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MATHEMATISCH-
NATURWISSENSCHAFTLICHE
FAKULTÄT

UNIVERSITÄT ZU KÖLN

DEKANAT

MODULHANDBUCH

PHYSIK (M.Sc. Physics)

1-FACH-MASTER OF SCIENCE

VERSION [x]
NACH DER PRÜFUNGSORDNUNG FÜR DEN 1-FACH-MASTER-STUDIENGANG PHYSIK
M.Sc. Physics
(FASSUNG 11.04.2014)

Universität
zu Köln

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Legend (Legende)

CT	Contact Time (= Time of Presence) = Kontaktzeit (= Präsenzzeit in LV)	SAoS	Secondary Area of Specialization = Nebenfach
CP	Credit Point = Leistungspunkt	SSt	Self-Study = Selbststudium
HPW	Hours per Week = Semesterwochenstunde	SuSe	Summer Semester
PAoS	Primary Area of Specialization = Schwerpunktmodul	WL	Workload = Arbeitsaufwand
PW	Preparation and Wrap-up Time = Vor- und Nachbereitungszeit	WiSe	Winter Semester

Inhaltsverzeichnis

1 The Field of Study: Physics (Das Studienfach Physik)

The physics courses at the University of Cologne aim to equip students with the knowledge and tools for independent scientific work. In the course of their studies, they gain the qualification to actively participate in the fundamental research carried out at the physics institutes at the University of Cologne.

1.1 Contents, Objectives and Requirements (Inhalte, Studienziele und Voraussetzungen)

The master courses in physics are based on the broad basic knowledge gained during bachelor studies. This knowledge of experimental and theoretical physics is deepened in the practical courses, lectures, and in intensively supervised exercise classes. In addition, students focus on individual fields of physics within the primary and secondary area of specialization. They will apply these skills to solve problems of current research.

At the end of their Master studies, the students will have acquired a number of broad and focused competencies within their area of specialization, which they will successfully apply to the different scientific and technical problems they will encounter in their following career, either within or outside academia. The master studies lead to a degree qualifying the graduate to enter a profession.

The admission regulations are given in §4 of the Examination Regulations (Prüfungsordnung). The main requirements for admission are a Higher Education Entrance Qualification and a scientific degree, which is equivalent to the Bachelor degree in Physics (B.Sc.) at the University of Cologne.

1.2 Structure and Sequence of Studies (Studienaufbau und -abfolge)

Students may begin with their studies either in the summer or the winter term. The practical course experiments and the courses for the primary and secondary area of specialization as well as the elective area can be chosen flexibly. This allows students to arrange their courses in the best order, matching their individual course choices and requirements.

In the first two semesters, students complete the practical courses, the theoretical physics module, the elective area, and the secondary area of specialization. They might also complete all courses of the primary area of specialization, except for either the advanced seminar or a specialized lecture. The advanced seminar usually takes place in the second or third semester.

The two introductory projects are conducted in the third semester.

The course is completed with the Master Thesis in the fourth semester.

The experiments for the Practical Course M will be chosen from two subjects out of the following:

- Molecular and Astrophysics
- Solid State Physics
- Nuclear Physics
- Biophysics

- Particle Physics

The course for the module theoretical physics can be chosen as either Advanced Quantum Mechanics or Advanced Statistical Physics.

The courses for the elective area module can be chosen from two different fields offered at the Faculties of Math and Natural Sciences at the Universities of Cologne and Bonn.

The primary and secondary area of specialization can be chosen from the following subjects:

- General Theory of Relativity / Quantum Field Theory
- Astrophysics
- Condensed Matter Physics
- Molecular Physics
- Nuclear and Particle Physics
- Solid State Theory / Computational Physics
- Statistical and Biological Physics

If approved by the module coordinator, fitting courses from Bonn may be credited in these modules as well. The courses passed in Bonn will be credited in Cologne according to their HPW (1 HPW = 1.5 CP).

The SAoS might also be chosen from the following modules offered in Bonn:

- Cosmology
- Experimental Hadron Physics
- High Energy Particle Physics
- Physics in Medicine
- Quantum Optics and optical Condensed Matter Physics
- Theoretical Hadron Physics
- Theoretical Particle Physics

The topic for the Master Thesis usually will be chosen from the primary area of specialization.

1.3 CP General Overview (LP-Gesamtübersicht)

The 120 CP of the Master studies split up into 66 CP for the lecture component, 24 CP for the introductory projects and 30 CP for the Master Thesis.

The two introductory projects prepare the students for the Master Thesis.

The Master Thesis completes the studies. It covers a well-defined topic of physics and is based on research conducted individually by the student. It is documented in a written thesis and presented orally in a colloquium.

CP General Overview	
Lecture Component and Introductory Projects	90 CP
Master Thesis	30 CP
Total	120 CP

1.4 CP Overview Corresponding to Semesters (Semesterbezogene LP-Übersicht)

The following table provides an overview of all modules. The first two columns indicate for which semester(s) the modules are planned for students starting either in the winter term or in the summer term.

CP Overview					
Sem. (WiSe Start)	Sem. (SuSe Start)	Module	CT	PW	CP
1	2	Advanced Quantum Mechanics or Advanced Statistical Physics	85	185	9
1	1	Practical Course M I	18	162	6
1– 2	1– 2	Elective Area	114	246	12
1– 3	1– 3	Primary Area of Specialization	179	451	21
2	1– 2	Practical Course M II	18	162	6
1– 2	1– 2	Second Area of Specialization	113	247	12
3	3	Introductory Project I	360 *		12
3	3	Introductory Project II	360 *		12
4	4	Research Module Master Thesis	900 *		30

* The distribution of the WL to CT and PW depends on the individual choice.

1.5 Calculation of the Overall Grade (Berechnung der Fachnote)

The modules contribute to the overall grade according to their individual credit points. The Master Thesis has weight 1.5; the Introductory Projects have weight 0; all other modules have weight 1. The following table provides the weighted contributions of each module.

Significance of the module mark for the overall grade		
Module	CP	Contribution to the overall grade
Advanced Quantum Mechanics or Advanced Statistical Physics	9	9/111
Elective Area	12	12/111
Primary Area of Specialization	21	21/111
Practical Course M I	6	6/111
Practical Course M II	6	6/111
Second Area of Specialization	12	12/111
Introductory Project I	12	0
Introductory Project II	12	0
Research Module Master Thesis	30	45/111

2 Descriptions and Tables of Modules (Modulbeschreibungen und Modultabellen)

2.1 Core Modules (Basismodule)

At the beginning of the Master studies, the two modules “Practical Course M” and a course from the field of theoretical physics deepen the basic knowledge gained in the bachelor studies. The theoretical physics course may be chosen as either “Advanced Quantum Mechanics” or “Advanced Statistical Physics”.

Practical Course M I

Practical Course M I						
Identification number		Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PraktMI		180 h	6 CP	1st Semester	Continually upon consultation, every semester	1 Semester
1	Type of lessons			Contact times	Self-study times	Intended group size
	a) Preparation for experiments			---	45 h	Max 3 students
	b) Perform experiments			15 h	---	
	c) Analysis and Report			---	95 h	
	d) Exam			1 h	24 h	
2	**Aims of the module and acquired skills** The course consists of advanced experiments introducing into important subfields of contemporary experimental physics. The students gain insight in relevant contemporary research by conducting experiments independently. Content of the course includes determination of experimental quantities and their errors, modern experimental physics methods, and the written presentation of scientific results.					
3	**Contents of the module** Advanced methods of performing physics experiments are introduced by setting up and conducting four experiments. The experiments introduce students to modern physics research. The experiments have to be selected from one category group out of atomic physics, solid state physics, nuclear physics, or biophysics. Experiments are selected from the catalogue of laboratory set-ups offered.					
4	**Teaching / Learning methods** After registration the participants will work in small subgroups of at most 3 students. Before carrying out an experiment, the student shall demonstrate to have acquired background knowledge for the experiments. For each experiment, the preparation, the measured results and the data analysis have to be documented in written form. The selected subfield of the experiments should be motivated and guided by the main focus of the selected master research fields.					

5	Requirements for participation Fundamentals at the level of the bachelor courses in physics
6	Type of module examinations In the categories molecular and astrophysics, solid state physics, biophysics, and nuclear physics the successful preparation, measurement and analysis of each experiment is certificated, but not graded. Failed experiments may be repeated twice.
7	Requisites for the allocation of credits Four completed experiments are required to be admitted to an oral exam, which determines the grade of the module.
8	Compatibility with other curricula and soft skills As elective subject in other M.Sc. programs Teamwork, collaboration capability, time management
9	Significance of the module mark for the overall grade The weight of the module is 6/111 ≈ 5.4 %.
10	Module coordinator F. Lewen, T. Lorenz, B. Maier, P. Reiter
11	Additional information Alternatively to the categories listed above, experiments in particle physics may be performed in Bonn and credited in Cologne. In this case, the module examinations follow the regulations of university Bonn.

Practical Course M II

Practical Course M II					
Identification number MN-P-PraktMII	Workload 180 h	Credits 6 CP	Term of studying 1st Semester	Frequency of occurrence Continually upon consultation, every semester	Duration 1 Semester

1	Type of lessons	Contact times	Self-study times	Intended group size
	a) Preparation for experiments	---	45 h	Max 3 students
	b) Perform experiments	15 h	---	
	c) Analysis and Report	---	95 h	
	d) Exam	1 h	24 h	
2	Aims of the module and acquired skills The course consists of advanced experiments introducing students to important subfields of contemporary experimental physics. The students gain insight into relevant contemporary research by conducting experiments independently. Content of the course includes the determination of experimental quantities and their errors, modern experimental physics methods, and the written presentation of scientific results.			

3	Contents of the module Advanced methods of performing physics experiments are introduced by setting up and conducting four experiments. The experiments introduce students to modern physics research. The experiments have to be selected from one category group out of atomic physics, solid state physics, nuclear physics, or biophysics. Experiments are selected from the catalogue of laboratory set-ups offered. The category chosen in this module must be different from the one chosen in Practical Course M II.
4	Teaching / Learning methods After registration the participants will work in small subgroups of at most 3 students. Before carrying out an experiment, the student needs to demonstrate to have the necessary background knowledge of the experiments. For each experiment, the preparation, the measured results and the data analysis have to be documented in written form. The selected subfield of the experiments should be motivated and guided by the main focus of the selected master research fields.
5	Requirements for participation Fundamentals at the level of the bachelor courses in physics
6	Type of module examinations In the categories molecular and astrophysics, solid state physics, biophysics, and nuclear physics the successful preparation, measurement and analysis of each experiment is certificated, but not graded. Failed experiments may be repeated twice.
7	Requisites for the allocation of credits Four completed experiments are required to be admitted to an oral exam, which determines the grade of the module.
8	Compatibility with other curricula and soft skills As elective subject in other M.Sc. programs Teamwork, collaboration capability, time management
9	Significance of the module mark for the overall grade The weight of the module is 6/111 ≈ 5.4 %.
10	Module coordinator F. Lewen, T. Lorenz, B. Maier, P. Reite
11	Additional information Alternatively to the categories listed above, experiments in particle physics may be performed in Bonn and credited in Cologne. In this case, the module examinations follow the regulations of university Bonn.

Advanced Quantum Mechanics

Advanced Quantum Mechanics						
Identification number		Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-QMII		270 h	9 CP	1st Semester	Every winter term	1 Semester
1	Type of lessons a) Lecture b) Problem Class c) Preparation for exam			Contact times 56 h 28 h ---	Self-study times 84 h 84 h 18 h	Intended group size 15–20 students per problem class
2	**Aims of the module and acquired skills** Building on the foundational exposition of quantum mechanics in the Bachelor course program, this course introduces the student to various themes of advanced quantum mechanics that are required knowledge for doing master thesis research in experimental or theoretical physics. The course especially caters to the needs of students specializing in condensed matter physics and nuclear physics.					
3	**Contents of the module** 1. Scattering theory • differential cross section • method of partial waves and scattering phases for systems with spherical symmetry • optical theorem, Lippmann-Schwinger equation, Born approximation • time-dependent scattering theory, Moeller operators • scattering matrix, multichannel scattering 2. The formalism of second quantization • construction of the Fock space for fermions and bosons • second quantization of one- and two-body operators • vacuum state and normal ordering • quantum theory of the free electromagnetic field 3. Relativistic quantum theory • Dirac equation, invariance properties (parity, time reversal, charge conjugation) • hole interpretation of the positron, nonrelativistic reduction • Pauli equation, spinors 4. Specialized topic in advanced quantum mechanics, for example, applications of group theory (theory of angular momentum and spin), the standard model of particle physics, or quantum information theory.					
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.					

5	**Requirements for participation** Classical theoretical physics (mechanics and electrodynamics), basic quantum mechanics (as taught in a one-semester theoretical physics course on quantum mechanics).
6	**Type of module examinations** The module is passed by passing a written exam, which is held during the semester and is offered again at the beginning of the following semester. To be accepted for the written exam, students must actively participate in the problem class, solve the homework problems and register for the exam.
7	**Requisites for the allocation of credits** The module is passed by passing a written exam. The grade given for the module is equal to the grade of the written exam.
8	**Compatibility with other Curricula** As elective subject in other M.Sc. programs.
9	**Significance of the module mark for the overall grade** The weight of the module is 9/111 ≈ 8.1 %.
10	**Module coordinator** M. Zirnbauer
11	**Additional information** Literature: Sakurai, Modern Quantum Mechanics (Addison-Wesley) Schwabl, Advanced Quantum Mechanics (Springer)

Advanced Statistical Physics

Advanced Statistical Physics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-StatPhysII	270 h	9 CP	1st Semester	Every winter term	1 Semester

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	56 h	84 h	15–20 Students per
	b) Problem Class	28 h	84 h	problem class
	c) Preparation for exam	---	18 h	

2	**Aims of the module and acquired skills** The course introduces the students to key concepts required for the theoretical description of classical many-particle systems. Participation in the lecture course and the exercise sessions enables the students to analyze interacting many-particle systems on the level of mean field approximations and scaling arguments. The course is a mandatory prerequisite for the Area of Specialization (AoS)"Statistical and Biological Physics".

3	**Contents of the module** 1. Macroscopic and microscopic degrees of freedom • conservation laws • fast and slow variables • elementary continuum mechanics and hydrodynamics 2. Phase transitions and critical phenomena • Universality • Landau theory • relevance of fluctuations • field-theoretic approach 3. Scaling and renormalization 4. Dynamics • Correlation- and response functions • Langevin- and Fokker-Planck equations • the Wiener integral • nonequilibrium stationary states 5. Disordered systems and glasses
4	**Teaching/Learning methods** The module consists of a lecture course, supplemented by a problem class.
5	**Requirements for participation** Classical theoretical physics; elementary thermodynamics and statistical physics.
6	**Type of module examinations** The module is passed by passing a written exam, which is held during the semester and is offered again at the beginning of the following semester. To be accepted for the written exam, students must actively participate in the problem class, solve the homework problems and register for the exam.
7	**Requisites for the allocation of credits** The module is passed by passing a written exam. The grade given for the module is equal to the grade of the written exam.
8	**Compatibility with other Curricula** As elective subject in other M.Sc. programs
9	**Significance of the module mark for the overall grade** The weight of the module is 9/111 ≈ 8.1 %.
10	**Module coordinator** J. Krug, T. Nattermann

11	**Additional information** Literature: Plischke and Bergersen, Equilibrium statistical physics (World Scientific) Goldenfeld, Lectures on phase transitions and the renormalization group (Westview Press) Chaikin and Lubensky, Principles of condensed matter physics (Cambridge University Press)

2.2 Advanced Modules (Aufbaumodule)

n/a

2.3 Specialization Modules (Schwerpunktmodule)

The students focus on specific fields of physics from the first semester on by attending specialization modules. At the beginning, basic knowledge is gained on two subjects – the primary and the secondary area of specialization. Later the students start with active research in their PAoS in the two introductory projects, preparing for the Master Thesis.

Primary Area of Specialization General Theory of Relativity / Quantum Field Theory

General Theory of Relativity / Quantum Field Theory						
Identification number MN-P-SP-GR-QFT		Workload (540 + 90) h	Credits 21 CP	Terms of study 1st to 3rd semester	Frequency of occurrence Details are provided online in the table “Course Offerings”.	Duration 3 semesters
1	Types of lesson a) Lecture courses b) Problem classes c) Advanced seminar d) Exam	Contact times These depend on the specific choices made 10 h 1 h		Self-study times These depend on the specific choices made 80 h 24 h	Intended group size 15–20 students per problem class Individual tutoring for the seminar	
2	**Aims of the module and acquired skills** The aim of the core courses to master the fundamental concepts of general relativity and/or quantum field theory, to an extent where students are able to read and comprehend original research articles in these areas. The specialized courses introduce students to an expanded range of subjects including related topics in nearby areas such as astrophysics, particle physics and physics-related mathematics. Presentation skills are acquired through the participation in an advanced student seminar. Ultimately, the goal is to prepare the candidate to do the research for a master thesis.					

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Relativity and Cosmology I (4+2 HPW, 9 CP): gravity as a geometric theory, Einstein field equations, Schwarzschild solution, experimental tests, gravitational waves • Relativity and Cosmology II (3+1 HPW, 6 CP): black holes, introduction to cosmology, the early universe • Quantum Field Theory I (4+2 HPW, 9 CP): second quantization and applications, functional integrals, perturbation theory, mean-field methods • Quantum Field Theory II (3+1 HPW, 6 CP): the role of correlation functions, spontaneous symmetry breaking, lattice gauge theory, topological aspects of QFT, renormalization 2. Specialized courses • Misc. courses: Quantum Aspects of Gravity (X HPW, X CP – cf. table 'course offerings') • Misc. courses: Particle– and Astrophysics (X HPW, X CP – cf. table 'course offerings') • Misc. courses: Mathematics (X HPW, X CP – cf. Table 'course offerings') • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the course descriptions online. 3. Advanced student seminar (2 HPW, 3 CP) • Seminar on current topics in Quantum Mechanics, General Relativity, or Quantum Field Theory
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** The theoretical physics curriculum at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the examination, students must actively participate in the problem sessions (including the solution of homework problems) and give a talk in the advanced seminar. The grade given for the module is the grade of the oral examination.
7	**Requisites for the allocation of credits** The Primary AoS GR-QFT is composed of: 1. Two core courses GR I-II or QFT I-II (lectures and exercises) 2. Specialized courses taken from the list above 3. Advanced student seminar

8	**Compatibility with other Curricula and Soft Skills** May be taken as an elective subject in other M.Sc. programs. Promotes scientific reading and presentation skills, in particular those for oral presentations.
9	**Significance of the module grade for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** C. Kiefer
11	**Additional information** Details of the course offerings and contents are given online and in the “kommentiertes Vorlesungsverzeichnis”.

Primary Area of Specialization Astrophysics

Astrophysics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-Astro	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** The students will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable them to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepare the students towards their own research activity within the master thesis.

3	**Contents of the module** The module is subdivided into a core course, specialized courses and the advanced seminar: 1. Core course • Advanced Astrophysics (4+2 HPW, 9 CP) 2. Specialized courses • Active Galaxies (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Data Analysis (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Experimental Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Galaxy Dynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Hydrodynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star Formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Interferometry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Detection Techniques in Molecular Astropyhsics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Methods in Infrared Astronomy (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Cosmology (Bonn, 2+1 HPW, 4 CP) / (2 HPW, 3 CP) • Radiointerferometry: Methods and Science (Bonn, 2+2 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Astrophysics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Atomic Physics, Astrophysics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS Astrophysics is composed of: 1. Core course Advanced Astrophysics (Lectures and Excercises) 2. Specialized courses (Lectures and Exercises) in Astrophysics 3. Advanced Seminar in Astrophysics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data. This module prepares for topics of current research in molecular physics and astrophysics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** P. Schilke
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Primary Area of Specialization   Condensed Matter Physics

Condensed Matter Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-CondMat	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Students shall deepen their understanding and knowledge of the main concepts (experimental & theoretical) of condensed matter physics and get familiar with some important experimental methods in condensed matter physics. In specialized courses selected up-to-date research topics of experimental condensed matter physics are discussed as applications of the main concepts and as a preparation for the master thesis. In advanced seminars, students shall acquire a comprehensive understanding of a particular topic and improve their presentation skills.

3	**Contents of the module** The module is subdivided into core courses and specialized courses: 1. Core course • Condensed Matter Physics I (3+1 HPW, 6 CP): Crystal structure and binding, Reciprocal space, Lattice dynamics and thermal properties, Free electron gas • Condensed Matter Physics II (3+1 HPW, 6 CP): Band structure, Metals and semiconductors, Transport properties, Dielectric function and screening, Superconductivity, Magnetism 2. Specialized courses • Experimental Methods of Condensed Matter Physics (2 HPW, 3 CP) • Superconductivity and Nanoscience (2 HPW, 3 CP) • Magnetism (2 HPW, 3 CP) • Semiconductor Physics (2 HPW, 3 CP) • Photons and Matter (2 HPW, 3 CP) • Physics of Surfaces and Nanostructures (2 HPW, 3 CP) • Introduction to Neutron Scattering (2 HPW, 3 CP) • Optical Spectroscopy (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced seminar in condensed matter physics (2 HPW, 3 CP) The contents of the specialized courses and of the advanced seminars can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Experimental and theoretical physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS Condensed Matter Physics is composed of: 1. Two core courses Condensed Matter Physics I and II (2 x (3+1) HPW) 2. Two specialized courses in Condensed Matter Physics At least one of the two has to be a course in experimental condensed matter physics, the second one can also be a course in theoretical condensed matter physics. 3. One advanced seminar in Condensed Matter Physics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data. This module prepares for topics of current research in condensed matter physics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** J. Hemberger
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Primary Area of Specialization Molecular Physics

Molecular Physics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-Mol	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

1	Type of lessons	Contact times	Self-study times	Intended group size
	a) Lecture	depending on	depending on	
	b) Problem class	the individual	the individual	15–20 Students per problem class
	c) Practical course	choice	choice	individual counseling for the seminar
	d) Advanced Seminar	10 h	80 h	
	e) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Understanding of the main concepts of molecular physics, the use of computer programs for the analysis of molecular spectra (computer aided analysis of scientific data), application of molecular physics concepts to current research in fundamental physics, atmospheric physics and astrophysics including practical courses (advanced experimental skills) and advanced seminars (presentation skills).
3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Molecular Physics I (3+1 HPW, 6 CP): Basics of Molecular Spectroscopy, Interaction of Radiation with Matter, Chemical Bond, Born- Oppenheimer-Approximation, Rigid Rotor, Harmonic Oscillator, Electronic States, Rotational Spectroscopy, Group Theory • Molecular Physics II (3+1 HPW, 6 CP): Rotational Spectroscopy, Vibrational Spectroscopy, Group Theory, Coupling of Rotation and Vibration, Transitions and Selection Rules, Nuclear Spin Statistics, Coupling of Angular Momenta, Hund`s Cases, Fine Structure (FS), HFS 2. Specialized courses • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Introduction Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Measurement Techniques in Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experiments in Molecular Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Experimental Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fundamentals of Molecular Symmetry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Detection Techniques in Molecular Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in molecular physics (2 HPW, 3 CP) The contents of the specialized courses can be found in the "kommentiertes Vorlesungsverzeichnis" and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. Students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.
5	**Requirements for participation** Atomic Physics and Quantum Mechanics at the level of the bachelor courses in physics

6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Primary AoS Molecular Physics is composed of: 1. Two core courses Molecular Physics I and II (2 x (3+1) HPW) 2. Specialized courses in Molecular Physics, Astrophysics and Atmospheric Physics 3. Optional: advanced practical courses in Molecular Physics, Astrophysics and Atmospheric Physics 4. Advanced Seminar in Molecular Physics, Astrophysics and Atmospheric Physics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data. This module prepares for topics of current research in molecular physics and astrophysics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** S. Schlemmer
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Primary Area of Specialization Nuclear and Particle Physics

Nuclear and Particle Physics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-Nuc	630 h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

1	Type of lessons	Contact times	Self-study times	Intended group size
	a) Lecture	196 h	319 h	
	b) Advanced Seminar	10 h	80 h	
	c) Exam	1 h	24 h	individual counseling for the seminar

2	**Aims of the module and acquired skills** Understanding of the main concepts of nuclear and particle physics, including reaction theory and the physical principles of detectors and accelerators used in nuclear and particle physics.
3	**Contents of the module** The module is subdivided into core courses and specialized courses. 1. Core courses • Nuclear Physics II (3 HPW, 4.5 CP): Study of nuclear reactions, fission and fusion. Accelerators. • Detector Physics (2 HPW, 3 CP) Interaction of radiation with matter, scintillators, semiconductor detectors, particle detectors. • Particle Physics (3 HPW, 4.5 CP): Introduction into particle physics 2. Specialized courses • Theoretical Nuclear Physics I (2 HPW, 3 CP) • Theoretical Nuclear Physics II (2 HPW, 3 CP) • Theoretical Nuclear Physics III (2 HPW, 3 CP) • Accelerator Mass Spectrometry (2 HPW, 3 CP) • Nuclear Astrophysics (2 HPW, 3 CP) • Neutron Physics (2 HPW, 3 CP) • Selected problems in Nuclear Structure (2 HPW, 3 CP) • Heavy Ion Physics (2 HPW, 3 CP) • Tools for Particle Physics (2 HPW, 3 CP) • Selected Topics on Future Energy Supply (2 HPW, 3 CP) • Applied Nuclear Physics (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Nuclear and Particle Physics (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. In discussions with others, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Nuclear and Particle Physics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of the core courses. To be admitted to the exam, students must actively have participated in the specialized courses and have presented a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS Nuclear and Particle Physics is composed of: 1. Three core courses (8 HPW, 12 CP) 2. Two specialized courses in Nuclear and Particle Physics (4 HPW, 6 CP) 3. Advanced Seminar in Nuclear and Particle Physics (3 CP)
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. This module prepares for topics of current research in nuclear and particle physics and provides the basis for the preparation of the master thesis in nuclear and hadronic physics.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** J. Jolie
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Primary Area of Specialization Solid State Theory / Computational Physics

Solid State Theory / Computational Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-THSol	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** A deep understanding of fundamental concepts used to theoretically describe solids and their excitations / ability to describe phenomena like superconductivity and magnetism / understanding of important quantum field-theoretical and computational methods / ability to translate mathematical concepts into algorithms / computational approach to problem solving with applications to many-body physics / ability to acquaint oneself with scientific questions and to present results / preparation for a master thesis in theoretical physics.

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar 1. Core Courses • Solid State Theory (3+1 HPW, 6 CP): Concepts of solid state theory and description of excitations in solid • Computational Many-Body Physics (3+1 HPW, 6 CP): Overview of elementary numerical approaches to study many-body systems, both classical and quantum. • Quantum Field Theory I (4+2 HPW, 9 CP): Modern methods to describe solids based on functional integrals and by using diagrammatic methods 2. Specialized courses: • Quantum Field Theory II (4+2 HPW, 9 CP) • One course chosen from the specialized courses of the module Condensed Matter Physics • Hydrodynamics (2+2 HPW, 6 CP) • Advanced Topics in Solid State Theory (3+1 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar on topical subjects of Solid State Theory (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets and implement computational algorithms. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic.
5	**Requirements for participation** Basic knowledge in theoretical physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems) and present a scientific talk in the advanced seminar course. The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The following courses have to be chosen from the list given above in order to acquire the necessary credit points: 1. Two of the core courses or, alternatively, both the courses Quantum Field Theory I and Quantum Field Theory II 2. One advanced seminar 3. Further core courses, specialized courses or a second advanced seminar The module is passed by passing an oral examination covering the topics of all attended courses.

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. This module prepares for topics of current research in solid stat theory and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** A. Rosch
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Primary Area of Specialization Statistical and Biological Physics

Statistical and Biological Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-SP-StatBio	(540 + 90) h	21 CP	1st to 3rd semester	Details are provided online in the table “Course Offerings”.	3 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 Students per problem class
	c) Advanced Seminar	10 h	80 h	individual counseling for the seminar
	d) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Bring students to the forefront of current research in statistical and biological physics, application of concepts from physics to biological systems, understanding of complex phenomena emerging from simple systems, learn to construct models and infer model parameters from empirical observations, train interdisciplinary skills and interaction between experiment and theory, train presentation skills in advanced seminars

3 **Contents of the module**

The module is subdivided into core courses, specialized courses and the advanced seminar:

1. Core courses

- Introduction to Biophysics (4+2 HPW, 9 CP): Introduction to molecular cell biology, random walks in biology, mechanical forces in molecular and cellular biology, photophysics, electrical signals in nerve cells, genetic networks, biophysical methods
- Evolutionary Biology and Genomics for Physicists (3+1 HPW, 6 CP): Basic concepts of evolutionary theory, introduction to molecular evolution and genomics, theory of bio-molecular networks, concepts and methods of data analysis
- Selected Topics in Statistical Physics (4+2 HPW, 9 CP), including soft and biological matter, non-equilibrium statistical physics, disordered systems as specified annually in the "kommentiertes Vorlesungsverzeichnis"

2. Specialized courses

- Computational soft matter physics (2+1 HPW, 4.5 CP)
- Information theory and statistical physics (3+1 HPW, 6 CP)
- Non-Equilibrium physics with interdisciplinary applications (2+1 HPW, 4.5 CP)
- Qualitative methods in theoretical physics (4 HPW, 6 CP)
- Probability theory and stochastic processes (3+1 HPW, 6 CP)
- Systems biophysics (2+1 HPW, 4.5 CP)
- and others, including fitting courses from Bonn University, if approved by the module coordinator

3. Advanced Seminar in Statistical and Biological Physics (2 HPW, 3 CP)

The contents of the specialized courses can be found in the "kommentiertes Vorlesungsverzeichnis" and in the lecture descriptions online.

4 **Teaching/Learning methods**

Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. By preparing an advanced seminar, they become acquainted with a current topic of research, scientific methods and literature. They also learn to communicate in a pedagogical way on an advanced topic. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.

5 **Requirements for participation**

Experimental and theoretical physics at the level of the bachelor courses in physics

The course Advanced Statistical Physics has to be chosen in the theoretical physics core module.

6 **Type of module examinations**

The module examination is by oral exam covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (as defined in the individual courses). The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Primary AoS StatBio is composed of: 1. At least one core course (lectures and exercises) 2. Specialized courses (lectures and exercises) 3. Advanced lab courses in Biological Physics 4. Advanced Seminar in Statistical Biology and Biophysics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Interdisciplinary approach. This module prepares for topics of current research in statistical and biological physics and provides the basis for the preparation of the master thesis.
9	**Significance of the module mark for the overall grade** The weight of the module is 21/111 ≈ 18.9 %.
10	**Module coordinator** B. Maier
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Secondary Area of Specialization General Theory of Relativity/Quantum Field Theory

General Theory of Relativity / Quantum Field Theory					
Identification number MN-P-PN-GR-QFT	**Workload** 360 h	**Credits** 12 CP	**Terms of study** 1st and 2nd semester	**Frequency of occurrence** Details are provided online in the table “Course Offerings”.	**Duration** 2 semesters

1	**Types of lesson** a) Lecture courses b) Problem classes c) Exam	**Contact times** These depend on the specific choices made 1 h	**Self-study times** These depend on the specific choices made 24 h	**Intended group size** 15–20 students per problem class
2	**Aims of the module and acquired skills** The aim of the core courses is for the student to master the fundamental concepts of general relativity and/or quantum field theory, to an extent where she is able to read and comprehend original research articles in these areas. The specialized courses introduce her to an expanded range of subjects including related topics in nearby areas such as astrophysics, particle physics and physics-related mathematics.			

3	**Contents of the module** The module is subdivided into core courses and specialized courses: 1. Core courses • Relativity and Cosmology I (4+2 HPW, 9 CP): gravity as a geometric theory, Einstein field equations, Schwarzschild solution, experimental tests, gravitational waves • Relativity and Cosmology II (3+1 HPW, 6 CP): black holes, introduction to cosmology, the early universe • Quantum Field Theory I (4+2 HPW, 9 CP): second quantization and applications, functional integrals, perturbation theory, mean-field methods • Quantum Field Theory II (3+1 HPW, 6 CP): the role of correlation functions, spontaneous symmetry breaking, lattice gauge theory, topological aspects of QFT, renormalization 2. Specialized courses • Misc. courses: Quantum Aspects of Gravity (X HPW, X CP – cf. table “course offerings”) • Misc. courses: Particle– and Astrophysics (X HPW, X CP – cf. table “course offerings”) • Misc. courses: Mathematics (X HPW, X CP – cf. Table “course offerings”) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the course descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** The theoretical physics curriculum at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Secondary AoS GR-QFT is composed of: 1. At least one core course (lectures and exercises) taken from the list above 2. At least one specialized course from the list above
8	**Compatibility with other Curricula and Soft Skills** May be taken as an elective subject in other M.Sc. programs. Promotes scientific reading and presentation skills, in particular those for oral presentations.
9	**Significance of the module grade for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.

10	Module coordinator C. Kiefer
11	Additional information Details of the course offerings and contents are given online and in the “kommentiertes Vorlesungsverzeichnis”.

Secondary Area of Specialization Astrophysics

Astrophysics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-Astro	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

1	Type of lessons a) Lecture b) Problem class c) Exam	Contact times depending on the individual choice 1 h	Self-study times depending on the individual choice 24 h	Intended group size 15–20 students per problem class
2	Aims of the module and acquired skills The students will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable them to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepare the students towards their own research activity within the master thesis.			

3	**Contents of the module** The module is subdivided into a core course, specialized courses and the advanced seminar: 1. Core course • Advanced Astrophysics (4+2 HPW, 9 CP) 2. Specialized courses • Active Galaxies (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Data Analysis (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Experimental Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Galaxy Dynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Hydrodynamics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star Formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Interferometry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Detection Techniques in Molecular Astropyhsics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Methods in Infrared Astronomy (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Observational Cosmology (Bonn, 2+1 HPW, 4 CP) / (2 HPW, 3 CP) • Radiointerferometry: Methods and Science (Bonn, 2+2 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar in Astrophysics (2 HPW, 3 CP) The contents of the specialized courses can be found in the "kommentiertes Vorlesungsverzeichnis" and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Atomic Physics, Astrophysics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.

7	**Requisites for the allocation of credits** The Secondary AoS Molecular Physics is composed of: 1. Core Course Advanced Astrophysics (Lectures and Exercises) 2. Specialized courses (Lectures and Exercises) in Astrophysics 3. Advanced Seminar in Astrophysics
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** P. Schilke
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Secondary Area of Specialization Condensed Matter Physics I

Condensed Matter Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-CondMat	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 students per problem class
	c) Exam	1 h	24 h	

2	**Aims of the module and acquired skills** Students shall deepen their understanding and knowledge of the main concepts (experimental & theoretical) of condensed matter physics and get familiar with some important experimental methods in condensed matter physics. In specialized courses selected up-to-date research topics of experimental condensed matter physics are discussed as applications of the main concepts.

3	**Contents of the module** The module is subdivided into core courses and specialized courses: 1. Core course • Condensed Matter Physics I (3+1 HPW, 6 CP): Crystal structure and binding, Reciprocal space, Lattice dynamics and thermal properties, Free electron gas • Condensed Matter Physics II (3+1 HPW, 6 CP): Band structure, Metals and semiconductors, Transport properties, Dielectric function and screening, Superconductivity, Magnetism 2. Specialized courses • Experimental Methods of Condensed Matter Physics (2 HPW, 3 CP) • Superconductivity and Nanoscience (2 HPW, 3 CP) • Magnetism (2 HPW, 3 CP) • Semiconductor Physics (2 HPW, 3 CP) • Photons and Matter (2 HPW, 3 CP) • Physics of Surfaces and Nanostructures (2 HPW, 3 CP) • Introduction to Neutron Scattering (2 HPW, 3 CP) • Optical Spectroscopy (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The Secondary AoS Condensed Matter Physics is composed of: 1. The core course Condensed Matter Physics I (Lectures and Exercises, 3+1 HPW) 2. Two specialized courses (2 HPW) in Condensed Matter Physics. Alternatively, the core course Condensed Matter Physics II (3+1 HPW) can be chosen instead of the two specialized courses.
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data.

9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 8.9%.
10	**Module coordinator** J. Hemberger
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Secondary Area of Specialization Molecular Physics

Molecular Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-Mol	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture b) Problem class c) Practical course c) Exam	depending on the individual choice 1 h	depending on the individual choice 24 h	 15–20 students per problem class

2	**Aims of the module and acquired skills** Understanding of the main concepts of molecular physics, use of computer programs for the analysis of molecular spectra (computer aided analysis of scientific data), application of molecular physics concepts to applications of current research in fundamental physics, atmospheric physics and astrophysics including practical courses (advanced experimental skills) and advanced seminars (presentation skills).

3	Contents of the module The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Molecular Physics I (3+1 HPW, 6 CP): Basics of Molecular Spectroscopy, Interaction of Radiation with Matter, Chemical Bond, Born- Oppenheimer-Approximation, Rigid Rotor, Harmonic Oscillator, Electronic States, Rotational Spectroscopy, Group Theory • Molecular Physics II (3+1 HPW, 6 CP): Rotational Spectroscopy, Vibrational Spectroscopy, Group Theory, Coupling of Rotation and Vibration, Transitions and Selection Rules, Nuclear Spin Statistics, Coupling of Angular Momenta, Hund`s Cases, Fine Structure (FS), HFS 2. Specialized courses • Astrochemistry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Introduction Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Measurement Techniques in Atmospheric Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Experiments in Molecular Physics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Methods of Experimental Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fundamentals of Molecular Symmetry (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Fourier-Transform and its Applications (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Star formation (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • The Physics of the Interstellar Medium (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • Detection Techniques in Molecular Astrophysics (2+1 HPW, 4.5 CP) / (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the "kommentiertes Vorlesungsverzeichnis" and in the lecture descriptions online.
4	Teaching/Learning methods Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.
5	Requirements for participation Atomic Physics and Quantum Mechanics at the level of the bachelor courses in physics
6	Type of module examinations The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	Requisites for the allocation of credits The courses can be chosen from the above set in order to acquire the necessary credit points.

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Computer aided analysis of scientific data.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** S. Schlemmer
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the "kommentiertes Vorlesungsverzeichnis".

Secondary Area of Specialization Nuclear and Particle Physics

Nuclear and Particle Physics					
Identification number	**Workload**	**Credits**	**Term of studying**	**Frequency of occurrence**	**Duration**
MN-P-PN-Nuc	360 h	12 CP	1st to 2rd semester	Details are provided online in the table "Course Offerings".	2 semesters

1	**Type of lessons** a) Lecture b) Exam	**Contact times** depending on the individual choice 1 h	**Self-study times** depending on the individual choice 24 h	**Intended group size**
2	**Aims of the module and acquired skills** Understanding of the main concepts of nuclear and particle physics..			

3	**Contents of the module** The module is subdivided into core courses and specialized courses. 1. Core courses • Nuclear Physics II (3 HPW, 4.5 CP): Study of nuclear reactions, fission and fusion. • Particle Physics (3 HPW, 4.5 CP): Introduction into particle physics, accelerators and particle detectors 2. Specialized courses • Detector Physics (2 HPW, 3 CP) • Theoretical Nuclear Physics I (2 HPW, 3 CP) • Theoretical Nuclear Physics II (2 HPW, 3 CP) • Theoretical Nuclear Physics III (2 HPW, 3 CP) • Accelerator Mass Spectrometry (2 HPW, 3 CP) • Nuclear Astrophysics (2 HPW, 3 CP) • Neutron Physics (2 HPW, 3 CP) • Selected problems in Nuclear Structure (2 HPW, 3 CP) • Heavy Ion Physics (2 HPW, 3 CP) • Tools for Particle Physics (2 HPW, 3 CP) • Selected Topics on Future Energy Supply (2 HPW, 3 CP) • Applied Nuclear Physics (2 HPW, 3 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Nuclear and Particle Physics and Quantum Mechanics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of the core courses. To be admitted to the exam, students must actively have participated in the specialized course. The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The secondary AoS Nuclear and Particle Physics is composed of: 1. Two core courses (6 HPW, 9 CP) 2. One specialized course in Nuclear and Particle Physics (2HPW, 3CP).

8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.
10	**Module coordinator** J. Jolie
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Secondary Area of Specialization   Solid State Theory / Computational Physics

Solid State Theory / Computational Physics					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-ThSol	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

1	Type of lessons	Contact times	Self-study times	Intended group size
	a) Lecture	depending on the	depending on the	
	b) Problem class	individual choice	individual choice	15–20 students per problem class
	c) Exam	1 h	24 h	
2	**Aims of the module and acquired skills** Comprehension of the fundamental concepts used to theoretically describe solids and their excitations / ability to describe phenomena like superconductivity and magnetism / computational approach to problem solving with applications to many-body physics			

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar 1. Core Courses • Solid State Theory (3+1 HPW, 6 CP): Concepts of solid state theory and description of excitations in solid • Computational Many-Body Physics (3+1 HPW, 6 CP): Overview of elementary numerical approaches to study many-body systems, both classical and quantum. • Quantum Field Theory I (4+2 HPW, 9 CP): Modern methods to describe solids based on functional integrals and by using diagrammatic methods 2. Specialized courses: • Quantum Field Theory II (4+2 HPW, 9 CP) • One course chosen from the specialized courses of the module Condensed Matter Physics • Advanced Topics in Solid State Theory (3+1 HPW, 6 CP) • Hydrodynamics (2+2 HPW, 6 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator 3. Advanced Seminar on topical subjects of Solid State Theory (2 HPW, 3 CP) The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets and implement computational algorithms. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results.
5	**Requirements for participation** Basic knowledge in theoretical physics at the level of the bachelor courses in physics
6	**Type of module examinations** The module is passed by passing an oral examination covering the topics of all attended courses. To be admitted to the exam, students must actively participate in the problem sessions (including the solution of homework problems). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The following courses have to be chosen from the list given above in order to acquire the necessary credit points: 1. one of the core courses 2. further core courses, specialized courses or an advanced seminar The module is passed by passing an oral examination covering the topics of all attended courses.
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Analysis of complex problems, scientific reading and presentation skills, in particular oral presentations.
9	**Significance of the module mark for the overall grade** The weight of the module is 12/111 ≈ 10.8 %.

10	**Module coordinator** A. Rosch
11	**Additional information** Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Secondary Area of Specialization   Statistical and Biological Physics

Statistical and Biological Physics

Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-PN-StatBio	360 h	12 CP	1st and 2nd semester	Details are provided online in the table “Course Offerings”.	2 semesters

	Type of lessons	Contact times	Self-study times	Intended group size
1	a) Lecture b) Problem class c) Exam	depending on the individual choice 1 h	depending on the individual choice 24 h	 15–20 students per problem class

2	**Aims of the module and acquired skills** Bring students to the forefront of current research in statistical and biological physics, application of concepts from physics to biological systems, understanding of complex phenomena emerging from simple systems, learning to construct models and infer model parameters from empirical observations, train interdisciplinary skills and interaction between experiment and theory, train presentation skills in advanced seminars

3	**Contents of the module** The module is subdivided into core courses, specialized courses and the advanced seminar: 1. Core courses • Introduction to Biophysics (4+2 HPW, 9 CP): Introduction to molecular cell biology, random walks in biology, mechanical forces in molecular and cellular biology, photophysics, electrical signals in nerve cells, genetic networks, biophysical methods • Evolutionary Biology and Genomics for Physicists (3+1 HPW, 6 CP): Basic concepts of evolutionary theory, introduction to molecular evolution and genomics, theory of bio-molecular networks, concepts and methods of data analysis • Selected Topics in Statistical Physics (4+2 HPW, 9 CP), including soft and biological matter, non-equilibrium statistical physics, disordered systems as specified annually in the “kommentiertes Vorlesungsverzeichnis” 2. Specialized courses • Computational soft matter physics (2+1 HPW, 4.5 CP) • Information theory and statistical physics (3+1 HPW, 6 CP) • Non-Equilibrium physics with interdisciplinary applications (2+1 HPW, 4.5 CP) • Qualitative methods in theoretical physics (4 HPW, 6 CP) • Probability theory and stochastic processes (3+1 HPW, 6 CP) • Systems biophysics (2+1 HPW, 4.5 CP) • and others, including fitting courses from Bonn University, if approved by the module coordinator The contents of the specialized courses can be found in the “kommentiertes Vorlesungsverzeichnis” and in the lecture descriptions online.
4	**Teaching/Learning methods** Besides the teaching in lectures, the self-study based on books and lecture notes plays an important role. The students work individually on problem sets. In discussions with others and in the problem classes, they learn to solve challenging problems in a team and to present their approaches and results. In the additional lab course the students also gain insight into state-of-the-art instrumentation by conducting experiments independently.
5	**Requirements for participation** Experimental and theoretical physics at the level of the bachelor courses in physics.
6	**Type of module examinations** The module examination is an oral exam covering the topics of all attended courses. To be admitted to this exam, students must actively participate in the problem sessions (as defined in the individual courses). The grade given for the module is equal to the grade of the oral examination.
7	**Requisites for the allocation of credits** The courses can be chosen from the above set in order to acquire the necessary credit points.
8	**Compatibility with other Curricula and Soft Skills** As elective subject in other M.Sc. programs. Scientific reading and presentation skills, in particular oral presentations. Interdisciplinary approach.

9	Significance of the module mark for the overall grade The weight of the module is 12/111 ≈ 10.8 %.
10	Module coordinator B. Maier
11	Additional information Detailed information on the occurrence and the course contents are provided online and in the “kommentiertes Vorlesungsverzeichnis”.

Other modules like Cosmology, Experimental Hadron Physics, High Energy Particle Physics, Physics in Medicine, Quantum Optics and Optical Condensed Matter Physics, Theoretical Hadron Physics, and Theoretical Particle Physics will be offered in Bonn and will be credited as SAoS in Cologne. The examination board decides on combinations of courses from Bonn University which are accepted as SAoS.

The courses passed in Bonn will be credited in Cologne according to their HPW (1 HPW = 1.5 CP). If students achieve more than 12 CP in the SAoS, they may choose which 12 out of these CP are to be used as weights for grading the module.

Introductory Project I

Introductory Project I					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-ProI	360 h	12 CP	3rd Semester	continually	3 months

1	Type of lessons Lab work Oral presentation	Contact times 20 h 1 h	Self-study times 315 h 24 h	Intended group size Individual counseling
2	Aims of the module and acquired skills Orientation and practice in an extensive research subject of modern physics and presentation of scientific results.			
3	Contents of the module Both introductory projects I and II provide a basis for the Master thesis and should have a topical cohesion with the latter. As a general rule, the topic of the introductory projects and the Master thesis cover an extensive research subject in the area of specialization selected by the student.			

4	Teaching/Learning methods In the introductory projects, the self-study based on books and current scientific publications plays an important role. The students work individually on a problem of current research. In discussions with their supervisor and fellow students, they learn to solve challenging problems in a team and to present their approaches and results. During their research and by preparing and presenting the master thesis, they become acquainted with scientific methods and learn to communicate an advanced topic in a pedagogical way. As a general rule, the topic of the second introductory project and the master thesis will be determined by the choice of topic and advisor for the introductory project I. The introductory project I lasts approximately ca. three months. The topic and the tasks shall be defined in such a way that the project can be terminated within this period of time. An oral report is required for the completion of the introductory project I.
5	Requirements for participation Successful participation in all courses of the first year of the Master program. Sufficient knowledge in the field of specialization of the Master course.
6	Type of module examinations The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
7	Requisites for the allocation of credits The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
8	Compatibility with other Curricula None
9	Significance of the module mark for the overall grade None
10	Module coordinator The chairman of the examination board
11	Additional information This module can be started any time after consultation with the advisor of the project. The grading document has to be picked up by the student at the examination office before the seminar talk and filled after the seminar talk by the supervisor.

Introductory Project II

Introductory Project II					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-ProII	360 h	12 CP	3rd Semester	continually	3 months

1	Type of lessons	Contact times	Self-study times	Intended group size
	Lab work	20 h	315 h	Individual counseling
	Oral presentation	1 h	24 h	

2	Aims of the module and acquired skills Consolidation in an extensive area of research of modern physics and presentation of the corresponding scientific results.
3	Contents of the module Both introductory projects I and II provide a basis for the Mater thesis and should have topical cohesion with the latter. As a general rule, the topic of the introductory projects and the Master thesis cover an extensive research subject in the area of specialization selected by the student. The introductory project II builds on the insights gained in the introductory project I and serves as an additional consolidation in preparation of the Master thesis.
4	Teaching/Learning methods In the research module, the self-study based on books and current scientific publications plays an important role. The students work individually on a problem of current research. In discussions with their supervisor and fellow students, they learn to solve challenging problems in a team and to present their approaches and results. During their research and by preparing and presenting the master thesis, they become acquainted with scientific methods and learn to communicate an advanced topic in a pedagogical way. The advisor for the introductory project I should also be in charge of the introductory project II. The introductory project I lasts approximately ca. three months. The topic and the tasks shall be defined in such a way that the project can be terminated within this period of time. An oral report is required for the completion of the introductory project II.
5	Requirements for participation Passed examinations of all modules of the first year of the Master course, sufficient knowledge in the field of specialization of the Master course, and the contents of the previously completed introductory project I.
6	Type of module examinations The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
7	Requisites for the allocation of credits The introductory project is finished by the student giving a seminar talk and is graded as passed or failed.
8	Compatibility with other Curricula None
9	Significance of the module mark for the overall grade None
10	Module coordinator The chairman of the examination board
11	Additional information The grading document has to be picked up by the student at the examination office before the seminar talk and filled after the seminar talk by the supervisor.

2.4 Supplementary Modules (Ergänzungsmodule)

Besides the two areas of specialization, the students gain knowledge on additional topics of natural sciences and mathematics in the elective area. Here, different courses can be chosen, adding up to a minimum of 12 CP in total. Each individual course must have at least 3 CP. Several courses from the same field form a subject (e.g. two math courses will form the subject Math). The elective area has to cover two subjects.

Elective Area

<table>
<tr><td colspan="8">Elective Area</td></tr>
<tr><td colspan="2">Identification number</td><td colspan="2">Workload</td><td>Credits</td><td>Term of studying</td><td>Frequency of occurrence</td><td>Duration</td></tr>
<tr><td colspan="2">MN-P-WaMa</td><td colspan="2">360 h</td><td>12 CP</td><td>1st Sem. and 2nd Sem.</td><td>Depends on the individual choice</td><td>Depends on the individual choice</td></tr>
<tr><td>1</td><td colspan="2">Type of lessons
Depends on the individual choice</td><td colspan="2">Contact times
Depends on the individual choice</td><td>Self-study times
Depends on the individual choice</td><td colspan="2">Intended group size
Depends on the individual choice</td></tr>
<tr><td>2</td><td colspan="7">Aims of the module and acquired skills
Specialization in a scientific subject.</td></tr>
<tr><td>3</td><td colspan="7">Contents of the module
The module “Elective Area” covers advanced courses (usually from the choice of master courses) with a minimum of 12 CP from two subjects. In general, the courses are from topics in Natural Sciences, including the modules in physics offered by the University of Bonn. They have to differ from the Primary Area of Specialization and the Secondary Area of Specialization. Each individual subject has to cover at least 3 CP.
If not credited elsewhere, either of both courses “Advanced Quantum Mechanics” and “Advanced Statistical Physics” may be credited here.</td></tr>
<tr><td>4</td><td colspan="7">Teaching/Learning methods
Elective subjects are organized by the associated department (i.e. the department offering the course in their curriculum, e.g. the department of Chemistry).</td></tr>
<tr><td>5</td><td colspan="7">Requirements for participation
See module descriptions of the associated department.</td></tr>
<tr><td>6</td><td colspan="7">Type of module examinations
See module descriptions of the related special field. The failed module can be compensated once by another selection of courses.</td></tr>
<tr><td>7</td><td colspan="7">Requisites for the allocation of credits
The module is passed by passing all required individual exams.</td></tr>
</table>

8	**Compatibility with other Curricula** As elective subject in other M.Sc. programs
9	**Significance of the module mark for the overall grade** The grade for the module is the weighted arithmetic average of the grades for the individual subjects. A subject is a set of courses which will be graded in one examination. If students achieve more than 12 CP in the Elective Area, they may choose which 12 out of these CP are to be used for the weighted average. The weight of the module for the final grade is 12/111 ≈ 10.8 %.
10	**Module coordinator** The chairman of the examination board
11	**Additional information** The courses have to be chosen from the master curricula of the associated departments.

2.5 Master Thesis (Master-Arbeit)

The master studies are completed by the Master Thesis. The students work independently on a well-defined problem of current physics research. The topic of the Master Thesis is usually closely connected to the topics of the two introductory projects. The scientific results of this work are presented in a written thesis as well as orally.

Master Thesis

Research Module					
Identification number	Workload	Credits	Term of studying	Frequency of occurrence	Duration
MN-P-For	900 h	30 CP	4th semester	Depending on the individual choice	6 months

1	**Type of lessons** Lab work Oral presentation	**Contact times** 20 h 1 h	**Self-study times** 315 h 24 h	**Intended group size** Individual counseling
2	**Aims of the module and acquired skills** Students acquire the scientific skills that are needed to carry out a substantial research project on one of the current topics of physics. They learn to present their results in written and oral form.			
3	**Contents of the module** As an integral part of the M.Sc. program, each student works on his/her own research project. The results of the project are written up as M.Sc. thesis. The thesis work is preceded by two introductory projects which introduce the student to the theme of the M.Sc. thesis and are evaluated separately. As a rule, the introductory projects and the M.Sc. thesis research are substantial pieces of scientific work, carried out in the area of specialization chosen by the student.			

4	Teaching/Learning methods The topic to be worked on is issued by the chairman of the examination board in consultation with the student's thesis research advisor. In the research module, the self-study based on books and current scientific publications plays an important role. The students work individually on a problem of current research. In discussions with their supervisor and fellow students, they learn to solve challenging problems in a team and to present their approaches and results. During their research and by preparing and presenting the master thesis, they become acquainted with scientific methods and learn to communicate an advanced topic in a pedagogical way. They also learn to finalize a project in time and to manage their time efficiently.
5	Requirements for participation Passed examinations of all modules of the first three semesters of the Master course and the contents of the previously completed introductory projects I and II.
6	Type of module examinations The Master Thesis and the colloquium will be evaluated by two and in the exceptional case by three referees. On the day of the colloquium the referee report/reports to the master thesis have to be present. The grading of the colloquium takes place on the day of the colloquium.
7	Requisites for the allocation of credits The module is passed by successfully preparing the M.Sc. thesis and by passing the colloquium.
8	Compatibility with other Curricula None
9	Significance of the module mark for the overall grade The total grade given for the module is the 3:1 weighted average of the two grades given for the written thesis and the colloquium talk. The weight of the module is 45/111 ≈ 40.5 %.
10	Module coordinator The chairman of the examination board
11	Additional information The Master Thesis and the Master Colloquium have to be registered at the examination office. The date of issue of the master topic is to be no later than two months after the student's completing the requirements for admission to the module. Students work on the introductory projects for three months each, and then on the M.Sc. thesis for six months. The topic and the problem posed have to be of such a kind that it is possible for the student to complete the M.Sc. thesis within the allotted time. To complete the M.Sc. thesis work, the student hands in a written thesis and subsequently reports on it by way of a colloquium open to members of the faculty. The length of the thesis should not exceed 70 pages (font 12pt, baselineskip 16pt). Both English and German are permitted as a language for the written thesis and the colloquium talk. No later than 8 weeks after completion of the Master thesis the candidate reports in a colloquium on the subject of the master thesis. Presentation time should not exceed 25 minutes; time for questions is limited to 20 minutes.

3 Studies Aids (Studienhilfen)

3.1 Model Study Plan (Musterstudienplan)

The Department of Physics recommends performing the studies according to the following plans. They are tailored to the beginning of studies either in the winter term or the summer term.

In general the study plan strongly depends on the individual choices and the selected areas of specialization. The different courses of each subject can be arranged individually. Also a number of courses is not offered every year. Therefore it is recommended to plan the courses early on. In case of major deviations from the study plan provided below, students are strongly advised to check their plan with the Student Advisory Service.

Study Plan MSc Physics (SuSe)

SuSe		WiSe		SuSe		WiSe	
1st Semester		2nd Semester		3rd Semester		4th Semester	
	CP		CP		CP		CP
Practical Courses M I + II	12	Adv. QM / Adv. Stat. Phys.	9	Introductory Project I	12	Master Thesis	30
Elective Area	6	Elective Area	6	Introductory Project II	12		
Primary Area of Specialization	6	Primary Area of Specialization	12	Advanced Seminar	3		
Secondary Area of Specialization	6	Secondary Area of Specialization	6				
Total	30	Total	33	Total	27	Total	30

Study Plan MSc Physics (WiSe)

WiSe		SuSe		WiSe		SuSe	
1st Semester		2nd Semester		3rd Semester		4th Semester	
	CP		CP		CP		CP
Practical Course M I	6	Practical Course M II	6	Introductory Project I	12	Master Thesis	30
Adv. QM / Adv. Stat. Phys.	9			Introductory Project II	12		
Elective Area	6	Elective Area	6				

Primary Area of Specialization	6	Primary Area of Specialization	12	Advanced Seminar	3		
Secondary Area of Specialization	6	Secondary Area of Specialization	6				
Total	33	Total	30	Total	27	Total	30

3.2 Subject and Exam Counseling (Fach- und Prüfungsberatung)

In addition to the services of the Student Advisory and Counseling Centre of the University of Cologne, the Department of Physics offers a special counseling for physics students (Dr. Petra Neubauer-Guenther (deputy: Dr. Harald Kierspel)). This counseling addresses bachelor students who consider continuing their studies up to the M.Sc. and master students at all stages before and during their studies.

An open consultation-hour is offered on a weekly basis during the whole year. Besides, also individual appointments can be arranged on short notice. Detailed information can also be provided via email or phone.

The counseling also addresses questions concerning examinations and their organization. Detailed questions on individual modules will be answered by the module coordinators. Detailed questions concerning examinations will also be answered by the examination office.

3.3 Further Offers of Information and Counseling (Weitere Informations- und Beratungsangebote)

Members of the BCGS honors branch will be assigned two mentors, one in Cologne and one in Bonn. These mentors will provide support for the organization and planning of the studies, as well as on subject questions.

The student's council organized by the physics students in Cologne also provides substantial support on any questions related to the studies.

Students who aim to perform part of their studies abroad via the **Erasmus Program** may contact Prof. Jolie for further counseling.

Further counseling offers at the University of Cologne are:

Student Advisory and Counseling Centre (Zentrale Studienberatung) *http://verwaltung.uni-koeln.de/abteilung21/content/beratungsangebote/faecheruebergreifende_studienberatung/index_ger.html*	General questions concerning studies, choice of subjects, etc. (Allgemeine Fragen zum Studium, Fächerwahl etc.)

Studierendensekretariat *http://verwaltung.uni-koeln.de/studsek/content/*	Questions concerning enrolling, etc. (Fragen zur Einschreibung, Rückmeldung etc.)
Kölner Studentenwerk *http://www.kstw.de/*	Social aspect concerning the studies (Soziale Aspekte im Zusammenhang mit dem Studium)
ASTA *http://www.asta.uni-koeln.de/*	Student Representation (Studierendenvertre-tung)
Rektoratsbeauftragter für Menschen mit Behinderung *http://www.hf.uni-koeln.de/34502*	Study with disabilities (Studieren mit Behinderung)
Akademisches Auslandsamt *http://verwaltung.uni-koeln.de/international/content/incoming/studium_in_koeln/index_ger.html*	Study with migration background (Studieren mit Migrationshintergrund)
Zentrale Gleichstellungsbeauftragte *http://www.gb.uni-koeln.de/*	Compatibility of studies and family, gender discrimination (Vereinbarkeit von Familie und Studium, Sexualisierte Diskriminierung)

Appendix A Course Offerings

This appendix provides the course offerings for the PAoS and SAoS as they are planned for the next four years. The latest version of the offerings is provided online.

Course Offerings Master

Primary and Secondary AoS Astrophysics (Astro)

Coordination: Schilke

last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Advanced Astrophysics	4+2	9	x		x		x		x	
Specialized courses										
Star Formation	2+1 / 2	4.5 / 3				x				x
Astrochemistry	2+1 / 2	4.5 / 3		x				x		
Physics of the Interstellar Medium	2+1 / 2	4.5 / 3		x				x		
Galaxy Dynamics	2+1 / 2	4.5 / 3		x				x		
Active Galaxies	2+1 / 2	4.5 / 3				x				x
Observational Cosmology (Bonn/BCGS)	2+1	4								
Methods of Experimental Astrophysics	2+1 / 2	4.5 / 3		x				x		
Interferometry	2+1 / 2	4.5 / 3		x				x		
Fourier-Transform and its Applications	2+1 / 2	4.5 / 3				x				x
Hydrodynamics	2/2+1/2+2	3 / 4.5 / 6		x(2/2+1)				x(2/2+2)		
Data Analysis	2+1 / 2	4.5 / 3		x				x		
Observational Methods in Infrared Astronomy	2+1 / 2	4.5 / 3				x				x
Radiointerferometry: Methods and Science (Bonn/BCGS)	2+2	4		x		x		x		x
Detection Techniques in Molecular Astrophysics	2+1 / 2	4.5 / 3	x			x				x
Additional Topical Specialized Lectures	2+1 / 2	4.5 / 3	(x)	(x)	(x)	(x)	(x)	(x)	(x)	(x)
Seminars										
Advanced Seminar	2	3	x	x	x	x	x	x	x	x

x confirmed
(x) planned

Course Offerings Master

Primary and Secondary AoS Condensed Matter Physics (ConMat)

Coordination: Braden, Grüninger

last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Condensed Matter Physics I	3+1	6	x		x		x		x	
Condensed Matter Physics II	3+1	6		x		x		x		x
Specialized courses										
Semiconductor Physics and Nanoscience	2	3		x		x		x		x
Superconductivity	2	3	x		x		x		x	
Magnetism	2	3		x		x		x		x
Experimental Methods in Condensed Matter Physics	2	3		x		x		(x)		(x)
Introduction to Neutron Scattering	2	3								
Physics of Surfaces and Nanostructures	2	3								
Photons and Matter	2	3		(x)						
Optical Spectroscopy	2	3								
Seminars										
Advanced Seminar	2	3	x	x	x	x	x	x	x	x

x confirmed
(x) planned

Course Offerings Master

Primary and Secondary AoS General Theory of Relativity / Quantum Field Theory (GR-QFT)

Coordination: Kiefer

last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Relativity and Cosmology I	4+2	9	x				x			
Relativity and Cosmology II	3+1	6		x				x		
Quantum Field Theory I	4+2	9			x			x		
Quantum Field Theory II	3+1	6	x			x			x	
Specialized courses										
Quantum Aspects of Gravity: Quantum Gravity, The Early Universe Quantum Field Theory in Curved Spacetime, Foundations of Theory	2	3	x	x	x	x	x	x	x	x
Particle- and Astrophysics: String Theory, Astrophysics II, Theoretical Particle Physics, Theoretical Astroparticle Physics, Superstring Theory, Supersymmetry, Advanced Theoretical Particle Physics	3+1	6	x	x	x	x	x	x	x	x
Mathematics: Topology[2], Differential Geometry[2], Theory of Groups[2], Functional Analysis[2], Geometry and Analysis on Supermanifolds and Lie Supergroups	2	3	x	x	x	x	x	x	x	x
Seminars										
Advanced Seminar on Relativity and Cosmology	2	3	x		x				x	
Advanced Seminar on Quantum Field Theory	2	3		x		x		x		x

x confirmed

(x) planned

2: lecture course of doubled load: HPW: 4+2, CP: 6

Course Offerings Master

Primary and Secondary AoS Molecular Physics (Mol)

Coordination: Schlemmer — last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Molecular Physics I	3+1	6	x		x		x		x	
Molecular Physics II	3+1	6		x		x		x		x
Specialized courses										
Astrochemistry	2+1 / 2	4.5 / 3		x				x		
Detection Techniques in Molecular Astrophysics	2+1 / 2	4.5 / 3	x			x				x
Experiments in Molecular Physics	2+1 / 2	4.5 / 3	x		x		x		x	
Introduction Atmospheric Physics	2+1 / 2	4.5 / 3		x		x		x		x
Measrurement Techniques in Atmospheric Physics	2+1 / 2	4.5 / 3			x		x		x	
Methods of Experimental Astrophysics	2+1 / 2	4.5 / 3		x				x		
Fundamentals of Molecular Symmetry	2+1 / 2	4.5 / 3		(x)	x	(x)	x	(x)	x	(x)
Fourier-Transform and its Applications	2+1 / 2	4.5 / 3				x				
Star Formation	2+1 / 2	4.5 / 3				x				x
The Physics of the Interstellar Medium				x				x		
Laser Spectroscopy (Bonn/BCGS)	3+1	6		(x)		(x)		(x)		(x)
Laser Physics and non-linear Optics (Bonn/BCGS)	3+1	6	(x)		(x)		(x)		(x)	
Seminars										
Advanced Seminar	2	3	x	x	x	x	x	x	x	x

x confirmed
(x) planned

Course Offerings Master

Primary and Secondary AoS Nuclear and Particle Physics (Nuc)

Coordination: Jolie | last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Nuclear Physics II	3	4.5	x		x		x		x	
Physics of Detectors	2	3		x		x		x		x
Particle Physics	3	4.5		x		x		x		x
Specialized courses										
Theoretical Nuclear Physics I	2	3			x					
Theoretical Nuclear Physics II	2	3				x				
Theoretical Nuclear Physics III	2	3	x				x			
Neutron Physics	2	3								
Applied Nuclear Physics	2	3			x					
Accelerator Mass Spectrometry	2	3		x		x				
Selected Problems in Nuclear Structure	2	3		x						
Heavy Ion Physics	2	3								
Nuclear Astrophysics	2	3		x						
Tools for Particle Physics	2	3	x		x		x		x	
Selected Topics on Future Energy Supply	2	3						x		
Seminars										
Advanced Seminar	2	3	x	x	x	x	x	x	x	x

x confirmed
(x) planned

Course Offerings Master

Primary and Secondary AoS Statistical and Biological Physics (StatBio)

Coordination: Maier — last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Introduction to biophysics	4+2	9	x		x		x		x	
Evolutionary biology and genomics for physicists	3+1	6		x		x		x		x
Selected topics in statistical physics:	4+2	9								
Soft and biological matter				x						x
Nonequilibrium statistical physics						x				
Specialized courses										
Computational soft matter physics	2+1	4.5					x			
Nonequilibrium physics with interdisciplinary applications	2+1	4.5								
Information theory and statistical physics	3+1	6					x			
Qualitative methods in theoretical physics	4+2	9				x				
Probability theory and stochastic processes	3+1	6	x							
Advanced lab courses										
Experimental evolution and genetics for physicists	3	4.5			x		(x)		(x)	
Seminars										
Advanced Seminar in Statistical biology and biophysics	2	3	x		x		x		x	

x confirmed

(x) planned

Course Offerings Master

Primary and Secondary AoS Solid State Theory / Computational Physics (ThSol)

Coordination: Bulla, Rosch, Trebst — last update: 2/26/2014

	HPW	CP	WS13/14	SS14	WS14/15	SS15	WS15/16	SS16	WS16/17	SS17
Core Courses										
Solid State Theory	3+1	6	x		x		x		x	
Computational Many-Body Physics	3+1	6		x		x			x	
Quantum Field Theory I	4+2	9		x		x		x		x
Specialized courses										
Specialized Courses of the module Condensed Matter Physics			x	x	x	x	x	x	x	x
Quantum Field Theory II	4+2	9	x		x		x		x	
Advanced Topics in Solid State Theory	3+1	6								
Hydrodynamics	2/2+1/2+2	3 / 4.5 / 6		x(2/2+1)				x(2/2+2)		
Seminars										
Advanced Seminar	2	3		x		x		x		x

x confirmed
(x) planned

Appendix B Course Descriptions

This appendix provides the course descriptions for the courses currently offered in the PAoS and SAoS. Please note, that some courses can be credited for more than one AoS. These course descriptions are provided in the field offering them.

The latest version of the descriptions is provided online.

Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa

Course: Active Galactic Nuclei

Lecturers: Andreas Eckart
Email: eckart@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Astrophysics I (Astrophysics II recommended)

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of fundamental concepts and physical radiation mechanisms for active galactic nuclei
Like Seyfert-galaxies, QSOs, quasars, and violently variable objects.

Contents of the course:
The lecture introduces to basic aspects of active galactic nuclei:
Types of sources HII-galaxies, LINERs, Seyfert I, Seyfert II, QSO I , QSO II, BLLac /OVV-sources
Structure of an active nucleus: Broad line region (BLR), Narrow line region (NLR) and extended narrow line region (ionization cone).
Forbidden and permitted line transitions as density and temperature probes
Continuum emission processes: free-free and synchrotron radiation
Radio galaxies, jets and lobes as well as super luminal motion in jets.

Recommended literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa

Course: Advanced Astrophysics

Lecturers: Andreas Eckart, Lucas Labadie, Peter Schilke, Jürgen Stutzki
Email: eckart, labadie, schilke, stutzki@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	4+2	9	WiSe

Requirements for participation:
Astrophysics I

Type of module examinations:
Written test and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
The students will gain the ability to apply fundamental concepts of physics to describe astrophysical phenomena and will obtain an overview of the experimental foundations of our knowledge about the cosmos. The courses will enable them to understand the fundamental principles of the universe and its history. The courses also give an introduction to topics of active research in astrophysics and thus prepare the students towards their own research activity within the master thesis.

Contents of the course:
Based on the introductory course 'Astrophysics' in the Bachelor program this course deepens the understanding in selected topical areas of relevance. These are:

- Interstellar medium: molecular clouds, HII regions, photon dominated regions, shock waves, radiation processes, radiative transfer, astrochemistry
- Star formation (low mass and high mass), planetary system formation
- Galaxies: galactic structure, morphology, dynamics, chemical evolution, nuclei of active galaxies
- Large scale structure of the universe: intergalactic distance ladder, galaxy clusters, dark matter, gravitational lenses, experimental cosmology

Recommended literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Module: Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa

Course: Data Analysis

Lecturers: Markus Röllig
Email: roellig@p1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2+1	4.5	SuSe
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:

Astrophysics I, Mathematics for Physicists I+II, Statistical Mechanics
(Some hands-on exercises require computer access and he basic understanding of a computational data analysis software of your choice (Excel, Matlab, Mathematica, R), or a programming language like python.

Type of module examinations:

One oral examination at the end of the module

Duration of the course:

1 semester

Aims of the course:

Understanding of fundamental concepts of statistical methods and data analysis.

Contents of the course:

The lecture introduces the basic aspects of data analysis and the application of statistical methods to data in astronomy and other physical sciences.

The course covers the following topics:
Descriptive statistics, uncertainties and errors, error propagation, probability distributions, statistical inference, data smoothing, interpolation, regression, multivariate analysis, least-squares fitting, correlation analysis, hypothesis testing, correlation and testing fits. We will also cover practical aspects, such as plotting and presenting data, data formats, and work with real data. If time allows additional topics like image processing, astronomical data reduction, and others.

The course will often use real astronomical data or applications from astronomy, but the contents of the course are of course applicable to all physical sciences.

Recommended literature:

Bevington and Robinson, Data Reduction and error analysis for the physical sciences (McGraw-Hill)
Taylor, An Introduction to error analysis (Springer)
Feigelson and Babu , Modern Statistical Methods for Astronomy (Cambridge University Press)
Wall and Jenkins, Practical Statistics for Astronomers (Cambridge University Press)

Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa

Course: Galaxy Dynamics

Lecturers: Andreas Eckart
Email: eckart@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Astrophysics I (Astrophysics II recommended)

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of fundamental concepts of stellar and galaxy dynamics.

Contents of the course:
The lecture introduces to basic aspects of stellar and galaxy dynamics: Multiple stellar systems, dynamics of open and compact stellar clusters, elliptical, disk and barred spiral galaxies, gas kinematics, galaxy evolution in galaxy clusters, gravitational friction, violent relaxation, the Hubble fork, galaxy collisions and mergers, cosmological evolution of stellar systems.

Recommended literature:
Binney and Merryfield, Galactic Astronomy (Princeton University Press)
Binney and Tremaine, Galactic Dynamics (Princeton University Press)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Schneider, Einführung in die extragalaktische Astronomie & Kosmologie (Springer, Berlin)
Weigert and Wendker, Astronomie und Astrophysik (VCH Verlag)

Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa

Course: Optical/Infrared Stellar Interferometry

Lecturers: Lucas Labadie
Email: labadie@p1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2+1	4.5	SuSe
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Astrophysics I

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Acquiring the fundamental knowledge on the technique of optical/IR interferometry to study a variety of astrophysical processes in galactic (YSOs, Massive stars, circumstellar disks) and extragalactic objects (AGNs) at very high angular resolution.

Contents of the course:
Part I: Key science cases for OIR interferometry: YSOs, massive stars, evolved stars, pre-main and main-sequence stars, multiplicity, Active Galactic Nuclei. Part II: principles of OIR interferometry, temporal and spatial coherence, fringe tracking and sensitivity, image reconstruction, 1st and 2nd generation VLTI instruments. Part III: Astrophysical results of OIR interferometry and future prospects.

Recommended literature:
A. Labeyrie, S.G. Lipson, P. Nisenson: An introduction to optical stellar interferometry (Cambridge University Press, 325p.)
B. A. Glindemann: Principles of Stellar Interferometry (Springer)
C. J.-P. Berger: Imaging the heart of astrophysical objects with optical long-baseline interferometry (Astron Astrophys Rev (2012))

Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa, MN-P-SP-Mol, MN-P-PN-Mol

Course: Methods of Experimental Astrophysics

Lecturers: Jürgen Stutzki, Volker Ossenkopf
Email: stutzki@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Astrophysics I (Astrophysics II recommended)

Type of module examinations:
Exercise and written test; or oral examination, and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Gain insight into which type of instrumentation, based on which principles, is employed for particular astronomical and astrophysical applications; and learn about their practical and fundamental limitations in resolution and sensitivity

Contents of the course:
- Detection of radiation: direct and coherent detection
- Signal/Noise ratio: fundamental and practical limits
- Principles of optical instruments: imaging
- Principles of optical instruments: spectroscopy
- Radio receivers: Local Oscillator, Mixer and Backend-Spectrometers
- Calibration: theory and measurement strategies

Recommended literature:
Rieke: Detection of Light
Kraus: Radioastronomy
Bracewell: The Fourier Transform and its Applications

Astrophysics and Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol, MN-P-WaMa

Course: The Fourier-Transform and its Applications

Lecturers: Jürgen Stutzki
Email: stutzki@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Elementary Physics, Elementary QM

Type of module examinations:
Exercise and written test; or oral examination, and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Strengthen inside into how the mathematical principles of Fourier Theory as a common principle affects many areas of physics (optics: diffraction/interference; QM: Heisenberg principle; statistics of noise and drifts; data acquisition: sampling) and other applications (data compression, signal processing).

Contents of the course:
- Introduction to the principles of Fourier Transform mathematics
- Delta-function and more general distributions
- Diffraction optics and interferometry
- Uncertainty principle in QM as application of FT
- Theory of noise, drifts and their statistics
- Intro to wavelet analysis and data compression

Recommended literature:
Bracewell: The Fourier Transform and its Applications

Astrophysics
and
Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol, MN-P-WaMa

Course: The Physics of the Interstellar Medium

Lecturers: Volker Ossenkopf
Email: ossk@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Astrophysics I (Astrophysics II recommended)

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding the fundamental processes structuring the interstellar medium (ISM) and ways to observe them

Contents of the course:
The dynamics of the interstellar gas, hydrodynamic instabilities, turbulence. Formation of and radiation from interstellar gas, dust and polycyclic aromatic hydrocarbons. The energy balance of the ISM, phases of the ISM and chemical phase transitions, Special interstellar regions: HII regions, diffuse Galactic clouds, molecular clouds, photon-dominated regions and X-ray dominated regions, interstellar shocks and supernova remnants, planetary nebulae

Recommended literature:
B.T. Draine: Physics of the Interstellar and Intergalactic Medium (Princeton Series in Astrophysics)
A.G.G.M. Tielens: The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
K.R. Lang: Astrophysical Formulae (Springer Study Edition)

Astrophysics and Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol, MN-P-WaMa

Course: Star Formation

Lecturers: Peter Schilke
Email: schilke@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Astrophysics I (Astrophysics II recommended)

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of fundamental concepts of star formation in a variety of environments.

Contents of the course:
The lecture introduces the basic aspects of Star Formation:
Physical Processes in the ISM, Interstellar Chemistry, ISM and Molecular Clouds, Equilibrium Configurations and Collapse, Protostars, Formation of High Mass Stars, Jets, Outflows, Disks, Pre-main sequence stars, Initial Mass Function, Structure of the Galaxy, Starburst Galaxies, Star Formation in the early Universe

Recommended literature:
Palla and Stahler, Formation of Stars (Wiley)
Carroll and Ostlie, An Introduction to Modern Astrophysics (Addison-Wesley)
Shu, The Physics of Astrophysics I & II (University Science Books, Mill Valley)
Tielens, The Physics and Chemistry of the Interstellar Medium (Cambridge University Press)
Spitzer, Physical Processes in the Interstellar Medium (Wiley)
Unsöld and Baschek, Der neue Kosmos (Springer, Berlin)

Astrophysics

Module No.: MN-P-SP-Astro, MN-P-PN-Astro, MN-P-WaMa

Course: Observational Methods in Infrared Astronomy

Lecturers: Lucas Labadie
Email: labadie@p1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2+1	4.5	SuSe
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Atomic Physics, Astrophysics I

Type of module examinations:
One oral examination at the end of the module

Duration of Course:
1 semester

Aims of the course:
The aim of the lecture is to give a detailed insight into the observational and instrumental techniques currently used in infrared astronomy, with an emphasis on high-angular resolution studies. The objective is to give the students the necessary technical background to understand the complete chain going from data acquisition, data calibration, data reduction and scientific interpretation. This lecture efficiently prepares those students that wish to start observational work in astrophysics in a professional environment.

Contents of the course:
- Infrared spectral range, observing sites
- Atmospheric turbulence and seeing
- Thermal background suppression and calibration, chopping and nodding
- Wavefront sensing, adaptive optics, laser guide stars
- Photometric calibration, PSF calibration
- Low-, medium-, and high-resolution spectroscopy; integrated field spectrograph
- Optical/Infrared detectors and error budget (SNR)
- Basics of data reduction, dark and flats
- Aperture photometry, line fitting, psf subtraction
- Image deconvolution, astrometry and orbital solutions
- Astronomy image file formats (fits, oifits) and tools (VO)

Recommended literature:
A. Daniel J. Schroeder: Astronomical Optics (Academic Press, 2000)
B. Pierre Léna, F. Lebrun: Observational Astrophysics (A&A Library)
C. A. Glindemann: Principles of Stellar Interferometry (Springer)
D. Bradley W. Carroll: An Introduction to Modern Astrophysics (Pearson Editor)

Astrophysics
and
Solid State Theory

Module No.: N-P-SP-Astro, MN-P-PN-Astro, MN-P-SP-ThSol, MN-P-PN-ThSol, MN-P-WaMa

Course: Hydrodynamics - from water droplets to Supernovae

Lecturers: Stefanie Walch
Email: walch@p1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2+2	6	SuSe 2016 and later
Specialized Course	Lecture	English	2+1	4.5	SuSe 2014
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Good bachelor level knowledge of theoretical physics and astrophysics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of fundamental concepts of gas hydrodynamics and basic computational implementations to simulate fluid flows.

Contents of the course:
The lecture introduces the basic aspects of Hydrodynamics:
Equations of ideal fluids, sound and potential waves, viscous fluids, hydrodynamical instabilities (e.g. Kelvin-Helmholtz-instability), convection, turbulence.
Basic numerical methods used in fluid hydrodynamics will be discussed, e.g. Riemann solvers.
The selected examples and exercises will mostly be related to astrophysical problems, like Supernova explosions, or turbulence in the interstellar medium.

Recommended literature:
Greiner & Stock – Theoretische Physik 2 – Hydrodynamik (Europa Lehrmittel Verlag, 1991)
Landau & Lifschitz – Band 6 – Hydrodynamik (Deutsch, 2007)
L.D. Landau & E.M. Lifshitz: Fluid mechanics (Pergamon Press, 2nd edition, 1987)
A.R. Choudhuri: The physics of fluids and plasmas (Cambridge University Press, 1998)
Bodenheimer, Laughlin, Rozyczka, Yorke – Numerical methods in astrophysics (Taylor & Francis, 2006)

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-WaMa

Course: Advanced Seminar

Lecturers: Markus Braden, Markus Grüninger, Thomas Michely, Paul van Loosdrecht
Email: braden@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Advanced Seminar	Seminar	English	2	3	WiSe, SuSe

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
Presentation in form of a seminar talk.Afterwards answering of questions from the audience.

Duration of the course:
1 semester

Aims of the course:
Deepening of the content of the condensed matter physics core courses in a chosen field of large current interest. Students learn to accumulate knowledge on a special subject by studying and summarizing various literature sources including scientific articles. Students learn to resume a scientific theme in an oral presentation.

Contents of the course:
Among the contents of the condensed matter physics courses each semester a special subject of great current interest is chosen. This subject is treated in small units by oral presentations given by the students. The students obtain various types of literature from the tutors which allows them to understand the subject and to summarize it in their presentation.

Recommended literature:
Depending on the chosen theme of the seminar.

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Condensed Matter Physics

Lecturers: Braden, Grüninger, Hemberger, van Loosdrecht, Lorenz, Michely
Email: braden@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core course	Lecture	English	3+1	6	WiSe
Core course	Lecture	English	3+1	6	SuSe

Requirements for participation:
Basic knowledge in condensed matter physics and quantum mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
2 semesters

Aims of the course:
Comprehensive introduction to the basic principles of condensed matter physics and to some experimental methods. Examples of current research will be discussed.

Contents of the course:
Topics covered are:

- Crystal structure
- Reciprocal space
- Lattice dynamics and thermal properties
- Electronic structure (free electron gas, Fermi surface, band structure)
- Semiconductors and metals
- Transport properties
- Dielectric function and screening
- Superconductivity
- Magnetism

Recommended literature:
Skriptum (available during the course)
Ashcroft/Mermin: Solid State Physics
Kittel: Introduction to Solid State Physics
Ibach/Lüth: Solid-State Physics. An Introduction to Principles of Materials Science

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course:
Experimental methods in condensed matter physics

Lecturers: Hemberger, Michely, Busse
Email: hemberger@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of experimental concepts in condensed matter science
Knowledge of basic fields and important applications

Contents of the course:
The lecture introduces to modern experimental approaches in condensed matter physics. Basic concepts are illustrated with examples of physical problems investigated employing different methods.

Topics covered are
- Introduction on sample preparation
- X-ray powder diffraction
- Specific heat, thermal expansion
- Magnetization and magnetic susceptibility
- DC transport
- Dielectric spectroscopy
- Photo-emission spectroscopy
- Inelastic scattering (neutrons, light)
- THz spectroscopy / Optical spectroscopy
- Scanning probe microscopy/spectroscopy (AFM, STM)

Recommended literature:
Skriptum (available during the course)
Ibach/Lüth: Solid-State Physics: An Introduction to Principles of Materials Science
Oura/Lifshits/Saranin/Zotov/Katayama: Surface Science - An Introduction
Fox: Optical Properties of Solids
Buckel/Kleiner: Superconductivity
Bergmann/Schäfer: Experimentalphysik (Band 6: Festkörper)
Ashcroft/Mermin: Solid State Physics

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Magnetism

Lecturers: Thomas Lorenz, Markus Braden
Email: tl@ph2.uni-koeln.de, braden@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of magnetism in condensed matter systems

Contents of the course:
The lecture introduces to the magnetism in condensed matter systems. Starting from basic concepts of the magnetic properties of free atoms it is aimed to illustrate the extremely rich field of collective magnetism that arises from the mutual interaction of an extremely large number of interacting particles.

Topics covered are
- magnetism of free atoms
- magnetism of ions in the crystal electric field
- magnetic interactions and ordering phenomena
- magnetic ground states and excitations
- itinerant magnetism
- magnetic frustration and low dimensionality
- magnetic order vs. competing ordering phenomena

Recommended literature:
Scriptum (available during the course)
S. Blundell: Magnetism in Condensed Matter
Ashcroft/Mermin: Solid State Physics
Ch. Kittel: Introduction to Solid State Physics
R.M. White: Quantum Theory of Magnetism
P. Fazekas: Lecture Notes on Electron Correlation & Magnetism
D. Khomskii: Basic Aspects of the Quantum Theory of Solids

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Introduction to neutron scattering

Lecturers: Markus Braden
Email: braden@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of the basic concepts and techniques of elastic and inelastic neutron scattering experiments.

Contents of the course:
The lecture introduces to the techniques of elastic and inelastic neutron scattering that can be used to determine the crystal or magnetic structure as well as the dispersion of nuclear or magnetic excitations. Topics covered are

- Crystal structures and reciprocal space
- Neutron powder diffraction
- Single-crystal diffraction
- Structure refinements
- Inelastic neutron scattering
- Phonon dispersion
- Magnetic excitations
- Examples of current research (high-temperature superconductors, manganates with colossal magnetoresistivity, multiferroics, …)
- Polarized neutron scattering

Recommended literature:
Skriptum (available during the course)
S. W. Lovesey, Theory of Neutron Scattering from Condensed Matter, Oxford (1981)
G. E. Bacon, Neutron Diffraction, Oxford (1979)
Shirane, Shapiro and, Tranquada, Neutr. Scattering with a triple-axis spectrometer, Cambridge (2002)
Izyumov, Ozerov, Magnetic Neutron Diffraction Plenum (1970)
W. Marshall and S.W. Lovesey, Theory of thermal neutron scattering, Oxford (1971)
G.L. Squires, Introduction to the theory of Thermal Neutron scattering, Cambridge (1978)
T. Chatterji, Neutron Scattering from Magnetic Materials, Elsevier B.V., Amsterdam (2006).

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Optical Spectroscopy

Lecturers: Markus Grüninger
Email: grueninger@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of the basic concepts and techniques of optical spectroscopy on solid-state samples.

Contents of the course:
Topics covered are:

- Electromagnetic waves in matter, dielectric function
- Electromagnetic response of metals and insulators, Drude-Lorentz model
- Kramers-Kronig relations
- THz spectroscopy (time domain and cw)
- Fourier-transform spectroscopy
- Ellipsometry
- Examples of current research (phonons, magnons, orbital excitations, superconductors, …)

Recommended literature:
Skriptum (available during the course)
Dressel/Grüner: Electrodynamics of Solids: Optical Properties of Electrons in Matter (Cambridge, 2002)
Klingshirn: Semiconductor Optics (Springer, 1997)
Kuzmany: Solid-State Spectroscopy: An Introduction (Springer, 2009)

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Photons and Matter

Lecturers: Paul van Loosdrecht
Email: pvl@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Profound understanding of the interaction of light and matter, the use of optical methods in inorganinc and organic condensed matter research, and optically induced phenomena in condensed matter. The student will be able to apply the required theoretical knowledge to interpret experimental data using examples taken from current research.

Contents of the course:
Topics covered are:

- Classical and quantum mechanical description of interaction of light and matter
- Elementary excitations of condensed matter
- Models for the optical response of materials.
- Effects of quantum confinement
- Linear spectroscopies
- Magneto-optical spectroscopies
- Time resolved spectroscopy
- Examples of current research

Recommended literature:

- Optical properties of Solids, Mark Fox, Oxford university press (2010)

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Semiconductor Physics and Nanoscience

Lecturers: Roger Wördenweber
Email: r.woerdenweber@fz-juelich.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of theoretical and experimental concepts of semiconductor physics, nanotechnology as well as aspects of future information technology.
Knowledge of basic fields and important applications of information technology.

Contents of the course:
Semiconducting materials and nanostructures represent the backbone of modern electronics and information technology. At the same time they are fundamental to the research of problems of modern solid state physics, information technology, and biophysics. This lecture will provide an introduction to semiconductor physics and its applications.

Topics covered are
- introduction to semiconductor physics, crystalline structure, band structure, electronic and optical properties,
- heterostructures, junctions and interfaces,
- basic semiconductor device concepts,
- up-to-date techniques and strategies of information technology ranging from nowadays preparation technologies and nanoscience to concepts of molecular electronics and bioelectronics.

Recommended literature:
Skriptum (available during the course)
Bergmann/Schäfer: Experimentalphysik (Band 6: Festkörper)
Ibach/Lüth: Solid-State Physics. An Introduction to Principles of Materials Science
R.F. Pierret: Advanced Semiconductor Fundamentals (Pearson Education, ISBN 0-13-061792-x)
N. Carcia, A. Damask, Physics for Computer Science Students (Springer-Verlag, ISBN 3-540-97656-6)
R. Waser: Nanoelectronics and Information Technology (Wiley-VCH, ISBN 3527403639)
S.M. Lindsay: Introduction to Nanoscience (Oxford University Press, ISBN 9780199544219)

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Superconductivity

Lecturers: Markus Braden, Markus Grüninger, Thomas Lorenz
Email: grueninger@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	WiSe

Requirements for participation:
Basic knowledge of condensed matter physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of the fundamental aspects of superconductivity.

Contents of the course:
The lecture provides an overview of the fundamental aspects of superconductivity. It discusses experimental results, the theoretical description, superconducting materials, technological applications, and recent developments. Topics covered are:

- Basic experimental properties (e.g. Meissner effect, thermodynamics, energy gap, type I and type II superconductors, fluxoid quantization, Josephson effects)
- Phenomenological description: London equations
- Microscopic description: Electron-phonon interaction, Cooper pairs, BCS theory
- Ginzburg-Landau theory
- Applications of superconductivity
- Brief introduction to unconventional superconductivity with recent examples

Recommended literature:

J. F. Annett: Superconductivity, Superfluids and Condensates (2005)
M. Tinkham: Introduction to Superconductivity (2004)
J. R. Waldram: Superconductivity of Metals and Cuprates (1996)
W. Buckel, R. Kleiner: Superconductivity: Fundamentals and Applications (2004)
D. R. Tilley and J. Tilley: Superfluidity and Superconductivity (1990)

Condensed Matter Physics

Module No.: MN-P-SP-CondMat, MN-P-PN-CondMat, MN-P-WaMa

Course: Physics of Surfaces and Nanostructures

Lecturers: Thomas Michely
Email: michely@ph2.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	

Requirements for participation:
Basic knowledge of solid state physics as provided by the lecture Condensed Matter Physics I

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding of the fundamental concepts in surface and nanostructure science
Knowledge of basic fields and important applications

Contents of the course:
The lecture introduces to modern topics of surface and nanostructure physics. Basic concepts are illustrated with examples and the link to technical applications is emphasized.

Topics covered are
- Surface structure and defects
- Surface electronic structure
- Adsorption and heterogeneous catalysis
- Thermodynamic aspects of surfaces
- Epitaxy and thin film processes
- Magnetism at surfaces
- Clusters
- Oxide films
- Ion beam processes at surfaces
- Nanotubes and 2D-materials

Recommended literature:
Skriptum (available during the course)
H. Ibach: Physics of Surfaces and Interfaces (Springer, Berlin 2006)
K. Oura et al: Surface Science – an introduction (Springer, Berlin 2003)
M. Prutton: Introduction to Surface Physics (Oxford University Press, 1994)
H. Lüth: Solid Surfaces, Interfaces, and Thin Films (Springer, Berlin 2001)
M. Henzler/W. Göpel: Oberflächenphysik des Festkörpers (Teubner, Stuttgart 1994)

General Theory of Relativity / Quantum Field Theory

Module No.: MN-P-SP-GR-QFT, MN-PN-GR-QFT, MN-PN-WaMa

Courses: Mathematics

Lecturers: various
Email: alexal@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	var	var	

Requirements for participation:
Bachelor of physics or mathematics

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the courses:
Courses to provide background knowledge in mathematics disciplines fundamental to gravity and/or quantum field theory.

Contents of the course:

- **Differential Geometry (4+2hpw, 6CP)**: geometric structure of differentiable manifolds, Riemannian geometry, concepts of differential topology, theory of fibre bundles
- **Topology (4+2hpw, 6CP)**: topological spaces, homotopy theory, homology, characteristic classes, knot theory
- **Theory of Groups (4+2hpw, 6CP):** Lie groups and algebras, representation theory, classical Lie groups.
- **Functional Analysis (4+2hpw, 6CP):** mathematics of inifinite dimensional vector spaces, theory of functionals, infinite dimensional analysis, mathematics of Hilbert and Banach spaces.
- **Geometry and Analysis on Supermanifolds and Lie Supergroups (2 HPW, 3 CP)**

General Theory of Relativity / Quantum Field Theory

Module No.: MN-P-SP-GR-QFT, MN-P-PN-GR-QFT

Course: Theoretical Particle or Astrophysics

Lecturers: various
Email: zirnbauer@uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture Course	English	variable	var	variable

Requirements for participation:
Variable; see below

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
This course header stands for an assembly of specialized courses that introduce the student to module-related topics in astrophysics or particle physics. The course may be any one of the following:

Contents of the course:

- **Astrophysics II** (offered each winter term in Cologne, 3+1 hpw, 6 cp; needs B.Sc. physics)
- **Group Theory** (offered each winter term in Bonn, 3+2 hpw, 6 cp; needs quantum mechanics from B.Sc. physics)
- **Theoretical Particle Physics** (offered each winter term in Bonn, 3+2 hpw, 6 cp; needs Advanced Quantum Mechanics, Group Theory, and QFT I)
- **Advanced Theoretical Particle Physics** (offered each summer term in Bonn, 3+2 hpw, 6 cp; needs Theoretical Particle Physics)
- **Theoretical Astroparticle Physics** (offered each summer term in Bonn, 3+2 hpw, 6 cp; needs GR, QFT, and Theoretical Particle Physics)
- **Supersymmetry** (offered sporadically in Bonn, 3+1 hpw, 6 cp; needs QFT I)
- **Superstring Theory** (offered sporadically in Bonn, 3+2 hpw, 6 cp; needs high-level preparation including QFT I+II)

General Theory of Relativity / Quantum Field Theory

Module No.: MN-P-SP-GR-QFT, MN-P-PN-GR-QFT

Course series: Quantum aspects of gravity

Lecturers: Claus Kiefer
Email: kiefer@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	

Requirements for participation:
Relativity and Cosmology I

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the courses:
This series of courses presents the material that is needed to work on quantum theories of gravity.

Contents of the courses:

- **Quantum gravity**: general introduction, major approaches, main applications (black holes and cosmology)
- **Quantum field theory in curved spacetime**: general formalism, cosmology, black holes (Hawking effect)
- **The Early Universe**: inflationary universe, quantum origin of structure
- **Foundations of Quantum Theory**: interpretational problems of quantum theory, quantum-to-classical transition, quantum information, quantum gravity

Recommended literature:

Quantum gravity: C. Kiefer, Quantum Gravity (3rd edition, Oxford University Press 2012);
Quantum field theory in curved spacetime: L. Parker and D. Toms, Quantum Field Theory in Curved Spacetime (Cambridge University Press 2009);
The Early Universe: V. Mukhanov, Physical Foundations of Cosmology (Cambridge University Press 2005);
Foundations of Quantum Theory: M. Schlosshauer, Decoherence and the quantum-to-classical Transition (Springer-Verlag 2007).

General Theory of Relativity / Quantum Field Theory

Module No.: MN-P-SP-GR-QFT, MN-PN-GR-QFT, MN-PN-WaMa

Course: Relativity and Cosmology I

Lecturers: C. Kiefer
Email: kiefer@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	4+2	9	WiSe

Requirements for participation:
Training in theoretical physics at the B.Sc. level

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction into Einstein's theory of general relativity and its major applications

Contents of the course:

- Gravity as a manifestation of geometry
- Introduction to differential geometry
- Einstein field equations
- The Schwarzschild solution
- Experimental tests
- Gravitational waves

Recommended literature:

1. T. Padmanabhan, Gravitation: Foundation and Frontiers
2. J. B. Hartle, Gravity: An introduction to Einstein's general relativity

General Theory of Relativity / Quantum Field Theory

Module No.: MN-P-SP-GR-QFT, MN-PN-GR-QFT, MN-PN-WaMa

Course: Relativity and Cosmology II

Lecturers: C. Kiefer
Email: kiefer@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3+1	6	SuSe

Requirements for participation:
Training in theoretical physics at the B.Sc. level

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Application of Einstein's theory of general relativity to black holes and cosmology

Contents of the course:

- Black holes
- Introduction to cosmology
- The early Universe

Recommended literature:

1. V. Mukhanov, Physical Foundations of Cosmology
2. T. Padmanabhan, Gravitation: Foundation and Frontiers
3. J. B. Hartle, Gravity: An introduction to Einstein's general relativity

General Theory of Relativity / Quantum Field Theory and Solid State Theory / Computational Physics

Module No.: MN-P-SP-GR-QFT, MN-P-SP-ThSol, MN-PN-GR-QFT, MN-PN- ThSol, MN-PN-WaMa

Course: Quantum Field Theory I

Lecturers: A. Altland, A. Rosch, M. Zirnbauer
Email: alexal@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	4+2	9	

Requirements for participation:
Training in theoretical physics at the B.Sc. level

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Methods of quantum field theory are in use in almost all areas of modern physics. Strongly oriented towards applications, this course offers an introduction based on examples and phenomena taken from the area of solid state physics.

Contents of the course:
- Second quantization and applications
- Functional integrals
- Perturbation theory
- Mean-field methods

Recommended literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

General Theory of Relativity / Quantum Field Theory and Solid State Theory / Computational Physics

Module No.: MN-P-SP-GR-QFT, MN-P-SP-ThSol, MN-PN-GR-QFT, MN-PN- ThSol, MN-PN-WaMa

Course: Quantum Field Theory II

Lecturers: A. Altland, A. Rosch, M. Zirnbauer
Email: alexal@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course (GR-QFT) Specialized Course (ThSol)	Lecture	English	3+1	6	

Requirements for participation:
Quantum Field Theory I

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Quantum field theory is one of the main tools of modern physics with many applications ranging from high-energy physics to solid state physics. A central topic of this course is the concept of spontaneous symmetry breaking and its relevance for phenomena like superconductivity, magnetism or mass generation in particle physics.

Contents of the course:
- Correlation functions: formalism, and their role as a bridge between theory and experiment
- Renormalization
- Topological concepts

Recommended literature:
A. Altland and B.D. Simons, Condensed Matter Field Theory (Cambridge University Press, Cambridge, second edition: 2010)

Astrophysics and Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol, MN-P-WaMa

Course: Advanced Seminar on Current Topics of Molecular and Astrophysics

Lecturers: S. Schlemmer, P. Schilke
Email: schlemmer@ph1.uni-koeln.de, schilke@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Advanced Seminar	Seminar	English	2	3	WiSe/SuSe

Requirements for participation:
Atomic Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I, Astrophysics I and II

Type of module examinations:
Presentation in form of a seminar talk. Afterwards answering of questions from the audience.

Duration of the course:
1 semester

Aims of the course:
At the beginning of each semester a list of current research topics is presented to the students in the seminar. The topics are mostly based on one or more recent publications of general interest to the subject of molecular and astrophysics. Students pick one topic, read selected papers, discuss the content with a tutor, prepare a seminar talk, make the presentation in front of an audience and answer questions of the audience related to the presentation.

Contents of the course:
- Depending on choice of topic of presentation

Recommended literature:
Selected reading of publications based on the topic of choice

Astrophysics
and
Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol, MN-P-WaMa

Course: Astrochemistry

Lecturers: S. Schlemmer, P. Schilke
Email: schlemmer@ph1.uni-koeln.de, schilke@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2+1	4.5	SuSe
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
The lecture introduces to astrochemistry of various astrophysical environments. Fundamental processes, such as molecular collisions, fragmentations, and chemical reactions, are explained, and implications for astrophysical observations by means of high resolution spectroscopy are treated.

Contents of the course:
- Detection of Molecules in Space
- Elementary Chemical Processes
- Chemical Networks
- Grain Formation (Condensation)
- Properties of Grains and Ice
- Grain Chemistry
- Diffuse Clouds, Shocks, Dark Clouds, Star Forming Regions

Recommended literature:
A. Tielens “The Physics and Chemistry of the Interstellar Medium” Cambridge University Press, 2005
S. Kwok “Physics and Chemistry of the Interstellar Medium” University Science Books, 2006
D. Rehder “Chemistry in Space, From Interstellar Matter to the Origin of Life” Wiley-VCCH, Weinheim, 2010
J. Lequeux “The interstellar Medium“ Spinger, 2004
A. Shaw ”Astrochemistry” Wiley, 2006
D. Whittet “Dust in the Galactic Environment”, Taylor and Francis, 2nd edition, 2002

Astrophysics
and
Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol, MN-P-WaMa

Course: Detection Methods in Molecular Astrophysics

Lecturers: S. Schlemmer, K. Jacobs
Email: schlemmer@ph1.uni-koeln.de , jacobs@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe
Specialized Course	Lecture & Seminar	English	2+1	4.5	SuSe

Requirements for participation:

Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Type of module examinations:

One oral examination at the end of the module

Duration of the course:

1 semester

Aims of the course:

The lecture introduces into various detection techniques used in current laboratory astrophysics and astronomy. In particular the sensitive detection of infrared and THz radiation is described. Also mass spectrometric detection techniques are introduced. This course prepares for the operation of state-of-the-art equipment in molecular astrophysics.

Contents of the course:

- Concept of THz detectors: principle and operation
- Heterodyne detection
- Infrared detectors: principle and operation
- Fundamentals of Mass Spectrometry
- Concepts of Ion Trapping
- Free Jets and Molecular Beams

Recommended literature:

O. Hachenber and B. Vowinkel, Technische Grundlagen der Radioasatronomie, BI Verlag 1982
J.D. Vincent, Fundamentals of IR detector operation and testing, Wiley 1990
G. Scoles (ed.) Atomic and Molecular beam Methods, Oxford 1988
D. Gerlich "Inhomogeneous Electrical Radio Frequency Fields: A Versatile Tool for the Study of Processes with Slow Ions" in: State Selected and State to State Ion Molecule Reaction Dynamics, edited by C.Y.Ng and M. Baer. Advances in Chemical Physics Series, LXXXII, J. Wiley & Sons (1992)
Peter H. Dawson, Quadrupole Mass Spectrometry and its Applications, American Inst. of Physics, 1997

Astrophysics
and
Molecular Physics

Module No.: MN-P-SP-Astro, MN-P-SP-Mol, MN-P-PN-Astro, MN-P-PN-Mol

Course: Experiments in Molecular Physics

Lecturers: S. Schlemmer
Email: schlemmer@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Advanced Laboratory Course & Lecture & Seminar	English	2	3	SuSe
Specialized Course	& Report	English	2 + 1	4.5	SuSe

Requirements for participation:
Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
In this advanced lab course detailed experiments in molecular physics will be conducted. The results will be analysed and compared to literature results. A lecture helps for introduction in the related subjects. At the end of the course participants will present their work in front of the other participants. Optionally, a written report finalizes the whole course yielding additional 1.5 CP. The intention of this course is to get hands on experience with state-of-the-art experimental techniques in molecular physics.

Contents of the course:
- THz spectroscopy: Molecular Rotation
- Infrared spectroscopy: Molecular Vibration, ro-vibrational spectroscopy
- Raman spectroscopy: Molecular Vibration and Rotation
- Other experiments depending on availability

Recommended literature:
Bachelorthesis, Staatsexamen, etc.…

Molecular Physics

Module No.: MN-P-SP-Mol, MN-P-PN-Mol, MN-P-WaMa

Course: Molecular Physics I

Lecturers: S. Schlemmer
Email: schlemmer@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3 + 1	6	WiSe
Core Course	Lecture	English	3	4.5	WiSe

Requirements for participation:
Atomic Physics and Quantum Mechanics at the level of the bachelor courses in physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
In the first part of the core courses the students learn the main concepts of molecular physics: separation of electronic, vibrational and rotational motion. Simple molecular spectra can be analyzed on the basis of the problem class. The spectrum of the rotation of polyatomic molecules is derived.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the course:

- Basics of molecular spectroscopy, phenomenology, diatomic molecules
- Born-Oppenheimer Approximation, separation of rotation and vibration
- Molecular Dipole moment and rotational transitions
- Rotational spectra and the rigid rotor approach
- Selection rules, parallel and perpendicular type spectra
- Nuclear spin statistics
- Hyperfine structure of molecular lines

Recommended literature:
Bernath,” Spectra of Atoms and Molecules”, Oxford University Press)
Townes Schawlow, “Microwave Spectroscopy” (Dover Publications)
Gordy & Cook, “Microwave Spectra” (Wiley)
Engelke, „Aufbau der Moleküle“ (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition,"(NRC Research Press, Ottawa)

Molecular Physics

Module No.: MN-P-SP-Mol, MN-PN-Mol, MN-P-WaMa

Course: Molecular Physics II

Lecturers: S. Schlemmer
Email: schlemmer@ph1.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3 + 1	6	SuSe
Core Course	Lecture	English	3	4.5	SuSe

Requirements for participation:

Atomic Physics, Molecular Physics and Quantum Mechanics at the level of the bachelor courses in physics, Molecular Physics I

Type of module examinations:

One oral examination at the end of the module

Duration of the course:

1 semester

Aims of the course:

In the second part of the core courses more complex issues of molecular spectra are introduced. The students will be enabled to analyze spectra of polyatomic molecules in particular the complex vibrational motion of molecules are described in the framework of normal modes.
If time permits also more involved subjects, e.g. couplings between electronic, vibrational and rotational motions are presented.
This module prepares for topics of current research in molecular physics and provides the basis for the preparation of the master thesis.

Contents of the course:

- Vibrational modes of polyatomic molecules
- Fundamentals of point group symmetry and permutation inversion symmetry
- Vibrational dipole moment and selection rules
- Characteristic ro-vibrational spectra of selected molecules
- Raman and Infrared Spectra of polyatomic molecules
- Tunneling motion
- Breakdown of Born-Oppenheimer Approximation
- Coupling of rotation and vibration
- Coupling of angular momenta in molecular physics

Recommended literature:

Bernath," Spectra of Atoms and Molecules", Oxford University Press)
Townes Schawlow, "Microwave Spectroscopy" (Dover Publications)
Gordy & Cook, "Microwave Spectra" (Wiley)
Engelke, „Aufbau der Moleküle“ (Teubner)
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition,"(NRC Research Press, Ottawa).

Molecular Physics

Module No.: MN-P-SP-Mol, MN-PN-Mol, MN-P-WaMa

Course: Fundamentals of Molecular Symmetry

Lecturers: P. Jensen
Email: jensen@uni-wuppertal.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:

Basic Knowledge of Quantum Mechanics

Type of module examinations:

One oral examination at the end of the module

Duration of the course:

1 semester

Aims of the course:

Understanding the fundamental concepts of representation theory and its application to describe the symmetry of molecules

Contents of the course:

The lecture introduces to group theory with special emphasis on representations and their use to describe the symmetry of molecules in high-resolution spectroscopy and in molecular physics generally. The theory is accompanied by a series of “prototypical” examples Topics covered are

- Symmetry in general and symmetry of a molecule.
- Groups and point groups.
- Irreducible representations, characters.
- Vanishing integral rule
- The Complete Nuclear Permutation-Inversion (CNPI) group.
- The Molecular Symmetry (MS) group.
- The molecular point group.
- Classification of molecular states: electronic, vibrational, rotational, and nuclear spin states
- Nuclear spin statistical weights
- Hyperfine structure
- Non-rigid molecules (inversion, internal rotation)

Recommended literature:

Jensen: Script (text of powerpoint presentation files; available during the course)
P. Jensen and P. R. Bunker: The Symmetry of Molecules, *in:* "Encyclopedia of Chemical Physics and Physical Chemistry" (J. H. Moore and N. D. Spencer, Eds.), IOP Publishing, Bristol, 2001.
P. R. Bunker and Per Jensen: "Molecular Symmetry and Spectroscopy, 2nd Edition," NRC Research Press, Ottawa, 1998 (ISBN 0-660-17519-3).
P. R. Bunker and P. Jensen: “Fundamentals of Molecular Symmetry," IOP Publishing, Bristol, 2004 (ISBN 0-7503-0941-5).

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Accelerator Mass Spectrometry

Lecturers: A. Dewald
Email: dewald@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic Knowledge in Nuclear Physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction into the basic concepts and techniques of mass spectrometry and accelerator mass spectrometry (AMS) will be given. Selected applications from different research fields will be presented.

Contents of the course:

- Definitions and general aspects of mass spectrometry
- Mass spectrometers
- Ion sources
- Accelerators
- Detectors
- AMS facilities (layouts)
- Ion optics
- Isobar separation
- Selected applications in Archeology, Geo-Science and Environmental Science

Recommended literature:
C. Tuniz, J. R. Bird, D. Fink, G. F. Herzog, Accelerator Mass Spectrometry, CRC Press

Nuclear and Particle Physics

Module No.: MN-P-PN-Nuc, MN-P-WaMa

Course: Advanced Seminar on Nuclear Physics

Lecturers: A, Dewald, D. Gotta, J. Jolie, P. Reiter, S. Schadmand, H. Ströher, A. Zilges
Email: zilges@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Advanced Seminar	Seminar	English	2	3	WiSe/SuSe

Requirements for participation:
Nuclear and Particle Physics and Quantum Mechanics at the level of the bachelor courses in physics,

Type of module examinations:
Presentation in form of a seminar talk. Afterwards answering of questions from the audience.

Duration of the course:
1 semester

Aims of the course:
At the beginning of each semester a list of current research topics is presented to the students in the seminar. The topics are mostly based on one or more recent publications of general interest to the subject of nuclear and hadron physics. Students pick one topic, read selected papers, discuss the content with a tutor, prepare a seminar talk, make the presentation in front of an audience and answer questions of the audience related to the presentation.

Contents of the course:
- Depending on choice of topic of presentation

Recommended literature:
Selected reading of publications based on the topic of choice

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Applied Nuclear Physics

Lecturers: A. Dewald
Email: dewald@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	WiSe

Requirements for participation:
Basic Knowledge in Nuclear Physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
The aim of this course is to introduce the basics of how radiation interacts with matter and to give some insight into the applications and techniques where radioactivity is used or techniques developed first in Nuclear Physics are applied in different fields of science and technology.

Contents of the course:
- Radiation and interaction with matter
- Detecting radioactivity
- Radioactive dating
- Nuclear methods for analysis of materials
- Mößbauer spectroscopy
- Nuclear medicine
- Nuclear energy

Recommended literature:
K. S.Krane, Introductory Nuclear Physics, John Wiley & Sons
W.T. Hering, Angewandte Kernphysik, Teubner Studienbücher Physik
Y. M. Tsipenyuk, Nuclear Methods in Science and Technology, Institute of Physics Publishing Bristol and Philadelphia

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Physics of Detectors

Lecturers: P. Reiter, A. Dewald, J. Jolie, A. Zilges
Email: preiter@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	2	3	SuSe

Requirements for participation:
Nuclear Physics I, Quantum Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Study of detection methods of experimental techniques in nuclear and particle physics.

Contents of the course:
- Interaction of electrons and charged heavy particles in matter
- Coherent effects: Cherenkov and transition radiation
- Interaction of gamma-radiation in matter
- Detection of neutral particles: neutrons and neutrinos
- Measurement of 4-momentum in particle physics
- Ionisation detectors: Bragg chamber, avalanche detectors
- Position sensitive detectors: drift chambers, time-projection chamber
- Anorganic and organic scintillators
- Energy detection, calorimeter and shower detectors
- Semiconductor detectors
- Position sensitive Si detectors (strip-, pixel-detectors)
- Ge detectors
- Low background measurements
- Lifetime measurements
- Mössbauer Spectroscopy
- Basic principles of analoge and digital signal processing

Recommended literature:
A script or slides of the course will be distributed during the course.
R. Leo, Techniques for Nuclear and Particle Physics Experiments
K Kleinknecht, Detektoren für Teilchenstrahlung
G.F. Knoll, Radiation Detection and Measurement

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course:
Heavy Ion Physics

Lecturers: P. Reiter
Email: preiter@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	WiSe

Requirements for participation:
Basic Knowledge in Nuclear Physics

Type of module examinations:
Part of courses for area of specialisation Nuclear and Particle Physics, separate oral examination is possible exceptionally.

Duration of the course:
1 semester

Aims of the course:
Study of selected topics related to the atomic and nuclear physics of heavy ions. The students should participate actively in the course.

Contents of the course:
- production of heavy ions
- fixed target and storage ring experiments
- atomic physics of heavy ions
- mass measurements
- fundamental QED tests
- radioactive decay of highly charged ions
- nuclear reactions with heavy ions

Recommended literature:
The course is based on recent review articles and up-to-date publications in various journals.

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course:
Neutron Physics

Lecturers: J. Jolie
Email: jolie@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	tba

Requirements for participation:
Nuclear Physics I

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction to the physics of and with neutrons.

Contents of the course:

- The neutron as a fundamental particle.
- Neutron sources
- Neutron detectors
- Neutron optics
- Nuclear reactions with neutrons
- Neutron capture in astrophysics

Recommended literature:
J. Byrne Neutrons, Nuclei and Matter, Institute of Physics Publishing 1994, ISBN 0 7503 0366 2 PBK

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Nuclear Astrophysics

Lecturers: A. Zilges
Email: zilges@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic Knowledge in Nuclear Physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction into basic aspects of experimental and theoretical Nuclear Astrophysics.

Contents of the course:

- Life and death of a star
- Abundance of the elements and isotopes
- Reaction rates on earth and in stars
- Nuclear hydrogen burning: pp chains and CNO cycle
- Nucleosynthesis up to A~60
- Synthesis of heavy nuclei: s-, r-, and p-process
- Other processes of stellar nucleosynthesis
- Laboratory experiments

Recommended literature:
C. Iliadis: “Nuclear Physics of stars”
C.E.Rolfs and W.S. Rodney: “Cauldrons in the Cosmos”
D. Arnett: “Supernovae and Nucleosynthesis”

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Nuclear Physics II

Lecturers: J. Jolie, A. Dewald, P. Reiter, A. Zilges
Email: jolie@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3	4.5	WiSe

Requirements for participation:
Nuclear Physics I, Quantum Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Study of nuclear reactions, fission and fusion. Basic principles of accelerators.

Contents of the course:
- Kinematics in nuclear reactions
- Cross section
- Rutherford scattering
- Scattering in quantum mechanics
- The Born approximation
- Partial wave analysis
- Inelastic scattering, resonances
- Optical model
- Direct, compound, spallation and fragmentation reactions
- Neutron sources and detectors
- Neutron cross sections
- Fission
- Nuclear reactors
- Fusion
- Solar fusion
- Man-made thermonuclear fusion
- Controlled thermonuclear fusion
- Basic principles of accelerators.

Recommended literature:
A script for parts of the course will be distributed during the course.
K.S. Krane, Introductory nuclear physics, chapters 11-15,

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Particle Physics

Lecturers: D. Gotta, S. Schadmand, H. Ströher
Email: d.gotta@fz-juelich.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3	4.5	SuSe

Requirements for participation:
Quantum Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction into particle physics.

Contents of the course:

- Relativistic kinematics
- Interaction of radiation with matter
- Particle accelerators
- Targets and detectors
- Symmetries in particle physics
- QED
- Weak interaction, neutrinos
- Quark model
- QCD
- Standard model
- Cosmology

Recommended literature:
A script for course will be available on-line
D.H. Perkins: Introduction to High Energy Physics, Cambridge University Press, ISBN 0521621968
H. Frauenfelder, E.M. Henley: Subatomic Physics, Prentice Hall, ISBN 0138594309
F. Halzen: A.D. Martin: Quarks and Leptons, John Wiley and Sons, ISBN 0471887412
D. Griffiths: Introduction to Elementary Particles, John Wiley and Sons ISBN: 0471603864
B. Povh, K. Rith, C. Scholz, F. Zetsche: Teilchen und Kerne, Springer-Verlag, ISBN 3540659285
C. Berger: Elementarteilchenphysik, Springer-Verlag, ISBN 3-540-41515-7

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Selected Problems in Nuclear Structure Physics

Lecturers: A. Zilges
Email: zilges@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic Knowledge in Nuclear Physics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Presentation of current research topics in Nuclear Structure Physics.

Contents of the course:
- Experimental techniques, facilities and instrumentation
- Modification of shell structures
- Halos and Clusters
- Collective response of nuclei
- Ground-state properties
- Nuclear Structure and the synthesis of the elements

Recommended literature:
The course is based on up-to-date publications in various journals.

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Theoretical Nuclear Physics I

Lecturers: J. Jolie
Email: jolie@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic Knowledge in Nuclear Physics and Quantum Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction to the theoretical description of nuclear structure. In part I emphasis is laid on angular momentum algebra and the shell model.

Contents of the course:
Angular momentum in quantum mechanics, the nuclear shell model, two identical particles outside a closed shell: Residual interaction, effects of configuration space, more identical particles outside a closed shell (optional), neutrons and protons: the isospin formalism.

The interacting boson model, second quantisation, occupation number representation, second quantisation: Bosons, second quantisation: Fermions, properties of the creation and annihilation operators, operators in second quantisation and their evaluation, angular momentum coupling, the Interacting Boson Model-I, the interacting boson approximation, the construction of the IBM-1 hamiltonian, the multipole expansion of the IBM-1 hamiltonian, operators in the IBM-1, the dynamical symmetries of the IBM-1, searching for a basis: analytically solvable Hamiltonians, the algebraic approach: dynamical symmetries, lie groups and algebras, Casimir operators, dynamical symmetries and the labelling of states, application to the interacting boson model, the generators of the U(6) group, the U(5) limit, the SU(3) limit, the O(6) limit, transitional regions

Recommended literature:
A script will be distributed during the course.

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Theoretical Nuclear Physics II

Lecturers: J. Jolie
Email: jolie@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Theoretical Nuclear Physics I

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction to the theoretical description of nuclear structure. In part II emphasis is laid on second quantisation, dynamical symmetries and the interacting boson model.

Contents of the course:

- Second quantization
- The Interacting Boson Model-I
- The algebraic approach: dynamical symmetries
- The dynamical symmetries of the IBM-1

Recommended literature:
A script will be distributed during the course.

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Theoretical Nuclear Physics III

Lecturers: J. Jolie
Email: jolie@ikp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Theoretical Nuclear Physics I and II

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Introduction to the theoretical description of nuclear structure. In part III emphasis is laid on boson-fermion and neutron proton degrees of freedom, dynamical symmetries and supersymmetries.

Contents of the course:

- Symmetry and supersymmetry in quantal many.body systems
- Symmetry in nuclear physics
- Supersymmetry in nuclear physics
- Symmetries with neutrons and protons
- Supersymmetries with neutrons and protons

Recommended literature:

A Frank, J. Jolie, P. Van Isacker Symmetries in Atomic Nuclei From Isospin to Supersymmetry
Springer Tracts in Modern Physics 230
http://link.springer.com/book/10.1007/978-0-387-87495-1

Nuclear and Particle Physics

Module No.: MN-P-SP-Nuc, MN-P-PN-Nuc, MN-P-WaMa

Course: Tools for Particle Physics

Lecturers: D. Gotta, S. Schadmand, H. Ströher
Email: d.gotta@fz-juelich.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2	3	SuSe

Requirements for participation:
Basic Knowledge in Atomic and Nuclear Physics and Quantum Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Study of concepts and methods used in particle physics experiments. The students should participate actively in the course.

Contents of the course:
- Physics principles in particle detection
- Accelerator concepts
- Charged and neutral particle detection
- Photon and hadron induced reactions
- Data analysis tools
- Cosmic particles
- Exotic atoms
- Spin offs and new concepts

Recommended literature:
Will be distributed during the course.

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Disordered Systems

Lecturers: T. Nattermann
Email: natter@thp.uni-koeln.de

Category	**Type**	**Language**	**Teaching Hours**	**CP**	**Semester**
Core Course	Lecture	English	4+2	9	SuSe

Requirements for participation:
Advanced Statistical Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding the novel types of behaviour that arise in systems with quenched disorder, as well as the specific mathematical challenges associated with their theoretical description.

Contents of the course:
- Disorder average
- Replica methods
- Percolation
- Phase transitions in disordered systems
- Localization
- Glassy dynamics

Recommended literature:
D. Stauffer and A..Aharony, Introduction to Percolation Theory (Taylor & Francis, London 1994)
K.H. Fischer and J.A. Hertz, Spin Glasses (Cambridge University Press, Cambridge 1991)
K. Binder and W. Kob, Glassy Materials and Disordered Solids (World Scientific, Singapore 2005)
T. Nattermann, lecture notes

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Experiment and simulation on biological systems

Lecturers: B. Maier and J. Berg
Email: berenike.maier@uni-koeln.de; berg@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Advanced Laboratory Course & Lecture & Seminar	English	3	4.5	WiSe

Requirements for participation:

Experimental physics at bachelor level, Introduction to Biophysics is recommended
Computational Physics at bachelor level or working knowledge of a programming language

Type of module examinations:

Oral examination or report and one oral examination at the end of the module

Duration of the course:

1 week (full-time) during the semester break

Application:

The number of participants is limited to 8. The application deadline will be announced on the webpage biophysics.uni-koeln.de.

Aims of the course:

In this advanced course detailed experiments in evolution, genetics, cellular decision making, and gene expression will be conducted. The course consists of both "wet" lab experiments and computer simulations on the same topics. Similarly, lectures on the biological background will be presented both from the experimental and the theoretical perspectives. At the end of the course, participants will present their work to the other participants. Participants of this course get hands-on experience with state-of-the-art experimental and computational techniques in biological physics.

Contents of the course:

- Conducting evolution experiments
- Modelling population genetics and evolution
- Measuring and modelling gene expression
- Statistical analysis of experiments

Recommended literature:

Phillips, R., Kondev, J., Theriot, J., Physical Biology of the Cell, Garland Science, New York, 2012
Additional literature will be announced during the course

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Evolutionary Biology and Genomics for Physicists

Lecturers: J. Berg, J. Krug, M. Lässig
Email: berg@thp.uni-koeln.de, krug@thp.uni-koeln.de, lassig@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3+1	6	SuSe

Requirements for participation:
Advanced Statistical Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Acquaintance with basic concepts of molecular and evolutionary biology; understanding of statistical issues arising in the analysis of biological data, application of methods from statistical physics addressing them.

Contents of the course:

- Basic concepts of evolutionary theory
- Introduction to molecular evolution and genomics
- Theory of bio-molecular networks
- Concepts and methods of data analysis

Recommended literature:

J.H. Gillespie, Population Genetics: A concise guide (Johns Hopkins University Press, 2004)
R. Durbin, S.R. Eddy, A. Krogh, G. Mitchison, Biological Sequence Analysis: Probabilistic Models of Proteins and Nucleic Acids (Cambridge University Press, 1998)
F. Kepes, Biological Networks (World Scientific, Singapore 2007)
D.J. Wilkinson, Stochastic Modelling for Systems Biology (Chapman&Hall, 2006)

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Information Theory and Statistical Physics

Lecturers: J. Berg
Email: berg@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	3+1	6	WiSe

Requirements for participation:
Statistical Mechanics on the bachelor level

Type of module examinations:
Oral Examination or Term Paper and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
This lecture course gives an introduction to information theory and statistical inference from the perspective of statistical physics.

Contents of the course:
- introduction to probability and information theory
- information theory and the foundations of statistical physics, the principle of maximum entropy
- Maxwell's demon and Szilard's engine: physics of information processing
- typical and rare events, the source coding theorem
- statistical inference
- inverse problems, the inverse Ising problem
- information processing in biology: sequence analysis, molecular structure prediction, regulation of gene expression

Recommended literature:
T. Cover and J. Thomas, Elements of Information Theory (Wiley, 1991)
D. MacKay, Information theory, Inference and Learning Algorithms (CUP, 2003)
M. Mézard and A. Montanari, Information, Physics, and Computation (OUP, 2009)

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Introduction to Biophysics

Lecturers: B. Maier
Email: berenike.maier@uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	4+2	9	WiSe

Requirements for participation:
Bachelor in Physical Sciences

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Life as an interplay between physics and genetics; understanding how physical principles guide the behavior of biological cells and organisms; introduction into biophysical methods.

Contents of the course:

- Introduction to molecular cell biology
- Random-walks in biology
- Mechanical forces in molecular and cellular biology
- Photophysics
- Signal transduction in nerve cells
- Genetic networks and decision making
- Physical methods for analysis of biological molecules and processes

Recommended literature:
Phillips, R., Kondev, J., Theriot, J., Physical Biology of the Cell, Garland Science, New York, 2009
Alberts

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Nonequilibrium Physics with Interdisciplinary Applications

Lecturers: A. Schadschneider
Email: as@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	2+1	4.5	SuSe

Requirements for participation:
Statistical Mechanics

Type of module examinations:
Oral Examination or Term Paper and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Acquaintance with basic concepts of nonequilibrium physics; ability to apply the basic methods for the investigation of nonequilibrium problems; application of physics-based models to interdisciplinary problems.

Contents of the course:
- Principles of nonequilibrium physics
- Stochastic systems and their desription (master equation, Fokker-Planck equation,…)
- Analytical and numerical methods
- Nonequilibrium phase transitions
- Applications to traffic, pedestrian dynamics, economic systems, biology, pattern formation,…

Recommended literature:
A. Schadschneider, D. Chowdhury, K. Nishinari: Stochastic Transport in Complex Systems (Elsevier, 2010)
P.L. Krapivsky, S. Redner, E. Ben-Naim: A Kinetic View of Statistical Physics (Cambridge University Press, 2010)
V. Privman (Ed.): Nonequilibrium Statistical Mechanics in One Dimension (Cambridge University Press, 1997)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Probability Theory and Stochastic Processes for Physicists

Lecturers: J. Krug
Email: krug@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	3+1	6	WiSe

Requirements for participation:

Statistical Mechanics on the bachelor level

Type of module examinations:

Oral Examination or Term Paper and one oral examination at the end of the module

Duration of the course:

1 semester

Aims of the course:

Acquaintance with probabilistic concepts and stochastic methods commonly used in the theory of disordered systems and nonequilibrium phenomena, as well as in interdisciplinary applications of statistical physics.

Contents of the course:

- Limit laws and extremal statistics
- Point processes
- Markov chains and birth-death processes
- Stochastic differential equations and path integrals
- Large deviations and rare events

Recommended literature:

D. Sornette: Critical Phenomena in Natural Sciences (Springer, 2004)
N.G.Van Kampen: Stochastic Processes in Physics and Chemistry (Elsevier, 1992)

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Qualitative Methods in Theoretical Physics

Lecturers: T. Nattermann
Email: natter@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Specialized Course	Lecture	English	4+2	9	SuSe

Requirements for participation:
no

Type of module examinations:
One Oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding the use of qualitative methods (dimensional analysis, symmetries, use of small parameters and simple models etc.) in mechanics, hydrodynamics, electrodynamics, statistical mechanics, quantum field theory and astrophysics.

Contents of the course:

- Buckingham theorem
- Navier-Stokes equation, Reynolds numbers, turbulence
- Classical wave equations (Maxwell, Weyl)
- Qualitative methods in quantum mechanics
- Screening of charge in QED and QCD,
- Weakly interacting quantum gases
- Astrophysics

Recommended literature:

B.A. Migdal, Qualitative Methods in Quantum Theory, Addison-Wesley 1989
P.W. Bridgman, Dimensional Analysis, Yale University Press 1922
G.I. Barenblatt, Scaling, Cambridge University Press 2003
T. Nattermann, lecture notes

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Selected Topics in Statistical Physics: Nonequilibrium statistical physics

Lecturers: J. Krug, M. Lässig
Email: krug@thp.uni-koeln.de, lassig@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	4+2	9	SuSe

Requirements for participation:
Advanced Statistical Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding the generic behaviour of fluctuation-dominated systems far from equilibrium, and acquaintance with the basic mathematical tools used for their description.

Contents of the course:
- Stochastic methods
- Transport processes
- Scale-invariant growth
- Pattern formation far from equilibrium

Recommended literature:
P.L. Krapivsky, S. Redner and E. Ben-Naim: A kinetic view of statistical physics (Cambridge University Press, 2010)
M. Kardar, Statistical Physics of Fields (Cambridge University Press, 2007)

Statistical and Biological Physics

Module No.: MN-P-SP-StatBio, MN-P-PN-StatBio, MN-P-WaMa

Course: Statistical Physics of Soft Matter and Biomolecules

Lecturers: G. Gompper
Email: g.gompper@fz-juelich.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	4+2	9	SuSe

Requirements for participation:
Advanced Statistical Mechanics

Type of module examinations:
One oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
Understanding the molecular structure and mesoscopic properties of various types of soft matter systems, in particular with regard to their role in living cells.

Contents of the course:

- Colloids, polymers and amphiphiles
- Biopolymers and proteins
- Membranes
- Physics of the cell

Recommended literature:
J. K. G. Dhont, An Introduction to Dynamics of Colloids (Elsevier, Amsterdam, 1996).
M. Doi and S. F. Edwards, The Theory of Polymer Dynamics (Clarendon Press, Oxford, 1986).
S. A. Safran, Statistical Thermodynamics of Surfaces, Interfaces, and Membranes (Addison-Wesley, Reading, MA, 1994).
G. Gompper, U. B. Kaupp, J. K. G. Dhont, D. Richter, and R. G. Winkler, eds., Physics meets Biology — From Soft Matter to Cell Biology, vol. 19 of *Matter and Materials* (FZ Jülich, Jülich, 2004).
D. H. Boal, Mechanics of the Cell (Cambridge University Press, Cambridge, 2002).

Solid State Theory

Module No.: MN-P-SP-ThSol, MN-P-PN-ThSol, MN-P-WaMa

Course: Advanced Seminar on Current Topics in Solid State Theory and Computational Physics

Lecturers: R. Bulla, A. Rosch, S. Trebst
Email: bulla@thp.uni-koeln.de, rosch@thp.uni-koeln.de, trebst@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Advanced Seminar	Seminar	English	2	3	SuSe

Requirements for participation:
Quantum Mechanics at the level of the bachelor courses in physics. For some of the talks knowledge in quantum field theory or solid state theory is required.

Type of module examinations:
Presentation in form of a seminar talk, answering of questions from the audience.

Duration of the course:
1 semester

Aims of the course:
The advanced seminar gives the opportunity to learn about a topic of current interest in solid state theory and computational physics. The subject of the advanced seminar changes each year. At the beginning of the seminar a list of possible topics is presented. Students pick one topic, read selected papers, discuss the content with a tutor, prepare a seminar talk, make the presentation in front of an audience and answer questions of the audience related to the presentation. The seminar gives the opportunity to read original literature, to learn to know about a topic at the forefront of current research and to train presentation skills.

Contents of the course:

- Depending on choice of topic of presentation

Recommended literature:
Selected reading of publications based on the topic

Solid State Theory

Module No.: MN-P-SP-ThSol, MN-P-PN-ThSol, MN-P-WaMa

Course: Computational Many-Body Physics

Lecturers: S. Trebst
Email: trebst@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3+1	6	SoSe

Requirements for participation:
Training in theoretical physics at the B.Sc. level, experimental solid state physics

Type of module examinations:
Written or Oral Examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
This course provides an overview of elementary numerical approaches to study many-body systems, both classical and quantum.

Contents of the course:
The lecture will provide an overview of modern numerical approaches to many-body systems, both classical and quantum. The in-depth introduction of elementary algorithms will be complemented by application of these methods to fundamental models and phenomena, mostly arising in the context of condensed matter physics.

A typical list of topics includes

- percolation
- phase transitions
- finite-size scaling
- Monte Carlo sampling
- extended ensemble techniques
- molecular dynamics
- Hartree-Fock / density-functional methods
- exact diagonalization
- quantum Monte Carlo
- series expansions
- numerical renormalization group
- density matrix renormalization group

Recommended literature:
J.M. Thijssen, Computational Physics, Cambridge University Press (2007)
Tao Pang, An Introduction to Computational Physics, Cambridge University Press (2006)
Werner Krauth, Statistical Mechanics: Algorithms and Computation, Oxford University Press (2006)

Solid State Theory

Module No.: MN-P-SP-ThSol, MN-P-PN-ThSol, MN-P-WaMa

Course: Solid State Theory

Lecturers: A. Rosch, R. Bulla, S. Trebst
Email: rosch@thp.uni-koeln.de

Category	Type	Language	Teaching Hours	CP	Semester
Core Course	Lecture	English	3+1	6	WiSe

Requirements for participation:
Training in theoretical physics at the B.Sc. level, experimental solid state physics

Type of module examinations:
Written or oral examination and one oral examination at the end of the module

Duration of the course:
1 semester

Aims of the course:
This course gives an introduction to the physics of electrons and phonons in solids together with theoretical concepts and techniques as applied to these systems.

Contents of the course:
The physics of solids shows an extremely rich phenomenology. Starting from a quantum theory describing the electrons and atoms in a solid, we investigate, for example, how excitations and associated quasi particles emerge. The lecture covers a broad range of methods and applications with emphasis on experimental and theoretical research directions of the physics department in Cologne.

Recommended literature:
Ashcroft/ Mermin: "Solid State Physics"