründungsinteressierte Masterstudierende kennen die wesentlichen theoretischen Aspekte der Gründungsforschung und können diese auf Fragestellungen aus der Praxis übertragen. Sie sind mit den Problemstellungen der Unternehmensgründung und -entwicklung vertraut und haben ein Grundverständnis für unternehmerisches Denken und Handeln.
(Study-Specific) Prerequisites	Keine
(recommended) Requirements	Vorkenntisse Einführung in die BWL oder Grundkenntnisse der BWL, Foundations of Entrepreneurship, Entrepreneurial Marketing and Finance (optional), Interesse für Entrepreneurship
References	-
Language	German/English
Examination Terms	Klausur (50%, benotet, 60min.), Schriftliche Hausarbeit (50%, benotet). Teilnehmerbeschränkt.
Miscellaneous	-
Module coordinator	Universitätsprofessor Dr. rer. pol. Malte Brettel
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	0
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Exam Start-up and Growth Management (801401701)	1st semester	no semester recommended	5	0
Exercise Start-up and Growth Management (801401702)	1st semester	no semester recommended	0	2

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Vorlesung Gründungs- und Wachstumsmanagement	1st semester	no semester recommended	-	2

Module titel	Microeconometrics (Compulsory elective subject)
Identifier	8014849
Version	V2
Duration (Semester)	one semester
Cycle (Semester)	irregularly
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	Estimation of linear and nonlinear models with cross-sectionald and panel data; OLS, instrumental variable estimation, fixed and ran-dom effects, binary choice models, selection models, duration models; Programming with STATA
Learning Objectives/ Learning Outcomes	Acquisition of skills to conduct basic and advanced empirical analysis in cross-sectional and panel data in order to answer economic questions Ability to read and judge empirical studies critically.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Introductory econometrics Statistics, matrix algebra
References	Begleitende Literatur: - Haupt Referenz: Jeffrey M. Wooldridge: Econometric Analysis of Cross Section and Panel Data, 2002 - Cameron, A. Colin and Pravin K. Trivedi: Microeconometrics, 2005 - Badi H. Baltagi: Econometric Analysis of Panel Data, 3. Auflage, 2005 Literatur für ökonometrische Grundlagen: - Stock, James H., und Mark W.Watson, Introduction to Econometrics, 2. /3. Auflage, Boston. - Wooldridge, Jeffrey, Introductory Econometrics - A Modern Approach, South-Western Cengage Learning, 4. Auflage, 2009. - Judge, George G. et al, Introduction to the Theory and Practice of Econometrics, Wiley, 2. Auflage, 1988. - Greene, William H., 2008, Econometric Analysis, Prentice Hall, 2011.
Language	English
Examination Terms	Exam (100%, 60 Min.). Module Component.
Miscellaneous	-
Module coordinator	Universitätsprofessorin Almut Balleer
ECTS Credits	5
Contact time (WSH)	6
Examination duration (min)	60
Total hours (h)	150,0
Contact hours (h)	90,0
Self-study hours (h)	60,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Microeconometrics (Exam) (801484901)	1st semester	no semester recommended	5	0

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Lecture Microeconometrics	1st semester	no semester recommended	-	3
Practice section Microeconometrics	1st semester	no semester recommended	-	3

Module titel	Quantitative Macroeconomics (Compulsory elective subject)
Identifier	8019166
Version	-
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Summer semester 2018
Valid until	-
Module level	Master
Content	The course will focus on building and analyzing macroeconomic models of economic growth and business cycles. Special topics may include technological change, human capital accumulation, unemployment dynamics, sustainable resource use and climate change. Students will apply quantitative methods (optimal control and statistics) to study and test economic growth models.
Learning Objectives/ Learning Outcomes	- understand the causes and consequences of economic growth - ability to formulate a mathematical model based on a macroeconomic research question - apply methods of optimal control and dynamic programming to solve economic models
(Study-Specific) Prerequisites	-
(recommended) Requirements	None in terms of ; economic knowledge. It is, however, required that students have the willingness and ability to follow formal and mathematical arguments.
References	-
Language	English
Examination Terms	Depending on the number of students successful examination (100%, graded, 60-75min.) or oral examination (100%, graded, 20-30min.)
Miscellaneous	-
Module coordinator	Universitätsprofessor ;Dr. Thomas Lontzek
ECTS Credits	5
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	60,0
Self-study hours (h)	90,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantitative Macroeconomics (Exam) (801916601)	1st semester	no semester recommended	5	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Quantitative Macroeconomics (Lecture)	1st semester	no semester recommended	-	2
Quantitative Macroeconomics (Exercise Unit)	1st semester	no semester recommended	-	2

Module titel	Entrepreneurship 101 - Thinking like an entrepreneur and becoming one (Compulsory elective subject)
Identifier	8023959
Version	-
Duration (Semester)	more semesters
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2021
Valid until	-
Module level	Master
Content	Participants first gain an insight into the field of entrepreneurship. They can then individually choose which focal topics in the field of entrepreneurship they would like to pursue, depending on their center of interest. Participants are offered a range of micromodules out of which they can design their individual learning path. This enables participants to customize the lecture based on their particular interest. Subjects to choose from, among others, include start-up financing, venture capital, entrepreneurial marketing as well as success factors of founding teams. The lecture takes place exclusively online via edX. The modules are self-paced, allowing participants to complete the modules at their individual learning pace. Due to the individually designable lecture, this course is suitable for participants with and without previous knowledge in this field. To gain an overall understanding of entrepreneurship, it is recommended to first select the micromodules "Thinking & Acting like an Entrepreneur“.
Learning Objectives/ Learning Outcomes	The aim of this course is to give the participant a basic insight into the topic of entrepreneurship on one hand, and to deepen their understanding in areas of particular interest on the other hand. This way, the participant gets to know different areas of entrepreneurship. Through exercises and quizzes, the new knowledge is directly applied and practiced.
(Study-Specific) Prerequisites	-
(recommended) Requirements	None.
References	-
Language	English
Examination Terms	Klausur (100%)
Miscellaneous	-
Module coordinator	Univ.-Prof. Dr. Malte Brettel
ECTS Credits	10
Contact time (WSH)	4
Examination duration (min)	-
Total hours (h)	300,0
Contact hours (h)	60,0

Self-study hours (h)	240,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 1 (802395901)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 2 (802395902)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 3 (802395903)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 4 (802395904)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Start-up CFO 1 (802395905)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Start-up CFO 2 (802395906)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Venture Capital 1 (802395907)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Venture Capital 2 (802395908)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Getting to Market 1 (802395909)	1st semester	no semester recommended	1	-
Entrepreneurship 101 - Getting to Market 2 (802395910)	1st semester	no semester recommended	1	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 1	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 2	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 3	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Thinking & Acting Like an Entrepreneur 4	1st semester	no semester recommended	-	2

Entrepreneurship 101 - Start-up CFO 1	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Start-up CFO 2	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Venture Capital 1	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Venture Capital 2	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Getting to Market 1	1st semester	no semester recommended	-	2
Entrepreneurship 101 - Getting to Market 2	1st semester	no semester recommended	-	2

Module titel	(Compulsory elective subject)
Identifier	7022753
Version	V1
Duration (Semester)	one semester
Cycle (Semester)	summer semester
Valid from	Winter semester 2020
Valid until	-
Module level	Bachelor
Content	Nachdem die Studierenden im Modul „Perspektiven der Wissenschaftssoziologie“ mit den grundlegenden Problemstellungen und Denkfiguren der Wissenschaftssoziologie vertraut gemacht worden sind, richtet das Modul „Praxisfelder der Wissenschaftssoziologie“ den Blick auf ausgesuchte aktuelle Fragestellungen der Wissenschaftssoziologie. Dabei werden erstens Fragen der so genannten neuen Governance von Wissenschaft behandelt, zweitens das Problem der Unabhängigkeit von Forschung entfaltet und drittens spezifische Praxisfelder vertieft, wie etwa der Wandel von Formen der Wissenschaftssozialisation, dem Verständnis von Disziplinen als Wissenskulturen, der Thematisierung wissenschaftlichen Nichtwissens oder der Expansion von Wissensproduktion als Realexperimenten.
Learning Objectives/ Learning Outcomes	Die Studierenden • kennen wichtige aktuelle Forschungsfelder der Wissenschaftssoziologie • haben dafür relevante theoretisch-konzeptionelle Denkfiguren kennen gelernt • haben ein Verständnis gewonnen, wie Forschungsfragen aus dem Stand der wissenschaftssoziologischen Forschung zu entwickeln sind. • Haben selbst Erfahrungen im Erschließen von Praxisfeldern der Wissenschaftssoziologie gesammelt.
(Study-Specific) Prerequisites	-
(recommended) Requirements	Empfohlen wird das Modul Perspektiven der Wissenschaftssoziologie erfolgreich abgeschlossen zu haben.
References	-
Language	German
Examination Terms	Die Benotung erfolgt im Rahmen einer schriftlichen Hausarbeit oder mündlichen Prüfung in der Veranstaltung „Praxisfelder der Wissenschaftssoziologie“. Die genaue Prüfungsform wird zu Beginn des Semester bekannt gegeben.
Miscellaneous	-
Module coordinator	• Modulangebotsorganisation: LeMa-Team Philosophische Fakultät, modulangebotsorganisation@fb7.rwth-aachen.de • Modulverantwortlicher: Prof. Dr. Stefan Böschen
ECTS Credits	6
Contact time (WSH)	2
Examination duration (min)	-
Total hours (h)	180,0

Contact hours (h)	30,0
Self-study hours (h)	150,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Examination on seminar Issues in Sociology of Science (702275301)	4th semester	no semester recommended	6	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Seminar Issues in Sociology of Science	4th semester	no semester recommended	-	2

+ Master's Seminar (1311144)

Module titel	Master's Seminar (Compulsory subject)
Identifier	1311144
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	Relevant topics in the field of the planned Master's thesis. These are presented in a seminar talk.
Learning Objectives/ Learning Outcomes	The Master's Seminar provides a deeper understanding of relevant topics in the field of the intended Master's Thesis.
(Study-Specific) Prerequisites	30 CP from the modules of the 1st and 2nd semester of the curriculum
(recommended) Requirements	None
References	Standard literature of the field of topics; topical publications in journals
Language	German/English
Examination Terms	Without grading
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Michael Krämer
ECTS Credits	15
Contact time (WSH)	0
Examination duration (min)	0
Total hours (h)	450,0
Contact hours (h)	,0
Self-study hours (h)	450,0

+ Master's Seminar (1311144)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master's Seminar (131114401)	3rd semester	no semester recommended	15	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master's Seminar	no semester recommended	no semester recommended	-	-

+ Master's Practical (1310580)

Module titel	Master's Practical (Compulsory subject)
Identifier	1310580
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	A project schedule for the planned Master's Thesis will be set up.
Learning Objectives/ Learning Outcomes	During the Master's practical the student acquires special knowlegde and proficiency in the research methods of the field of the intended Master's Thesis.
(Study-Specific) Prerequisites	30 Credits aus den Modulen des 1. und 2. Semesters
(recommended) Requirements	none
References	Topical journal publications
Language	German/English
Examination Terms	Without grading
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Michael Krämer
ECTS Credits	15
Contact time (WSH)	0
Examination duration (min)	0
Total hours (h)	450,0
Contact hours (h)	,0
Self-study hours (h)	450,0

+ Master's Practical (1310580)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master's Practical (131058001)	3rd semester	no semester recommended	15	-

Offer node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master's Practical	no semester recommended	no semester recommended	-	-

Master's Thesis & Defence Colloquium
Master's Defence Colloquium (1311146)

Module titel	Master's Defence Colloquium (Compulsory subject)
Identifier	1311146
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Summer semester 2011
Valid until	-
Module level	Master
Content	The student presents the main results of the research project of his/her Master's Thesis by giving a talk in front of the research group. A discussion on the topic of the Master's Thesis and adjacent fields follows.
Learning Objectives/ Learning Outcomes	The student is able to present the main results of his research project within a scientific talk. He/She can answer specific questions about these results and participate in a scientific discussion on the topic of his/ her Master's Thesis.
(Study-Specific) Prerequisites	Master's Seminar und Master's Practical
(recommended) Requirements	None
References	Standard literature of the field of topics; topical publications in journals
Language	German/English
Examination Terms	Grading of the talk and the scientific discussion.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Michael Krämer
ECTS Credits	5
Contact time (WSH)	0
Examination duration (min)	-
Total hours (h)	150,0
Contact hours (h)	,0
Self-study hours (h)	150,0

Master's Defence Colloquium (1311146)

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master's Defence Colloquium (131114601)	4th semester	no semester recommended	5	0

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Master's Thesis & Defence Colloquium
Master's Thesis (1311145)

Module titel	Master's Thesis (Compulsory subject)
Identifier	1311145
Version	-
Duration (Semester)	one semester
Cycle (Semester)	winter/summer semester
Valid from	Winter semester 2010
Valid until	-
Module level	Master
Content	The Master's thesis represents an independent research work in one of the fields of study of the Master's program in physics. The topic of the research project is agreed upon by the supervisor and the student together. The results of the project are presented as a scientific essay of generally no more than 80 pages.
Learning Objectives/ Learning Outcomes	The student is able to carry out a research project under supervision and within a given time using common scientific methods.
(Study-Specific) Prerequisites	Master's Seminar und Master's Practical
(recommended) Requirements	None
References	Standard literature of the field of topics; topical publications in journals
Language	German/English
Examination Terms	Grading of the thesis.
Miscellaneous	-
Module coordinator	Modulangebotsorganisator: Modulangebotsverantwortlicher Physik Modellierungsteamverantwortlicher: Dr. rer. nat. Katja Petzoldt Modulverantworlicher: Universitätsprofessor Dr. rer. nat. Michael Krämer
ECTS Credits	25
Contact time (WSH)	0
Examination duration (min)	-
Total hours (h)	750,0
Contact hours (h)	,0
Self-study hours (h)	750,0

Exam node

Title	Recommended Semester (Study start winter)	Recommended Semester (Study start summer)	ECTS Credits	Contact time (WSH)
Master's Thesis (131114501)	4th semester	no semester recommended	25	0