Modules and Courses
Master of Science in Physics

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2 List of Modules and Courses

2.1 Overview of the Modules

List of Modules - Master	Module	Teaching hours (SWS)	CP
Experimental Physics			
Experimental Physics	ExPh	3 V + 1 Ü	6
Summed credit points for courses in Experimental Physics			**6**
Theoretical Physics			
Theoretical Physics	ThPh	4 V + 2 Ü	9
Summed credit points of courses in Theoretical Physics			**9**
Seminars			
Seminar I	Sem	2 S	4
Seminar II	Sem	2 S	4
Sum credit points for Seminars			**8**
Lab courses			
Advanced laboratory course	P	8 P	10
Summed credit points for lab courses			**10**
Research Phase			
Research Phase – Specialization	FoSp	F	15
Research Phase – Methodological Knowledge	FoMk	F	15
Research Phase – Master thesis	FoMA	F	30
Summed credit points for Research Phase			**60**
Elective Modules			
Topical Course I	SV	3 V + 1 Ü	6
Topical Course II	SV	3-4 V + 1-2 Ü	6-9
Advanced Course	VV	3 V + 1 Ü	6
Research Module	FoM	4 SWS	6
		To choose:	**18-12**
Subsidiary Subject			
		To choose:	**9-15**
Total			**120**

2.2 Topical Courses – List of Courses

Topical Courses – course list
Condensed Matter Physics
Selected Topics in Condensed Matter Physics
Modern Experimental Methods in Condensed Matter Physics
Materials Science
Introduction to Condensed Matter Theory
Selected Chapters of Condensed Matter Theory
Theory of Soft Matter I
Computer Simulations in Statistical Physics
Modern Computational Techniques in Condensed/Soft Matter Physics
Quantum, Atomic and Neutron Physics
Quantum Optics (Q-Ex-1)
Photonics (Q-Ex-2)
Quantum Information (Q-Ex-3)
Precision Fundamental Physics (Q-Ex-4)
Nuclear and Particle Physics
Statistics, Data Analysis and Simulation
Particle Detectors
Accelerator Physics
Particle Physics
Astroparticle Physics
Cosmology and General Relativity
Symmetries in Physics
Modern Methods in Theoretical High Energy, Particle and Nuclear Physics
Theoretical Particle Physics
Introduction to Lattice Gauge Theory
Introduction to String Theory
Effective Field Theories
Theoretical Astroparticle Physics
Amplitudes and Precision Physics at the LHC
Functional Methods and Exact Renormalization Group

2.3 Advanced Courses – List of Courses

Advanced Courses – course list
Condensed Matter Physics
Selected Topics in Condensed Matter Physics
Modern Experimental Methods in Condensed Matter Physics
Materials Science
Introduction to Condensed Matter Theory
Selected Chapters of Condensed Matter Theory
Theory of Soft Matter I
Computer Simulations in Statistical Physics
Modern Computational Techniques in Condensed/Soft Matter Physics
Theory of Soft Matter II
Quantum, Atomic and Neutron Physics
Quantum Optics (Q-Ex-1)
Photonics (Q-Ex-2)
Quantum Information (Q-Ex-3)
Precision Fundamental Physics (Q-Ex-4)
Nuclear and Particle Physics
Statistics, Data analysis and Simulation
Particle Detectors
Accelerator Physics
Particle Physics
Astroparticle Physics
Cosmology and General Relativity
Symmetries in Physics
Modern Methods in Theoretical High Energy, Particle and Nuclear Physics
Theoretical Particle Physics
Introduction to Lattice Gauge Theory
Introduction to String Theory
Effective Field Theories
Theoretical Astroparticle Physics
Amplitudes and Precision Physics at the LHC
Functional Methods and Exact Renormalization Group
Advanced Particle Physics
Advanced Chapters on Subatomic Physics
Advanced Astroparticle- and Astrophysics
Advanced Accelerator Physics

2.4 Subsidiary Subjects

Subsidiary Subject	SWS	CP
Chemistry		
Nuclear Chemistry	2 V + 1 Ü + 5 P	9
Nuclear Chemistry (with 1 additional advanced lecture)	4 V + 1 Ü + 5 P	12
Nuclear Chemistry (with 2 additional advanced lectures)	6 V + 1 Ü + 5 P	15
Introduction in Theoretical Chemistry	4 V + 1 Ü + 5 P	9
Theoretical Chemistry	4 V + 2 Ü + 10P	12
Computer Science		
Computer Science I	2 V + 2 Ü + 2 P	9
Computer Science II	4 V + 4 Ü	12
Computer Science III	4 V + 4 Ü + 2 P	15
Economics		
International Economics & Public Policy	6 V+Ü	12
Finance & Accounting	6 V+Ü	12
Marketing, Management & Operations	6 V+Ü	12
History of Natural Science		
History of Natural Science II	2 S + 2 P	9
Mathematics		
Functional Analysis	4 V + 2 Ü	9
Functional Analysis (with Functional Analysis II)	8 V + 2 Ü	15
Partial differential equations	4 V + 2 Ü	9
Partial differential equations (with partial differential equations. II)	8 V + 2 Ü	15
Fundamentals in stochastics	4 V + 2 Ü	9
Fundamentals in stochastics (with stochastics I)	8 V + 2 Ü	15
Stochastics I	4 V + 2 Ü	9
Stochastics I (with stochastics II)	8 V + 2 Ü	15
Basic numerics	4 V + 2 Ü	9
Basic numerics (with numerical methods of ordinary diff. equations)	8 V + 2 Ü	15
Numerics of differential equations	4 V + 2 Ü	9
Numerics of differential equations (with partial diff. equations)	8 V + 2 Ü	15
Algebra	4 V + 2 Ü	9
Algebra (with lecture „Fields, Rings, Modules")	8 V + 2 Ü	15
Topology	4 V + 2 Ü	9
Topology (with lecture „Algebraic curves and Riemannian surfaces")	8 V + 2 Ü	15
Computer algebra	4 V + 2 Ü	9
Computer algebra (with Number Theory)	8 V + 2 Ü	15
Meteorology		
Dynamics oft he Atmosphere	4 V + 3 Ü	9
Atmospheric Modeling	6 V + 4 Ü	14
Atmospheric Radiation	4 V + 2 Ü	9
Atmospheric Dynamics	4 V + 3 Ü + 2 P	11
Philosophy		
Modern Philosophy	6 S	15
Interdisciplinary Courses		
History of Natural Science I	3 V	3
History of Natural Science II	3 V	3

3 IMPORTANT REMARKS

3.1 GENERAL REMARKS

1) Within the Master of Science in Physics studies, a minimum of 120 credit points (CP) must be obtained. If the number of credit points is exceeded by more than 6 CP, the study advisor has to be contacted to discuss the situation.

2) Before completion of the master studies either
   - all three experimental physics courses (Ex-5a, Ex-5b, Ex-5c) and 5 course lectures in theoretical physics
   - or at least two of the three experimental physics courses and 6 course lectures in theoretical physics

   have to be completed successfully. In case only one of the experimental physics courses was part of the bachelor studies a corresponding requirement will be issued at the time of admission to the master studies.

3) Within the subsidiary subject at least 9 credit points have to be obtained. On request, subsidiary subjects not listed in this document, may be chosen among courses given at the Johannes Gutenberg-Universität Mainz, the TU Darmstadt or the Goethe-Universität Frankfurt. Please consult the chair of the examination committee before submitting such a request. While many subsidiary subjects will only be given in German, it is worth asking the docent to provide the lectures in English if there is a need.

4) The 6 credit points from the module "Advanced Lectures" can be replaced with 15 CP instead of 9 CP in the subsidiary subject.

5) In case all three experimental physics lectures (Ex-5a, Ex-5b, Ex-5c) were completed successfully before the start of the master studies, an additional advanced course has to be taken.

6) Equivalent courses taken at other universities may be recognised with the credit points awarded for the corresponding course in Mainz. Moderate additional requirements may be imposed.

7) Upon request, the second course of the module "Topical Courses I/II" (Spezialvorlesung I/II) may be replaced with a 4 hour course lecture in theoretical physics.

8) Each course in the module "Topical Courses I/II" can be chosen instead of a course in the module "Advanced lectures" but not vice versa. This choice has to be taken at latest at the end of the 3rd enrolment phase through the corresponding enrolment via the module "Topical Courses I/II" or the "Advanced Lectures".

9) The interdisciplinary course is optional. In addition to the courses listed in this document, also courses from the "Studium Generale" and internships ("summer student programmes") at large research laboratories may be accepted. Language courses outside of "Studium Generale" or internships in industry or research institutes can only be recognised after consulting the study advisor.

10) The research module is designed for students who wish to take more advanced courses, i.e. from a graduate school. This module may be chosen instead of the module "Advanced Lectures".

3.2 Remarks Concerning Research Phase

1) The research phase of the Master of Science in Physics programme consists of the three modules “Specialization” (3 months, seminar talk without grades, 15 CP), “Methodological Knowledge” (3 months, graded either through a seminar talk or a portfolio of documents representing the work, 15 CP) and “Master’s Thesis” (6 months including a colloquium, 30 CP). These three modules are considered as one unit and have to be completed consecutively within one year.

2) Students are allowed to enrol into the research phase if at most one of the required courses to reach the 60 CP is missing (e.g. the “Advanced Lectures”, one of the two lectures from “Topical Courses I/II” or one of the two seminars). The start of the master thesis is 6 month after the start of the research phase. At this point in time, at least 60 of the required credit points (§6 subparagraph 2) have to be collected.

3) As the module “Specialization” is part of the preparation towards the master’s thesis, it cannot be taken in parallel to the 6 months long Master’s Thesis module.

4) A change of the master’s thesis advisor can only happen once before the start of the module “Methodological Knowledge”.

5) The enrolment into the research phase is processed by the “Studienbüro Physik” with the help of the following form:
http://www.phmi.uni-mainz.de/Dateien/Anmeldeformular_Masterarbeit_Physik.pdf .
The “Studienbüro” will then take care of the actual enrolment inside Jogustine.

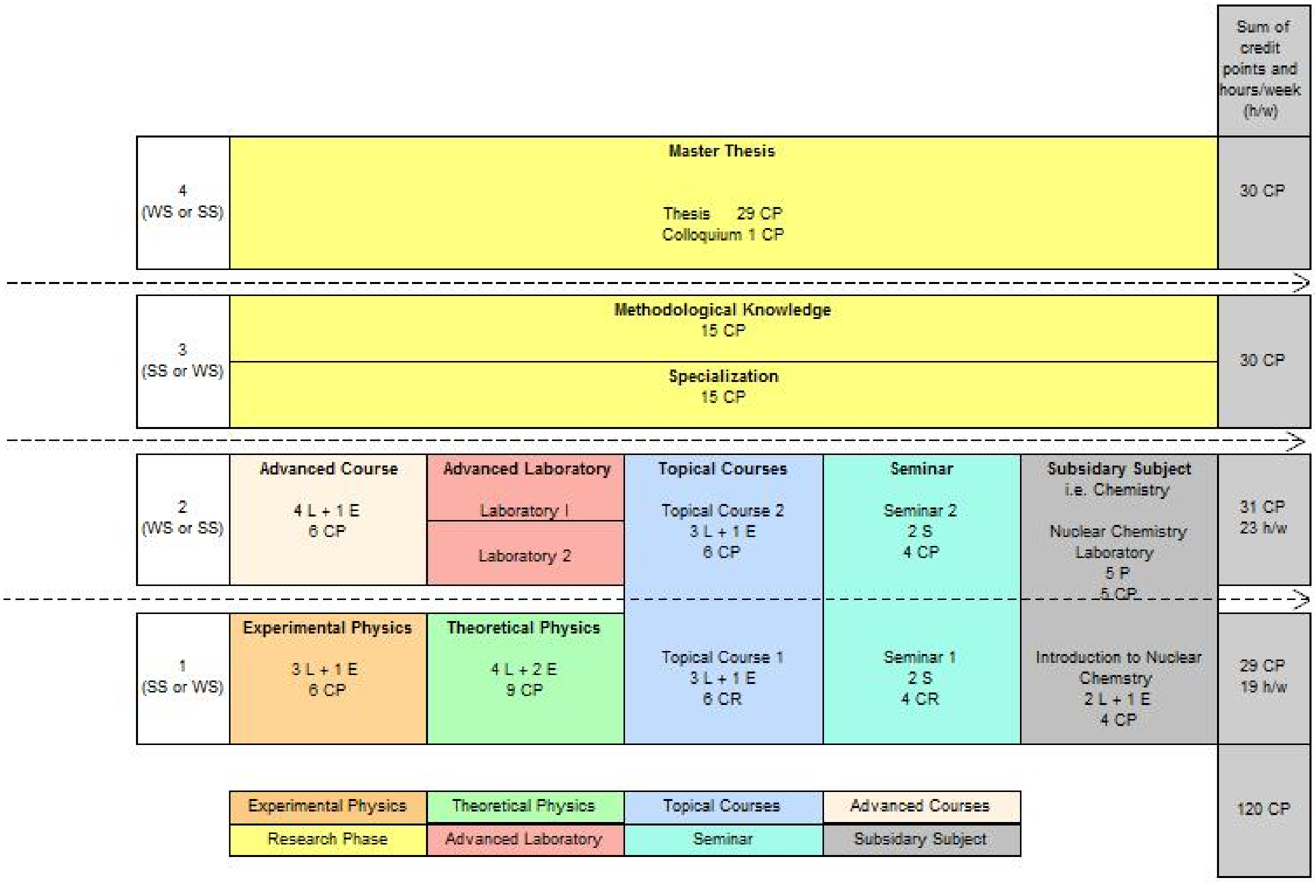
6) A master’s thesis outside the department pf physics, mathematics and computer science (08) has to be requested (please submit an informal request at the Studienbüro). The primary evaluation of an external master’s thesis has to be provided by a professor of the department 08.

7) The end date of the master’s thesis may be extended by at most 4 weeks by the chair of the examination committee. For this to happen, the candidate has to submit a justified written request to the “Studienbüro” which has also to be signed by the corresponding thesis advisor.

8) The “Studienbüro” will enter the mark for the module “Methodological Knowledge” into the system at the end of the one-year research phase. The thesis advisors are requested to submit the mark of the module “Methodological Knowledge” when handing in the primary evaluation to the “Studienbür”o.

9) In case the master’s thesis failed, the module can be repeated once. The new subject of the master thesis has to be sufficiently close to the subjects of the modules “Specialization” and “Methodological Knowledge”.

3.3 EXAMPLE FOR MODULE SEQUENCE



4 Detailed description of the Modules and Courses

4.1 Experimental Physics

Module Experimental Physics: „Atomic and Quantum Physics“					
ID number 08.128.050		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Atomic and Quantum Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		

2. Group sizes

Lecture: unlimited
Excercise: 20

3. Qualification and program goals//Competences

Students should acquire a
- basic knowledge on the physics of atoms, molecules and quanta,
- understand the structure of atoms and simple molecules as well as their interactions with quanta,
- apply quantum mechanical approaches to practical examples and thus deepen their understanding,
- achieve insights into modern experimental techniques in atomic physics, spectroscopy and the manipulation of quantum systems by coherent radiation

4. Course content

Profound introduction to the experimental quantum physics of atoms and molecules and their interaction with light. The strong experiment-theory interlink in this field is detailed and can be supported by the embedding of guest lectures.
The lectures cover the following set of topics:
- relativistic effects and Dirac equation for the hydrogen atom, influences of the atomic nucleus, atoms in external fields
- atoms in laser fields – light-atom interaction, coherent and spontaneous scattering processes
- many electron systems, fundamentals of laser spectroscopy on atoms and molecules;
- manipulation and trapping of neutral atoms, molecules and ions, Ramsey method, atomic clocks,
- as well as Bose Einstein condensation

5. Applicable to the following programs

BSc. physics, MSc. physics, MSc. mathematics

6. Recommended prerequisites

Theoretical Physics 3 „Quantum Mechanics“, Experimental Physics 3 “Waves and Quantum Mechanics”

7. Entry requirements

8. Mode and duration of examinations

8.1. Active participation

successful completion of the exercises

8.2.Course achievements

8.3. Module examination

Written exam (120-180 Min.) or oral examination (30 Min.)

9. Weighting of the achievement in the overall grade

6/120

Module Experimental Physics: „Atomic and Quantum Physics“

10.	Frequency of the module offering Winter semester
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. F. Schmidt-Kaler, Prof. Dr. K. Wendt Lecturers: All lecturers in experimental physics
12.	Auxiliary Information Course language: • German or English on request Literature: • Physics of Atoms and Molecules, B.H. Bransden & C.J. Joachain • Atom- und Quantenphysik, H. Haken & H.C. Wolf • Experimental Physics 3: Atoms, Molecules and Solid State Physics, Demtröder • specialized literature

Module Experimental Physics: „Nuclear and Particle Physics“

ID number 08.128.055	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	***Lecture with excercises „Kern- und Elementarteilchenphysik“ (WP)***		138 h	6 LP
	Lecture (WP)	3 SWS/31.5 h		
	Excercises (WP)	1 SWS/10.5 h		

2.	Group sizes Lecture: unlimited Excercise: 20
3.	Qualification and program goals/ /Competences Upon completion of the course, students should have gained • a basic understanding of the physics of elementary building blocks of matter (quarks and leptons) and their compound systems (mesons, baryons and nucleons) as well as an understanding of their fundamental and effective interactions as well as • an exemplary understanding of the importance of scattering reactions, symmetries, model building in complex systems and perturbative calculations (Feynman diagrams). As a result of the course, students should comprehend the current scientific view of the structure of matter as well as key experiments.
4.	Course content The course covers the following subjects: • properties, stability, structure, shape, and excitations of nuclei as well as the forces between nucleons, • elastic, inelastic and deep-inelastic scattering reactions, • strong, weak and electro-weak interactions and an introduction to the standard model of particle physics, • ep, pp und e^+e^- reactions, • bound systems (quarkonia, mesons, baryons), • essential symmetries used to classify particles and important selection rules governing particle reactions.
5.	Applicable to the following programs BSc. Physics, MSc. Physics, MSc. Mathematics
6.	Recommended prerequisites
7.	Entry requirements
8.	Mode and duration of examinations *8.1. Active participation*

Module Experimental Physics: „Nuclear and Particle Physics“	
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Written exam (120-180 Min.) or oral examination (30 Min.)
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every semester
11.	Persons responsible for this module and full-time lecturers
	Module responsibles: Prof. Dr. L. Köpke, Prof. Dr. J. Arends Lecturers: All lecturers in experimental nuclear and particle physics
12.	Auxiliary Information
	Course language: - German or English on request - Literature: Povh, Rith, Scholz „Teilchen und Kerne“ (DOI: 10.1007/978-3-642-37822-5) Other books on nuclear and particle physics

Module Experimental Physics: „Condensed Matter Physics“					
ID number 08.128.060		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Condensed Matter Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The Module „Condensed Matter Physics“ provides the students • with a substantial knowledge of the interrelation of the different constituents and states of condensed matter and on elementary excitations, their relation to material properties and on their role in complex processes as well as with • the capability to use the basic elements and concepts of quantum mechanics and statistical mechanics to describe the many body nature of condensed matter phenomena. The lecture provides a solid foundation for a comprehensive understanding of material science problems and a key to grasp the numerous effects behind technical applications of modern condensed matter physics.				
4.	Course content				
	• *Processes of structural change*: model systems, nucleation and growth, glass transition • *Electrons in solids*: single electron models, free electron gas, band model, semi-conductors, specific heat of metals, anharmonic effects, heat conduction • *Correlated electrons*: magnetism, superconductivity, heavy fermions • *Applications*: surfaces, spectroscopic methods				
5.	Applicable to the following programs				
	BSc. Physics, MSc. Physics, MSc. Mathematics				
6.	Recommended prerequisites				

Module Experimental Physics: „Condensed Matter Physics“	
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Written exam (120-180 Min.) or oral examination (30 Min.)
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. Th. Palberg, Prof. Dr. G. Schönhense Lecturers: All lecturers in experimental condensed matter physics
12.	Auxiliary Information
	Course language: German or English on request Literature:

4.2 Theoretical Physics

Module Theoretical Physics: „Advanced Quantum Mechanics“					
ID number 08.128.151		Workload	Duration of Course	Designated term	Credit Points
		270 h	1 Semester	1. Semester	9 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Advanced Quantum Mechanics“ (WP)			207 h	9 LP
	Lectures (WP)		4 SWS/42 h		
	Excercises (WP)		2 SWS/21 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The aim of this course is to get the students acquainted with advanced methods of quantum mechanics. In this context, the methods of second quantization and relativistic quantum mechanics are discussed, thereby guiding students towards current research topics. During the last third part of the course, the lecturers will focus on a selected topic of their choice.				
4.	Course content				
	Many-particle systems: Many-particle Schrödinger equation, second quantization for bosons and fermions, Fock space, creation and annihilation operators, Hartree-Fock approximation, interaction of non-relativstic matter with the radiation field (e.g. emission and absorption of photons by atoms, scattering of photons on atoms). *Relativistic quantum mechanics:* Klein-Gordon equation and Dirac equation with associated Lagrange density, interaction with radiation field, applications e.g. hydrogen atom. Additional in-depth topics may vary according to the lecturer. Possible topics are: Introduction to the path integral formalism, advanced group theory (Poincare group, representation theory, Wigner-Eckart theorem, spinor representations), quantum optics, examples from many-particle physics.				
5.	Applicable to the following programs				
	BSc. Physics, MSc. Physics				
6.	Recommended prerequisites				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Written exam (120-180 Min.) or oral examination (30 Min.)				
9.	Weighting of the achievement in the overall grade				
	9/120				
10.	Frequency of the module offering				
	Every semester				
11.	Persons responsible for this module and full-time lecturers				
	Responsible: Prof. Dr. S. Weinzierl Lecturers: All lecturers in theoretical physics				
12.	Auxiliary Information				

Module Theoretical Physics: „Advanced Quantum Mechanics“	
	Course language: - German or English on request Literature: Text books on theoretical physics, e.g. F. Schwabl, Advanced Quantum Mechanics, J.J. Sakurai, Advanced Quantum Mechanics, J.D. Bjorken and S.D. Drell, Relativistic Quantum Mechanics

Module Theoretical Physics: „Relativistic Quantum Field Theory“					
ID number 08.128.165		Workload	Duration of Course	Designated term	Credit Points
		270 h	1 Semester	1. Semester	9 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Relativistic Quantum Field Theory“ (WP)			207 h	9 LP
	Lectures (WP)		4 SWS/42 h		
	Excercises (WP)		2 SWS/21 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	Relativistic quantum field theory constitutes the foundation of the Standard Model of particle physics and is essential for an understanding of modern particle and hadron physics. This lecture aims at theoretical interested students, which would like to start in the field of particle and hadron physics. The lecture provides the basic tools of relativistic quantum field theory. Subsequent specialized lectures may build on these basic tools.				
4.	Course content				
	Path integrals, Grassmann numbers, quantization of the Klein-Gordon field, Dirac, Maxwell and interacting fields, Wick's theorem, Feynman rules, cross sections, S-matrix, LSZ-reduction formula, basics and outlook of non-abelian gauge theories and spontaneous symmetry breaking.				
5.	Applicable to the following programs				
	MSc. Physcs				
6.	Recommended prerequisites				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Written exam (120-180 Min.) or oral examination (30 Min.)				
9.	Weighting of the achievement in the overall grade				
	9/120				
10.	Frequency of the module offering				
	Every semester				
11.	Persons responsible for this module and full-time lecturers				
	Responsible: Prof. Dr. S. Weinzierl Lecturers: All lecturers in theoretical physics				
12.	Auxiliary Information				
	Course language: - English Literature: Text books on theoretical physics, e.g. - M. E. Peskin and D.V. Schroeder, An Introduction to Quantum Field Theory - M.D. Schwartz, Quantum Field Theory and the Standard Model				

Module Theoretical Physics: „Advanced Statistical Physics“

ID number 08.128.170	Workload	Duration of Course	Designated term	Credit Points
	270 h	1 Semester	1. Semester	9 LP

1.	Courses/Teaching methods	Contact time	Self-study	Credit Points
	Lectures with excercises „Advanced Statistical Physics“ (WP)		207 h	9 LP
	Lectures (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		

2. Group sizes

Lecture: unlimited
Excercise: 20

3. Qualification and program goals//Competences

Students will get to know advanced concepts and applications of statistical physics. They will learn central concepts on how to describe systems and materials whose behavior is dominated by large fluctuations, such as liquids in general, many plastics, most biomaterials, but also systems beyond the scope of natural sciences (e.g. in finance). The focus lies on general overarching principles, such as symmetries, cooperative processes and phase transitions, scales and scale free behavior, as well as coarse-graining. Specific examples will be selected based on the current research topics in Mainz and will to a large extent be related to soft matter.

4. Course content

1) Basic concepts in a statistical description of complex systems at equilibrium and non-equilibrium, linear response and transport, stochastic processes, structure and scattering;
2) Modeling concepts, symmetries and conservation laws, coarse-graining concepts (reduction of degrees of freedom), Newtonian dynamics, Brownian dynamics, hydrodynamics at low Reynolds numbers, simulation methods;
3) Phase transitions, mean-field approaches, Landau theory, fluctuations and critical exponents, scale invariance and renormalization, and (possibly) basic concepts of statistical field theory;
4) Concepts of polymer physics such as polymer models, ideal and real chains, scale invariance and ''blob'' concept, polymer dynamics (Rouse, Zimm, Reptation), polymer mixtures and Flory Huggins theory, and (possibly) basic concepts of polymer field theory.

Other topics are selected based on the preferences of the lecturers. Possibilities are: Non-equilibrium thermodynamics, stochastic thermodynamics, disordered systems and glasses, statistical physics of complex soft matter (e.g., self assembling systems, membranes, liquid crystals, colloidal systems, charged systems, entangled systems, biomolecules, biomaterials), as well as interdisciplinary applications of statistical physics, e.g., in finance.

5. Applicable to the following programs

MSc. Physics

6. Recommended prerequisites

Theory 1-4

7. Entry requirements

8. Mode and duration of examinations

8.1.Activeparticipation

Successful completion of the exercises

8.2.Course achievements

8.3. Module examination

Written exam (120-180 Min.) or oral examination (30 Min.)

9. Weighting of the achievement in the overall grade

9/120

10. Frequency of the module offering

At least once per year

11. Persons responsible for this module and full-time lecturers

Module Theoretical Physics: „Advanced Statistical Physics“	
	Responsible: Prof. Dr. F. Schmid Lecturers: All lecturers in theoretical physics
12.	Auxiliary Information
	Course language: German or English on request Literature: Chaikin/Lubensky: Principles of Condensed Matter Physics, Plischke/Bergersen: Equilibrium Statistical Physics. Landau-Lifshitz: Theoretical physics V und IX. Goldenfeld: Lectures on phase transitions and the renormalization group. Paul/Baschnagel: Stochastic processes. From physics to finance. Risken: The Fokker-Planck equation. Guyon, Hulin, Petit, Mitesu: Physical Hydrodynamics. de Gennes: Scaling Concepts in Polymer Physics. Doi/Edwards: The Theory of Polymer Dynamics. Grosberg/Khokhlov: Statistical Mechanics of Macromolecules. Rubinstein/Colby: Polymer Physics

Module Theoretical Physics: „Theoretical quantum optics and many body physics“

ID number 08.128.175		Workload	Duration of Course	Designated term	Credit Points
		63 h	1 Semester	1. Semester	9 LP
13.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture with excercises ***“Theoretical quantum optics and many body physics“***			138 h	9 LP
	Lectures (WP)		4 SWS/31,5 h		
	Excercises (WP)		2 SWS/10,5 h		

14. Group sizes

Lecture: unlimited
Excercise: 20

15. Qualification and program goals/ /Competences

After this course, the students should amongst others:

- be able to apply advanced methods of Theoretical Quantum Physics,
- be familiar with the interpretation, examination and formulation of quantum field theories,
- have a deeper understanding of the most important phenomena and models of many-particle theory and theoretical quantum optics

This is to create a solid basis to deal with research-related topics in the field.

16. Course content

The course offers a profound theoretical introduction to the overlapping fields of theoretical many particle physics, quantum optics and solid state quantum theory. It also offers an introduction to quantum information, ultracold gases and photonics. The strong theory-experiment interlink I this research area is supported by the possible embedding of focused experimental guest lectures into the course.

Selection of topics:

- Introduction: 1-particle and many-body Schrödinger equation, spin and its physical consequences, fermions and bosons, Green functions
- Quantum many-body theory: creation and annihilation operators, observables, quantum field theory, applications (interacting Fermi gas, interacting Bose gas, ultra-cold quantum gases, ^{4}He), coherent states, path integrals
- Quantum theory of the electromagnetic field: classical Maxwell field, Lagrange and Hamilton formalisms, quantization of the electromagnetic field, interaction of the electromagnetic field with matter, Casimir effect, Rayleigh and Thomson scattering, Raman effect
- Quantum optics: photon statistics, photon antibunching, coherent states, squeezed light, number states, atoms in cavities, quantum information (cryptography, computing, teleportation)
- Methods and models of quantum optics: coherent interactions, Jaynes-Cummings model, operators, operator identities and basis states, quantum statistics, characteristic functions, quasi-probability distributions, dissipative processes, spin-boson model, master equations, dressed states.

17. Applicable to the following programs

MSc. Physics

Module Theoretical Physics: „Theoretical quantum optics and many body physics“	
18.	Recommended prerequisites
	Knowledge at the level of the courses Theoretical Physics 1-5 of the Bachelor's degree program
19.	Entry requirements
	Bachelor sc. degree
20.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Written exam (120-180 Min.) or oral examination (30 Min.)
21.	Weighting of the achievement in the overall grade
	9/120
22.	Frequency of the module offering
	Annually in winter term
23.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. P. van Dongen, Prof. Dr. P. van Loock Lecturers: All lecturers in theoretical “hard” condensed matter physics and in theoretical quantum optics
24.	Auxiliary Informations
	Course language: - German or English Literature: • *F. Schwabl*, Quantenmechanik für Fortgeschrittene, Springer-Verlag, Berlin, 1997. • *J. J. Sakurai*, Advanced Quantum Mechanics, Addison Wesley, Reading, 1967. • *S. M. Barnett, P.M. Radmore*, Methods in Theoretical Quantum Optics, Oxford Univ. Press, Oxford, 2002. • *M. Fox*, Quantum Optics, Oxford Univ. Press, Oxford, 2006. • *M. A. Nielsen, I. L. Chuang*, Quantum Computation and Quantum Information, Cambridge Univ. Press, Cambridge, 2000. • *M. Lewenstein, A. Sanpera, V. Ahufinger*, Ultracold atoms in optical lattices, Oxford Univ. Press, Oxford, 2012. • *J. W. Negele, H. Orland*, Quantum Many-particle Systems, Perseus Books, New York, 1994. • *R. Loudon,* The Quantum Theory of Light, Oxford Univ. Press, Oxford, 2000.

4.3 Laboratory Courses and Seminars

Module Advanced Laboratory Course					
ID number M.08.128.620		Workload	Duration of Course	Designated term	Credit Points
		300 h	1 Semester	2. Semester	10 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	a) Advanced Laboratory Part 1 (P)		4 SWS/42 h	108 h	5 LP
	b) Advanced Laboratory Part 2 (P)		4 SWS/42 h	108 h	5 LP
2.	Group sizes typical 2 student working on the same laboratory experiment				
3.	Qualification and program goals/ /Competences The students are supposed to deepen advanced work in experimental and numerical-theoretical fields of physics. This is practiced by carrying out challenging experiments in two-person teams, extending over several days under supervision of experienced assistants. Usually complex data acquisition systems and computer-based analysis methods are used. Compared to the bachelor advanced laboratory course here is more emphasis on independent work.				
4.	Course content In both parts 1 and 2, experiments will be performed summing up to a total of 10 laboratory days. *Part 1*: 2-3 advanced two-day experiments from the fields: atomic physics, quantum optics, nuclear physics, elementary particle physics, solid state physics, detectors and particle detection, and atmospheric physics. *Part 2*: the remaining time may be filled with existing experiments or with extended projects in an experimental or theoretical work group.				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites				
7.	Entry requirements				
8.	Mode and duration of examinations *8.1. Active participation* *8.2.Course achievements* *8.3. Module examination* Portfolio of experiments from part 1 and part 2				
9.	Weighting of the achievement in the overall grade 10/120				
10.	Frequency of the module offering Every semester				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. H.-J. Arends Lecturers: All lecturers in physics				
12.	Auxiliary Information Course language: - German or English Literature: Manuals of experiments with special references				

Module Seminars				
ID number M.08.128.630	Workload	Duration of Course	Designated term	Credit Points
	300 h	2 Semesters	1. Semester	8 LP

1.	Courses/Teaching methods	Contact time	Self-study	Credit Points
	a) Seminar 1 (P))	2 SWS/42 h	99 h	4 LP
	b) Seminar 2 (P)	2 SWS/42 h	99 h	4 LP

2. Group sizes

3. Qualification and program goals/ /Competences

The goal of the seminars is to learn and practice giving presentations on topical physics areas. Specifically, the students should

- learn and practice presentation techniques and
- to discuss the physics contents.

Seminar 2 should include a deepened examination and discussion of up-to-date questions in physics research.

4. Course content

a) Student presentations of topics from a broad spectrum of current experimental and theoretical physics.
b) Student presentations on up-to-date topics relevant to the experimental or theoretical working groups of the physics institutes. Usually,several subjects will be offered to choose from with focus on atomic physics, condensed matter, nuclear and particle physics.

5. Applicable to the following programs

MSc. Physics

6. Recommended prerequisites

7. Entry requirements

8. Mode and duration of examinations

8.1. Active participation

Attendance of all seminars

8.2.Course achievements

8.3. Module examination

The students's presenations are graded both for seminar 1 and seminar 2

9. Weighting of the achievement in the overall grade

8/120

10. Frequency of the module offering

Every semester

11. Persons responsible for this module and full-time lecturers

Responsible: Prof. Dr. H.-J. Arends
Lecturers: All lecturers in physics

12. Auxiliary Information

Course language:
- German or English

Literature:

4.4 Topical and Advanced Courses

4.4.1 Condensed Matter Physics

Module Topical Courses: „Selected topics in Condensed Matter Physics“					
ID number 08.128.720		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Selected topics in Condensed Matter Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences Students shall be guided towards a selection of special problems in modern Condensed Matter Physics to obtain a solid background when dealing with research related topics. Magnetism and super conductivity emerge through the correlated dynamics of electrons in solids and provide the basis of modern electronics and information technology. Surface Science is essential for an in depth understanding of miniaturized devices as well as for novel diagnostic techniques. Soft Matter shows fascinating structural and dynamic properties and nurtures a rapidly developing field of applications. Its fundamental scientific questions also related to other disciplines like biology, chemistry and medicine. By an depth treatment of one or more of these topics, the course will provide a solid basis for conducting a master thesis in the area of Condensed Matter Physics.				
4.	Course content Depending on the lecturer, the course will focus on specific topics, such as magnetism, super conductivity, heavy fermions, applied solid state physics, surface science or soft matter physics				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites Knowledge of experimental physics on the level of the module Experimental Physics 5c "Physics of Condensed Matter"				
7.	Entry requirements				
8.	Mode and duration of examinations *8.1. Active participation* *successful completion of the exercises* *8.2.Course achievements* *8.3. Module examination* Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Frequency of the module offering Each summer semester				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. T. Palberg, Prof. Dr. M. Kläui Lecturers: All lecturers in experimental condensed matter physics				
12.	Auxiliary Information				

Module Topical Courses: „Selected topics in Condensed Matter Physics“	
	Course language: - German or English on request Literature: will be provided by the lecturer

Module Topical Courses: „Modern Experimental Methods in Condensed Matter Physics“					
ID number 08.128.721		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Modern experimental methods in Condensed Matter Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences Students shall be guided towards both fundamental facts and special aspects of state-of-the-art experimental methods in material science. The course will therefore present important and state of the art techniques and approaches. Examples may include spectroscopic methods, scattering techniques, scanning probe techniques as well as application related characterization of novel materials, sample preparation and conditioning techniques. Dealing with one or more of such topics, the course will develop an enhanced understanding of a research related area of expertise in Condensed Matter Physics. It will further provide a solid basis for conducting a master thesis in Condensed Matter Physics in this or a related area.				
4.	Course content Depending on the lecturers, the course will focus on specific topics such as spectroscopic methods, scattering techniques, modern microscopy techniques, scanning probe techniques, synthesis strategies, sample preparation techniques or methods for material characterization under application related conditions.				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites Knowledge of experimental physics on the level of the module Experimental Physics 5c "Physics of condensed matter"				
7.	Entry requirements				
8.	Mode and duration of examinations *8.1. Active participation* *successful completion of the exercises* *8.2.Course achievements* *8.3. Module examination* Common oral examination (30 – 45 Min.) covering both topical courses				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Frequency of the module offering Every winter semester				
11.	Persons responsible for this module and full-time lecturers				

Module Topical Courses: „Modern Experimental Methods in Condensed Matter Physics“

	Responsible: Prof. Dr. T. Palberg, Prof. Dr. M. Kläui Lecturers: All lecturers in experimental condensed matter physics
12.	Auxiliary Information
	Course language: - German or English on request Literature:

Module Topical Courses: „Materials Science“

ID number 08.128.722	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP

1.	Courses/Teaching methods	Contact time	Self-study	Credit Points
	Lectures with excercises „Materials Science“ (WP)		138 h	6 LP
	Lectures (WP)	3 SWS/31,5 h		
	Excercises (WP)	1 SWS/10,5 h		

2.	Group sizes
	Lecture: unlimited Excercise: 20
3.	Qualification and program goals/ /Competences
	Students shall be guided towards the essential physics of Material Science that is necessary for an understanding of processes in novel materials on the atomic and the nano-scale. Topics of interest covered by the course are, for example, the structure and properties of functional materials, nanomaterials, fluids and soft materials, glasses, functionalized surfaces, formation of and transitions within solids, modern methods of material science, as well as concepts and fundamentals of novel materials including their development and application. Dealing with one or more of such topics, the course will develop an enhanced understanding of a research related area of expertise in Condensed Matter Physics. It will further provide a solid basis for conducting a master thesis in Condensed Matter Physics in this or a related area.
4.	Course content
	Depending on the lecturer, the course will focus on specific topics like e.g. functional materials, nano materials, soft matter materials, glasses, functionalized sufaces, development strategies, characterization methods, phase transitions or materials for specific applications
5.	Applicable to the following programs
	MSc. Physics
6.	Recommended prerequisites
	Knowledge of Experimental Physics on the level of the Modul Experimentalphysik 5c "Physik kondensierter Materie" of the Bachelor degree programme
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade

Module Topical Courses: „Materials Science“	
	6/120
10.	Frequency of the module offering Every semester
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. T. Palberg, Prof. Dr. M. Kläui Lecturers: All lecturers in experimental condensed matter physics
12.	Auxiliary Information Course language: - German or English on request Literature:

Module Topical Courses: „Introduction to Condensed Matter Theory“

ID number 08.128.723		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Introduction to Condensed Matter Theory“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		

2.	Group sizes Lecture: unlimited Excercise: 20
3.	Qualification and program goals/ /Competences Building on the introductory courses on quantum mechanics and statistical thermodynamics, the central concepts of the description of crystalline solids shall be discussed. Starting from lattice periodicity and crystal symmetry, concepts like the electronic structure (electrons in a crystal field potential) and elementary excitations (phonons, magnons, plasmons, etc.) and their consequences for the various physical properties of solids at low temperatures are explained, thereby creating a solid basis to deal with research-related topics in the field of condensed matter theory.
4.	Course content Crystal structure, symmetry, the concept "reciprocal lattice", lattice dynamics in the harmonic approximation, relation to the elastic constants, electrons in a crystal field (Bloch wave and Wannier functions, energy bands, etc.), basic concepts of magnetism, magnons, etc. Also, depending on the choice of the lecturer, selected advanced topics (e.g., scattering theory of solids, electron-phonon interaction, plasmons and dielectric response, etc.) are presented.
5.	Applicable to the following programs MSc. Physics
6.	Recommended prerequisites Knowledge at the level of the courses Theoretical Physics 1-5 of the Bachelor's degree program
7.	Entry requirements
8.	Mode and duration of examinations *8.1. Active participation* *successful completion of the exercises* *8.2.Course achievements*

Module Topical Courses: „Introduction to Condensed Matter Theory“	
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every summer semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. P. van Dongen Lecturers: All lecturers in theoretical “hard” condensed matter physics
12.	Auxiliary Information
	Course language: - German or English on request Literature:

Module Topical Courses: „Selected Chapters of Condensed Matter Theory“

ID number 08.128.724	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	***Lectures with excercises „Selected Chapters of Condensed Matter Theory“ (WP)***		138 h	6 LP
	Lectures (WP)	3 SWS/31.5 h		
	Excercises (WP)	1 SWS/10.5 h		

2.	Group sizes
	Lecture: unlimited Excercise: 20
3.	Qualification and program goals/ /Competences
	Building on the foundations of statistical thermodynamics and/or quantum mechanics of many-body systems, the students will be introduced to specific aspects of the theory of quantum many-particle systems ("hard" condensed matter). Topics to be treated may include the theory of correlated fermions, modern static and dynamic phenomena of magnetism, low-dimensional systems, disorder, quantum phase transitions, many-body theory and their numerical methods, the theory of superfluidity and superconductivity, and topological quantum matter. Having completed this course, the student should have achieved a deeper understanding and a research-level specialization of condensed matter theory, which should form a solid foundation to successfully complete a master’s thesis in a related field of physics.
4.	Course content
	Depending on the lecturer, the lecture may be focused on numerical methods in many-body physics, the theory of correlated fermions, the theory of superconductivity, modern magnetism, or topological systems.
5.	Applicable to the following programs
	MSc. Physics
6.	Recommended prerequisites
	Knowledge at the level of the courses Theoretical Physics 1-5 of the bachelor's degree program
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises

Module Topical Courses: „Selected Chapters of Condensed Matter Theory“	
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering both topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every summer semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. P. van Dongen Lecturers: All lecturers in theoretical “hard” condensed matter physics
12.	Auxiliary Information
	Course language: - German or English on request Literature:

Module Topical Courses: „Theory of Soft Matter I“					
ID number 08.128.725		Workload	Duration ofCourse	Designatedterm	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Theory of soft matter I“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals//Competences				
	The students become acquainted with the statistical description of systems with large fluctuations for the example of various soft matter systems. A special focus lies on general principles that may be applied for different material classes.				
4.	Course content				
	General concepts: Modeling, symmetry, and conservation laws, scattering laws, self similarity and scale invariance, mean-field approaches and Landau theories, Brownian dynamics, Critical dynamics; *Structure:* Polymers (random walk, self-avoiding walk, blob concept, Flory screening, Flory Huggins theory, Path integral description of polymers, polymer field theory), Membranes (fluid, hexatic and crystalline membranes), Landau-de Gennes theory of liquid crystals; *Dynamics:* Polymers (Rouse model), hydrodynamics at low Reynolds numbers, and (possibly) active and nonequilibrium matter.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Theory 1-4, in particular Statistical Physics				
7.	Entry requirements				
8.	Mode and duration of examinations				

Module Topical Courses: „Theory of Soft Matter I“

	8.1.Activeparticipation
	Successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Upon request
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. K. Kremer, Prof. Dr. F. Schmid Lecturers: All lecturers in theoretical condensed matter physics
12.	Auxiliary Information
	Course language: German or English (on request) Literature: - de Gennes, Scaling Concepts in Polymer Physics - Doi/Edwards, The Theory of Polymer Dynamics - Grosberg/Khokhlov, Statistical Mechanics of Macromolecules - Chaikin/Lubensky, Principles of Condensed Matter Physics - Russel/Saville/Schowalter, Colloidal Dispersions - Dhont, An introduction to the dynamics of colloids

Module Topical Courses: „Modern Comp. Techniques in Condensed/Soft Matter Physics“

ID number 08.128.745		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Computer simulations in statistical physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals//Competences				
	Students attending the course will learn the use of advanced tools and techniques for efficiently performing computer simulations in the field of condensed and soft matter physics, possibly including molecular biophysics. These techniques will enable them to study phenomena like phase transitions in a variety of systems (liquids, solids, polymer melts etc.), conformational changes, chemical reactions, non-equilibrium or driven phenomena etc.				
4.	Course content				
	The topics of the course will be selected according to the docent and can include free energy calculations, enhanced sampling techniques, simulation of rare events, critical phenomena, non-equilibrium dynamics, coarse-graining, density functional theory, force-field optimization, polarizable force fields, long range interactions, etc.				
5.	Applicable to the following programs				
	MSc. Physics, Master “Computational Sciences” with focus on physics				
6.	Recommended prerequisites				

Module Topical Courses: „Modern Comp. Techniques in Condensed/Soft Matter Physics“	
	Theory 1-4, if possible (not strictly necessary) Theory 7 (Advanced Statistical Mechanics), Computer Simulations in Statistical Physics
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	Successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	At least once per year
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. F. Schmid Lecturers: All lecturers in condensed matter theory
12.	Auxiliary Information
	Course language: German or English on request Literature: To be announced in class

Module Topical Courses: „Computer Simulations in Statistical Physics“

ID number 08.128.801		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods	Contact time		Self-study	Credit Points
	Lectures with excercises „Computer Simulations in Statistical Physics“ (WP)			138 h	6 LP
	Lectures (WP)	3 SWS/31.5 h			
	Excercises (WP)	1 SWS/10.5 h			
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals//Competences				
	Students will learn to describe complex physical problems in terms of simple models, to translate these into algorithms, and to implement the algorithms correctly and in an efficient way on modern computer architectures. They will learn to appreciate the importance of computer simulations in their interaction with theory and experiment.				
4.	Course content				
	Molecular dynamics simulations, symplectic integrators, Markov chain Monte Carlos, random number generators, analysis of time series, finite size effects and simulations in different thermodynamic ensembles.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				

Module Topical Courses: „Computer Simulations in Statistical Physics“	
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	Successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every winter semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. F. Schmid Lecturers:Lecturers in theoretical condensed matter physics
12.	Auxiliary Information
	Course language: German or English on request Literature: - D. Frenkel, B. Smit, Understanding Molecular Simulation – From Algorithms to Applications, Academic Press, San Diego, 2002 - D. P. Landau, K. Binder, A Guide to Monte Carlo Simulations in Statistical Physics, Cambridge University Press, New York, 2005 - M. P. Allen, D. J. Tildesley, Computer Simulations of Liquids, Clarendon Press, Oxford, 1987 - J. M. Haile, Molecular Dynamics Simulations – Elementary Methods, Wiley, New York, 1997.

Module Advanced Course: „Theory of Soft Matter II“

ID number 08.128.800	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	2. Semester	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	***Lectures with excercises „Theory of Soft Matter II“ (WP)***		138 h	6 LP
	Lectures (WP)	3 SWS/31.5 h		
	Excercises (WP)	1 SWS/10.5 h		

2\. Group sizes

Lecture: unlimited
Excercise: 20

3\. Qualification and program goals//Competences

The students get acquainted with the statistical description of systems with large fluctuations, given the example of different soft matter systems. Special focus lies on general principles which can be applied for different material classes.

4\. Course content

Topics are selected depending on the preferences of the lecturers. Possible topics are: DLVO theory, hydrodynamic interactions in colloids and polymers, micro swimmers and active particles, Zimm model, reptation model, networks and rubber elasticity, structure of polyelectrolytes, viscoelasticity, materials science aspects of soft matter systems, statistical physics of interfaces, wetting, capillary waves.

5\. Applicable to the following programs

MSc. Physics

6\. Recommended prerequisites

7\. Entry requirements

8\. Mode and duration of examinations

8.1. Active participation

successful completion of the exercises

8.2.Course achievements

8.3. Module examination

Written exam (90-180 Min.) or oral examination (30 Min.)

9\. Weighting of the achievement in the overall grade

6/120

10\. Frequency of the module offering

11\. Persons responsible for this module and full-time lecturers

Responsible: Prof. Dr. Kurt Kremer, Prof. Dr. F. Schmid
Lecturers: All lecturers in theoretical condensed matter physics

12\. Auxiliary Informations

Course language: German or English on request
Literature:

- de Gennes, Scaling Concepts in Polymer Physics
- Doi/Edwards, The Theory of Polymer Dynamics
- Grosberg/Khokhlov, Statistical Mechanics of Macromolecules
- Chaikin/Lubensky, Principles of Condensed Matter Physics
- Russel/Saville/Schowalter, Colloidal Dispersions.
- Dhont: An Introduction to Dynamics of Colloids

4.4.2 Quantum, Atomic and Neutron Physics

Module Topical Courses: „Quantum Optics (Q-Ex-1)“					
ID number 08.128.729		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises ***Quantum Optics (WP), frequently joint theoretical-experimental course***			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The students shall be introduced to the principles of the quantized description of radiation fields. Theoretical methods shall be discussed along with selected experiments which demonstrate effects of quantized radiation fields.				
4.	Course content				
	Basic entry course to experimental quantum optics. Interdisciplinary experiment-theory course, frequently lectured jointly by experimentalists and theorists. Contents: • Quantization of electromagnetic fields, quantum states of radiation fields • correlations in the radiation field and in photon statistics • quantized interaction of atoms with light, Jaynes-Cummings Hamiltonian • ``dressed states'' Further possible topics: • Photon detectors • single photon sources and entangled photons • Bell equations, quantum mechanical correlations of entangled photon pairs • cavity quantum electrodynamics				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Experimental Physics 5a “Atomic and Quantum Physics”, Theoretical Physics 3 “Quantum Mechanics”				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade				
	6/120				
10.	Frequency of the module offering				

Module Topical Courses: „Quantum Optics (Q-Ex-1)“	
	Annually in winter term
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. J. Walz Lecturers: All lecturers in experimental physics
12.	Auxiliary Information
	Course language: - German or English Literature: Textbooks on quantum optics and light-atom interaction, - Introductory quantum optics, Gerry & Knight - The quantum theory of light, Loudon - Quantum optics, Scully & Zubairy - Quantum optics, Walls & Milburn - Atom photon interactions, Cohen-Tannoudji, Dupont-Roc & Grynberg.

Module Topical Courses: „Photonics (Q-Ex-2)“					
ID number 08.128.803		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Photonics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The students shall be introduced to the advanced description of light propagation and the interaction with matter. A deep understanding of laser spectroscopy – based on incoherent and coherent licht-matter interaction and highly stable lasers shall be acquired; in particular the difference between coherent and incoherent processes will be detailed. The students should learn to understand the working principle of lasers and fundamentals of non-linear optics.				
4.	Course content				
	Fundamentals of experimental quantum physics. Possible topics: • Gaussian optics and resonators • connection between classical, semi-calssical and quantum mechanical description of light-matter interaction • coherent light and lasers • laser modulators, optical fibers • short pulses and frequency comb techniques • incoherent spectroscopy techniques (absorption, fluorescence, Doppler-free, frequency modulation) • comparison with coherent techniques (Rabi, Ramsey, Spin-Echo) • non-linear media, sum- and difference frequency generation, $\chi^{(2)}$ vs. $\chi^{(3)}$ processes, • laser cooling				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Experimental physics 3 “Waves and Quantum Mechanics”, 5a “Atomic and Quantum Physics”, Theoretical Physics 3 “Quantum Mechanics”				

Module Topical Courses: „Photonics (Q-Ex-2)“	
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Annually in summer term
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. K. Wendt, Prof. Dr. J, Walz Lecturers: All lecturers in experimental physics
12.	Auxiliary Information
	Course language: • German or English Literature: Specialized textbooks in photonics , e.g. • Laser Spectroscopy, W. Demtröder • Optics, Light and Lasers, D. Meschede • Lasers, A.E. Siegman, • Fundamentals of Photonics, B. E. A. Saleh and M.C. Teich • publications close to current research.

Module Topical Courses: „Quantum Information (Q-Ex-3)“					
ID number 08.128.804		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises ***„Quantum Information“ (WP) frequently*** ***joint theoretical-experimental course***			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	Based on their knowledge of atomic and quantum physics as well as quantum mechanics, the students will study and derive the basic theoretical concepts of quantum information processing and quantum computing. On the experimental side, concepts, experimental realizations, platforms and applications of these concepts will be introduced involving the necessary aspects of quantum optics.				
4.	Course content				

Module Topical Courses: „Quantum Information (Q-Ex-3)“	
	Advanced course in the field of quantum optics, atomic physics and its application to quantum information. “Stand-alone” course, applies concepts from Quantum Optics and many boy physics. Interdisciplinary course, frequently lectured jointly by experimentalists and theorists. Contents: • storage and processing to quantum information in different systems • lead to quantum communication and computing • entangled states, quantum jumps, quantum Zeno effect • decoherence, macroscopical quantum superposition (“Schrödinger cat states”) Further possible topics: • quantum gates and algorithms • quantum cryptography, quantum teleportation, quantum repeaters • error correction, error prone quantum processing • quantum simulation • Systems: ion trap, in particular Paul trap based quantum computers, cavity QED, linear optical quantum computers, neutral atoms in optical lattices, solid state and superconducting quantum processors.
5.	Applicable to the following programs
	MSc. Physics
6.	Recommended prerequisites
	Experimental Physics 5a "Atomic - and Quantum Physics", Theoretical Physics 3 "Quantum Mechanics“
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Annually in summer term
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. F. Schmidt-Kaler Lecturers: Selected lecturers in experimental physics, WA Quantum
12.	Auxiliary Information
	Course language: - German or English Literature: Text books on quantum optics and quantum information processing, i.e. - Introductory quantum optics, Gerry & Knight - Quantum Computation and Quantum Information, Nielsen & Chuang - Introduction to Quantum Computation and Quantum Information, Lo, Popescu & Spiller - The Physics of Quantum Information, Bouwmeester, Ekert & Zeilinger - Exploring the Quantum - Atoms, Cavities and Photons, Haroche & Raimond

Module Topical Courses: „Precision fundamental physics (Q-Ex-4)“				
ID number 08.128.805	Workload	Duration of Course	Designated term	Credit Points

Module Topical Courses: „Precision fundamental physics (Q-Ex-4)“					
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Precision Experiments at Lowest Energies“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	Current dedicated measurements have reached fascinating levels of experimental precision and can explore fundamental questions of physics and cosmology. These include: fundamental symmetries of physics, precision measurements in neutron decay, tests of the weak interaction, tests of CPT invariance, precision measurements of fundamental constants, and modern experiments in gravitation. The students shall be introduced to problems of modern atomic physics, quantum physics, neutron physics, and cosmology. The students shall profoundly deal with these topics, close to current research.				
4.	Course content				
	Discrete symmetries and fundamental interactions in physics • tests of QED and CP violation, CPT-invariance, time reversal symmetry • weak interaction, matter/ antimatter asymmetry, EDM • variation of fundamental constants tests of the equivalence principle, Newton’s gravitation law at short distances Methods • Atoms, neutrons, protons, antimatter, penning traps, mass spectrometry Neutron Physics • the neutron as probe – structure analysis of matter, properties of the neutron and measurements, interaction with matter, neutron sources, detectors, quantum effects in neutron optics				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Experimental Physics 5a “Atomic and Quantum Physics”, Theoretical Physics 3 “Quantum Mechanics”				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade				
	6/120				
10.	Frequency of the module offering				
	Annually in winter term				
11.	Persons responsible for this module and full-time lecturers				
	Responsible: Prof. Dr. J. Walz Lecturers: All lecturers in experimental physics				
12.	Auxiliary Informations				

Module Topical Courses: „Precision fundamental physics (Q-Ex-4)“	
	Course language: • German or English Literature: • Textbooks in atomics physics • proceedings of summer-schools • publications close to current research.

4.4.3 Nuclear and Particle Physics

Module Topical Courses: „Statistics, Data Analysis and Simulation"					
ID number 08.128.730		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods	Contact time	Self-study	Credit Points	
	Lectures with excercises „Statistics, data analysis and simulation" (WP)		138 h	6 LP	
	Lectures (WP)	3 SWS/31.5 h			
	Exercises (WP)	1 SWS/10.5 h			
2.	Group sizes Lecture: unlimited Exercise: 20				
3.	Qualification and program goals/ /Competences The course provides an overview of the statistical methods to analyze data and offers an introduction to Monte Carlo techniques. While the methods are often introduced with the help of examples taken from the areas of particle, hadronic and nuclear physics, we recommend the lectures also to students specializing in other fields. The goal of the course is to provide a solid basis that helps to successfully complete a master's thesis in a related area of physics.				
4.	Course content The following areas shall be covered: • Probability distributions and the statistical description of data; • error propagations and the estimation of parameters; • significance levels and decisions on hypotheses; • Monte Carlo methods, as well as • Statistical analysis methods.				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites				
7.	Entry requirements				
8.	Mode and duration of examinations *8.1. Active participation* successful completion of the exercises *8.2.Course achievements* *8.3. Module examination* Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Frequency of the module offering Every summer semester				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. L. Köpke Lecturers: All lecturers in experimental nuclear and particle physics				
12.	Auxiliary Informations				

Module Topical Courses: „Statistics, Data Analysis and Simulation”	
	Course language: German or English on request Literature: - R.J. Barlow, Statistics - Glen Cowan, Statistical data analysis - Olaf Behnke, Data analysis in high energy physics

Module Topical Courses: „Particle Detectors“					
ID number 08.128.731		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with exercises „Particle Detectors“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Exercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Exercise: 20				
3.	Qualification and program goals/ /Competences				
	The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nuclear, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's thesis. Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play important roles. Therefore the course is also suitable to students that focus on other areas of physics.				
4.	Course content				
	The following subjects shall be covered: • Particle sources and accelerators; • Detection methods for charged and neutral radiation; • Data acquisition; • Particle detectors to measure time, energy, momentum and particle type; • Applications in complex detector systems.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade				
	6/120				
10.	Frequency of the module offering				
	Every winter semester				

Module Topical Courses: „Particle Detectors“	
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. L. Köpke Lecturers: All lecturers in experimental nuclear and particle physics
12.	Auxiliary Informations
	Course language: 1. German or English on request Literature: 2. K. Kleinknecht, Detectors for particle radiation 3. C. Grupen, B. Shwartz, Particle Detectors

Module Topical Courses: „Cosmology and General Relativity“					
ID number 08.128.732		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods	Contact time	Self-study	Credit Points	
	Lectures with excercises „Cosmology and General Relativity“ (WP)		138 h	6 LP	
	Lectures (WP)	3 SWS/31,5 h			
	Excercises (WP)	1 SWS/10,5 h			
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The lectures' program goal is to provide a basic understanding of the theory of General Relativity as well as of the current concepts and phenomena of cosmology.				
4.	Course content				
	General coordinate transformations, differential geometry, Einstein equation, Schwarzschild metric, black holes, Friedmann-Robertson-Walker cosmology, big-bang nucleosynthesis, cosmic microwave background, structure development in the early universe, dark matter and dark energy.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Knowledge corresponding to Theoretical Physics 5 (Classical Field Theory)				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade				
	6/120				
10.	Frequency of the module offering				

Module Topical Courses: „Cosmology and General Relativity“	
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Neubert Lecturers: Häusling, Neubert, Papadopoulos, Reuter, Spiesberger, Weinzierl
12.	Auxiliary Informations Course language: 4. German or English on request Literature: 5. Caroll, Wald, Kolb & Turner, Dodelson

Module Topical Courses: „Symmetries in Physics“

ID number 08.128.733	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP

Courses/Teaching methods	Contact time	Self-study	Credit Points
Lectures with excercises „Symmetries in Physics“ (WP)		138 h	6 LP
Lectures (WP)	3 SWS/31.5 h		
Excercises (WP)	1 SWS/10.5 h		

Group sizes Lecture: unlimited Excercise: 20
Qualification and program goals/ /Competences The lectures’ program goal is to provide a basic understanding of group theory and its’ applications in physics.
Course content Group theory, representations, unitary symmetries, Lie groups, applications and exercises in particle and nuclear physics.
Applicable to the following programs MSc. Physics
Recommended prerequisites
Entry requirements
Mode and duration of examinations *8.1. Active participation* *successful completion of the exercises* *8.2.Course achievements* *8.3. Module examination* Common oral examination (30 – 45 Min.) covering two topical courses
Weighting of the achievement in the overall grade 6/120
Frequency of the module offering
Persons responsible for this module and full-time lecturers

Module Topical Courses: „Symmetries in Physics“
Responsible: Prof. Dr. M. Neubert Lecturers: Neubert, Scherer, Spiesberger, Weinzierl
Auxiliary Informations
Course language: 6. German or English on request Literature: 7. Georgi, Tung

Module Topical Courses: „Modern Methods in Theoretical High Energy, Particle and Nuclear Physics“				
ID number 08.128.733, 08.128.741-744	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP
Courses/Teaching methods		Contact time	Self-study	Credit Points
Lectures with excercises „Modern Methods in Theoretical High Energy, Particle and Nuclear Physics“ (WP)			138 h	6 LP
Lectures (WP)		3 SWS/31.5 h		
Excercises (WP)		1 SWS/10.5 h		
Group sizes				
Lecture: unlimited Excercise: 20				
Qualification and program goals/ /Competences				
The lectures’ program goal is to provide a basic understanding of a topic related to current research in the field of high energy, particle and nuclear physics. An additional goal is to teach the methods which are required for the maters’s thesis.				
Course content				
Concerning to the lecturer the focus is put on a current scientifically topic from the following research areas: electroweak and strong interactions, lattice gauge theory, effective field theories, mathematical aspects of perturbation theory, functional integration in der quantum mechanics und quantum field theory, concepts of model building beyond the standard model (e.g. supersymmetry, string theory) and others. Lectures of this module are offered by different lecturers and topics can change every semester. In this case a student can subscribe to this module more than once and the module will not be counted as identical.				
Applicable to the following programs				
MSc. Physics				
Recommended prerequisites				
Theoretical Physics 5 (Classical Field Theory), Theoretical Physics 6 (Quantum Field Theory)				
Entry requirements				
Mode and duration of examinations				
8.1. Active participation				
successful completion of the exercises				
8.2.Course achievements				
8.3. Module examination				
Common oral examination (30 – 45 Min.) covering two topical courses				
Weighting of the achievement in the overall grade				
6/120				
Frequency of the module offering				

Module Topical Courses: „Modern Methods in Theoretical High Energy, Particle and Nuclear Physics“

	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. M. Neubert, Prof. Dr. H. Wittig Lecturers:
	Auxiliary Information
	Course language: 8. German or English on request Literature: 9. various textbooks, publications close to science

Module Topical Courses: „Accelerator Physics“

ID number 08.128.735	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP

		Contact time	Self-study	Credit Points
•	Courses/Teaching methods	Contact time	Self-study	Credit Points
	Lectures with excercises „Accelerator Physics“ (WP)		138 h	6 LP
	Lectures (WP)	3 SWS/31.5 h		
	Excercises (WP)	1 SWS/10.5 h		

• Group sizes

Lecture: unlimited
Excercise: 20

• Qualification and program goals/ /Competences

The purpose of the lecture is to provide an understanding of the underlying physical principles of modern particle accelerators and radiation sources. This concerns in particular the layout of pivotal components such as magnetic structures and radiofrequency-systems. Another objective is to teach the mathematical framework with respect to analytical and numerical methods. Such knowledge will form a suitable basis for doing a master's thesis within the accelerator physics groups at Mainz university.

• Course content

Linear and non linear beam-dynamics, in conjunction with properties of linear and recirculating accelerators. Building blocks of beam transport systems, e.g. normal und superconducting magnets. Radiofrequency systems for charged particle acceleration, including superconducting systems. Introduction to superconductivity. Introduction to radiation physics (Synchrotron-radiation), Collective effects, e.g. free electron laser. Recent developments such as energy recovery linacs.

• Applicable to the following programs

MSc. Physics

• Recommended prerequisites

• Entry requirements

• Mode and duration of examinations

8.1. Active participation

successful completion of the exercises

8.2.Course achievements

8.3. Module examination

Common oral examination (30 – 45 Min.) covering two topical courses

• Weighting of the achievement in the overall grade

Module Topical Courses: „Accelerator Physics“	
	6/120
•	Frequency of the module offering Every winter semester
•	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. K. Aulenbacher Lecturers: Prof. Dr. K. Aulenbacher
•	Auxiliary Informations Course language: 10. German or English on request Literature:

Module Topical Courses: „Astroparticle Physics“				
ID number 08.128.737	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	1. Semester	6 LP

1.	Courses/Teaching methods	Contact time	Self-study	Credit Points
	Lectures with exercises „Astroparticle Physics“ (WP)		138 h	6 LP
	Lectures (WP)	3 SWS/31,5 h		
	Exercises (WP)	1 SWS/10,5 h		

2.	Group sizes Lecture: unlimited Exercise: 20
3.	Qualification and program goals/ /Competences The course provides an overview of cosmology and astroparticle physics and of topical research themes. It provides essential knowledge to successfully complete a master's thesis in a related subject area.
4.	Course content The main themes of the course relate to: • Cosmology and the evolution of the Universe • Dark matter and • Cosmic radiation of charged particles, neutrinos, and gammas as well as gravitational waves. The subject “cosmology and evolution of the universe“ covers cosmological models and parameters, cosmological distances and related measurements, the matter/antimatter problem, the synthesis of light elements, the microwave background radiation, structure formation, the formation, classification, development of galaxies, active galactic nuclei and galaxy clusters, as well as the formation, energy budget, development, and final stages of stars, including the related nucleosynthesis. The theme “dark matter" covers the evidence, as well as direct and indirect searches performed to detect viable particle candidates. Keywords important for the chapter on “cosmic rays” are: sources, composition, propagation, and detection of charged cosmic radiation, sources and detection of resolved and diffuse gamma-ray sources, determination of neutrino properties (oscillations, direct mass measurement, neutrino-less double beta decay), sources and detection of terrestrial and astrophysical neutrinos, the theory and prospective sources of gravitational waves, as well as their indirect and direct detection.
5.	Applicable to the following programs MSc. Physics
6.	Recommended prerequisites Knowledge equivalent to module Experimental Physics 5b “Nuclear and Particle Physics”
7.	Entry requirements
8.	Mode and duration of examinations *8.1. Active participation*

Module Topical Courses: „Astroparticle Physics“	
	Successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every summer semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. L. Köpke, Prof. Dr. U. Oberlack Lecturers: Prof. S. Böser, Apl Prof. Dr. Egelhoff, Apl Prof. Dr. Kabuss, Prof. Dr. Köpke, Prof. U. Oberlack, Prof. M. Wurm.
12.	Auxiliary Information
	Course language: German or English on request Literature: - A. Liddle, An introduction to modern cosmology - P. Schneider, Extragalaktische Astronomie und Kosmologie - C. Grupen, Astroteilchenphysik - D. Perkins, Particle Astrophysics

Module Topical Courses: „Particle Physics“					
ID number 08.128.738		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with exercises „Particle Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Exercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Exercise: 20				
3.	Qualification and program goals/ /Competences				
	The course is intended to deepen the understanding of the fundamental building blocks of matter and their interactions. Basic principles will be covered by using topical research as an example. The course provides the required knowledge in order to successfully complete a master’s thesis in a related subject.				
4.	Course content				
	Die following subjects shall be covered: • Brief outline of experimental methods, • Symmetries and the quark model, • Lepton scattering at high energies, • Particles and interaction in the Standard Model, as well as models for its unification and extension. While covering the subjects, ground breaking and actual experiments will be discussed. Depending on the docent’s interest, extension of the Standard Mode or bound systems will be covered in more detail.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				

Module Topical Courses: „Particle Physics“	
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. L. Köpke Lecturers: All lecturers in experimental nuclear and particle physics
12.	Auxiliary Information
	Course language: English Literature: - C. Berger, Elementarteilchenphysik, Springer-Verlag, 2006. - D. Griffiths, Introduction to Elementary Particles, Wiley-VCH Verlag, 2008. - E. Lohrmann, Hochenergiephysik, Teubner-Verlag, 2005. - D. H. Perkins, High Energy Physics - B. Povh et al., Teilchen und Kerne

Module Topical Courses: „Theoretical Particle Physics“					
ID number 08.128.809		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	1. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Theoretical Particle Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The lecture course “Theoretical Particle Physics” builds upon and continues the lecture course “Relativistic Quantum Field Theory”. The lectures’ program goal is to provide a basic understanding of concepts and methods of quantum field theory which are required for a MA thesis in theoretical particle physics.				
4.	Course content				
	Path integral formalism, quantum corrections, renormalization in QED, renormalization group; non-Abelian gauge theories, quantum chromodynamics (QCD), spontaneous symmetry breaking, Higgs mechanism, standard model of particle physics.				
5.	Applicable to the following programs				
	MSc. Physics				

Module Topical Courses: „Theoretical Particle Physics“	
6.	Recommended prerequisites
	Relativistic Quantum Field Thoery
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering both topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Usually every semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. S. Weinzierl Lecturers: All professors of theoretical high energy physics
12.	Auxiliary Information
	Course language: - German or English on request Literature: - Peskin & Schroeder, Ryder, Schwartz, Zee

Module Topical Courses: „Introduction to Lattice Gauge Theory“					
ID number 08.128.746		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Introduction to Lattice Gauge Theory“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The lectures’ program goal is to provide a basic understanding of the methods of lattice gauge theory and its applications to problems in particle and nuclear physics. A particular goal is to teach the methods which are required for pursuing a master’s thesis in this field.				
4.	Course content				

Module Topical Courses: „Introduction to Lattice Gauge Theory“	
	Discretization of PDEs by finite differences; path integral in quantum mechanics; Euclidean correlation functions in QFT; transfer matrix; scalar field theories on the lattice and spin models; Ising model at high and low temperature; Z_2 lattice gauge theory, Elitzur's theorem and Wegner loop; QED and QCD in the continuum; Wilson loop; lattice gauge theory with Wilson action; Haar measure; fermions on the lattice; static potential and strong-coupling expansion; renormalization group and continuum limit; lattice perturbation theory; Monte Carlo simulations and determination of hadronic properties.
5.	Applicable to the following programs
	MSc. Physics
6.	Recommended prerequisites
	Theoretical Physics 6 (Quantum Field Theory)
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Irregular
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. H. Wittig Lecturers: Prof. Dr. H. Wittig, Prof. Dr. H. Meyer, PD Dr. G. von Hippel
12.	Auxiliary Information
	Course language: English Literature: - C. Gattringer and C.B. Lang, *Quantum Chromodynamics on the Lattice* (Lect. Notes Phys. **788**), Springer, Berlin Heidelberg 2010. - J. Smit, *Introduction to Quantum Fields on a Lattice: a robust mate* (Cambridge Lect. Notes Phys. **15**), Cambridge University Press 2002. - I. Montvay and G. Münster, *Quantum Fields on a Lattice*, Cambridge University Press 1994. - J.B. Kogut, An Introduction to Lattice Gauge Theory and Spin Systems, Rev. Mod. Phys. **51** (1979) 659.

Module Topical Courses: „Introduction to String Theory“					
ID number 08.128.760		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Introduction to String Theory“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				

Module Topical Courses: „Introduction to String Theory“	
	Lecture: unlimited Excercise: 20
3.	Qualification and program goals/ /Competences
	The lectures' program goal is to provide a basic understanding of classical and quantised bosonic and fermionic string theories. An additional goal is to teach methods which are required for the maters's thesis.
4.	Course content
	Classical bosonic string, quantisation (lightcone, covariant, path integral, BRST formalism), D-branes, superstrings, introduction to conformal field theory, string amplitudes.
5.	Applicable to the following programs
	MSc. Physics
6.	Recommended prerequisites
	Recommended, but not required: Theoretical Physics 6 (Quantum Field Theory), Cosmology and General Relativity
7.	Entry requirements
8.	Mode and duration of examinations
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Common oral examination (30 – 45 Min.) covering two topical courses
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Irregular
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. G. Honecker Lecturers: All professors of theoretical high energy physics
12.	Auxiliary Information
	Course language: English Literature: various textbooks, publications close to science, e.g.: - Zwiebach: A First Course in String Theory, Cambridge University Press 2004; - Blumenhagen, Lüst, Theisen: Basic Concepts of String Theory, Springer 2012; - Polchinski: String Theory, Vol. 1 & 2, Cambridge University Press 1998; - Green, Schwarz, Witten: String Theory, Vol. 1 & 2, Cambridge University Press 1987; - Becker, Becker, Schwarz: String Theory and M-Theory - A Modern Introduction, Cambridge University Press 2007

Module Topical Courses: „Effective Field Theories“				
ID number 08.128.766	Workload	Duration of Course	Designated term	Credit Points

Module Topical Courses: „Effective Field Theories“					
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Effective Field Theories“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The lectures introduce the basic ideas of the effective field theory approach like relevant and irrelevant operators, renormalization group, decoupling of heavy particle. The lectures also provide a deeper understanding of its most important applications in modern research fields.				
4.	Course content				
	The method of effective field theory provides a systematic approach to multi-scale problems. An effective field theory uses the appropriate degrees of freedom to describe the phenomena at a given energy scale, while all degrees of freedom only relevant at much higher scales are eliminated from the theory. These concepts lead to a large variety of phenomenological applications in modern particle physics. Especially in the theory of strong interactions with its different behaviour at the various energy scales the important examples of the electroweak Lagrangian, heavy-quark-effective theory, and soft-collinear-effective theories allow for most suitable descriptions of the respective theoretical systems.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Theoretical Physics 6 (Quantum Field Theory)				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade				
	6/120				
10.	Frequency of the module offering				
	Irregular				
11.	Persons responsible for this module and full-time lecturers				
	Responsible: Prof. Dr. M. Neubert Lecturers: All professors of theoretical high energy and hadron physics				
12.	Auxiliary Information				

Module Topical Courses: „Effective Field Theories“
Course language: English Literature: - Lecture notes "Effective Field Theory" by A. Pich - Lecture notes " Effective Field Theories" by A. Manohar - Lecture notes "Effective Field Theories and Heavy Quark Physics" by M. Neubert

Module Topical Courses: „Theoretical Astroparticle Physics“

ID number 08.128.762		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Theoretical Astroparticle Physics“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences This lecture aims to give, from a theorists point of view, a broad but thorough overview of state of the art astroparticle physics. Its goal is to prepare students to understand the current scientific literature on cosmology, dark matter, neutrinos and related topics and to prepare them for their own research projects (Master / PhD) in experimental or theoretical astroparticle physics.				
4.	Course content The big bang theory (Friedmann equation, expansion of the Universe); big bang nucleosynthesis; cosmic microwave background; formation of structure in the Universe; dark matter (production in the early Universe by thermal freeze-out, searches in terrestrial and astrophysical experiments); the cosmic matter–antimatter asymmetry; high energy cosmic rays; neutrinos (mechanisms to explain the smallness of neutrino masses; theory and phenomenology of neutrino oscillations; impact of neutrinos on cosmology; supernova neutrinos); axions				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites Theoretical Physics 6 (Quantum Field Theory)				
7.	Entry requirements				
8.	Mode and duration of examinations *8.1. Active participation* *successful completion of the exercises* *8.2.Course achievements* *8.3. Module examination* Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Frequency of the module offering				

Module Topical Courses: „Theoretical Astroparticle Physics“	
	Irregular
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. J. Kopp Lecturers: All professors of theoretical high energy physics
12.	Auxiliary Information
	Course language: English Literature: - various textbooks, publications close to science

Module Topical Courses: „Amplitudes and Precision Physics at the LHC“					
ID number 08.128.764		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises ***„Amplitudes and Precision Physics at the LHC“ (WP)***			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The goal of this lecture is to introduce students to recently developed methods for calculating scattering amplitudes within quantum field theory. A particular emphasis is put on the efficiency of the methods to be used. These new methods allow to predict cross sections for the experiments at the LHC, which are difficult to compute with traditional methods.				
4.	Course content				
	Spin- and helicity methods, colour decomposition, off-shell recursion relations, on-shell recursion relations, scattering equations; loop integrals, differential equations for loop integrals, classes of functions (for example multiple polylogarithms).				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Theoretical Physics 6 (Quantum Field Theory)				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade				

Module Topical Courses: „Amplitudes and Precision Physics at the LHC“	
	6/120
10.	Frequency of the module offering
	Irregular
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. J. Henn, Prof. Dr. S. Weinzierl Lecturers: All professors of theoretical high energy physics
12.	Auxiliary Information
	Course language: English Literature: - J. Henn, J. Plefka, „Scattering Amplitudes in Gauge Theories“, Springer, 2014; - H. Elvang, Y. Huang, „Scattering Amplitudes in Gauge Theory and Gravity“, Cambridge University Press, 2015; - L. Dixon, „Calculating Scattering Amplitudes Efficiently“, arxiv.org/abs/hep-ph/9601359

Module Topical Courses: „Functional Methods and Exact Renormalization Group“					
ID number 08.128.747		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with excercises „Functional Methods and Exact Renormalization Group“ (WP)			138 h	6 LP
	Lectures (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
2.	Group sizes				
	Lecture: unlimited Excercise: 20				
3.	Qualification and program goals/ /Competences				
	The goal of this lecture is to introduce students to path integrals, functional integral quantization of field theories and the functional renormalization group equation.				
4.	Course content				
	(A) Path integrals in quantum mechanics: Relation to the canonical approach, discretization and operator ordering, topological aspects (multiply connected configuration spaces, etc.), evaluation of functional integrals (exactly soluble examples, semiclassical expansion, perturbation theory), instantons in quantum mechanics (double well, periodic potentials, n- and Theta-vacua). (B) Functional integral quantization of field theories: Functional Schroedinger picture, wave functionals, field-particle relationship, symmetry and covariance properties, from transition amplitudes to (vacuum-) correlators and generating functionals, the Schwinger-Symanzik approach, functional integral representation via the Schroedinger picture and the Schwinger-Symanzik approach, the effective action (canonical and diagrammatic approaches, Legendre-Fenchel transform), computational techniques (semiclassical and perturbative expansion), perturbative Yang-Mills theory, nonperturbative Yang-Mills theory ("large" gauge transformations, homotopy classes- and groups, instantons and tunneling, nonperturbative vacuum structure). C) The functional renormalization group equation (FRGE): Functional (i.e. "exact") vs. perturbative renormalization, critical phenomena, Wilsonian renormalization group in statistical mechanics and quantum field theory (theory space, block spin transformations, coupling constant flows), notions of nonperturbative renormalizability, continuum limits and phase transitions, construction and "solution" of quantum field theories by means of FRGE methods.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Theoretical Physics 6 (Quantum Field Theory)				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Common oral examination (30 – 45 Min.) covering two topical courses				

Module Topical Courses: „Functional Methods and Exact Renormalization Group“	
9.	Weighting of the achievement in the overall grade 6/120
10.	Frequency of the module offering Irregular
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Reuter Lecturers: All professors of theoretical high energy physics
12.	Auxiliary Information Course language: English

Module Advanced Course: „Advanced Particle Physics“

ID number 08.128.806	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	2. Semester	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	***Lectures with exercises „Advanced Particle Physics“ (WP)***		138 h	6 LP
	Lectures (WP)	3 SWS/31.5 h		
	Exercises (WP)	1 SWS/10.5 h		

2. Group sizes

Lecture: unlimited
Exercise: 20

3. Qualification and program goals/ /Competences

This course covers special aspects of the fundamental building blocks of matter and their interactions in detail. The newest experimental methods and results will be presented for topical research areas in particle physics. The course provides the students with advanced knowledge that will help in completing an experimental master's thesis in a related research area.

4. Course content

The content of the course is variable and will typically include one of the following subjects:

- Lepton scattering at high energies,
- Strong interaction,
- Electro-weak interaction, as well as
- Models for the unification and extrension of the Standard Model.

5. Applicable to the following programs

MSc. Physics

6. Recommended prerequisites

Knowledge on the level of the module Experimental Physics 5b "Nuclear and Particle Physics" is strongly recommended. Helpful, however not essential, is the successful completion of the Special Subject Course "Elementary Particle Physics".

7. Entry requirements

8. Mode and duration of examinations

8.1. Active participation

successful completion of the exercises

8.2.Course achievements

8.3. Module examination

Written exam (90-180 Min.) or oral examination (30 Min.)

9. Weighting of the achievement in the overall grade

6/120

10. Frequency of the module offering

11. Persons responsible for this module and full-time lecturers

Responsible: Prof. Dr. L. Köpke
Lecturers: All lecturers in experimental particle physics

12. Auxiliary Information

Module Advanced Course: „Advanced Particle Physics“
Course language: German or English on request Literature: - C. Berger, Elementarteilchenphysik - D. Griffiths, Introduction to Elementary Particles Recommendations for specialized books and recent publication on current topics will be provided.

Module Advanced Course: „Advanced Chapters on Subatomic Physics“				
ID number 08.128.807	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	2. Semester	6 LP
Courses/Teaching methods		Contact time	Self-study	Credit Points
Lectures with excercises ***„Advanced lecture on subatomic physics“ (WP)***			138 h	6 LP
Lectures (WP)		3 SWS/31.5 h		
Excercises (WP)		1 SWS/10.5 h		
Group sizes				
Lecture: unlimited Excercise: 20				
Qualification and program goals/ /Competences				
The lecture intends to provide a deep understanding on research-oriented topics of hadron physics. Basic concepts as well as topical research topics will be presented. The lecture will provide the essential knowledge necessary to successfully complete an experimental master's thesis in related fields.				
Course content				
Current experimental methods, electromagnetic and hadronic probes, polarization experiments; resonances, decays, form factors and structure functions of hadrons; effective theories; spectroscopy, symmetry and structures of hadrons, the impact of hadron physics on precision tests of the Standard Model. Key experiments will be discussed for all topics.				
Applicable to the following programs				
MSc. Physics				
Recommended prerequisites				
Knowledge at the level of Experimental Physics 5 “Nuclear and Particle Physics”.				
Entry requirements				
Mode and duration of examinations				
8.1. Active participation				
successful completion of the exercises				
8.2.Course achievements				
8.3. Module examination				
Written exam (90-180 Min.) or oral examination (30 Min.)				
Weighting of the achievement in the overall grade				
6/120				
Frequency of the module offering				
Persons responsible for this module and full-time lecturers				

Module Advanced Course: „Advanced Chapters on Subatomic Physics“	
	Responsible: Prof. Dr. A. Denig Lecturers: from the field of experimental nuclear and particle physics
	Auxiliary Information
	Course language: 11. German or English on request Literature: Several text books, e.g. • B. Povh et al., Particles and Nuclei • D. H. Perkins, High Energy Physics - W. Thomas and W. Weise, The Structure of the Nucleon

Module Advanced Course: „Advanced Astroparticle- and Astrophysics“					
ID number 08.128.808		Workload	Duration of Course	Designated term	Credit Points
		180 h	1 Semester	2. Semester	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lectures with exercises ***„Advanced Astroparticle- and Astrophysics“ (WP)***			138 h	6 LP
	Lectures (WP)		3 SWS/31,5 h		
	Exercises (WP)		1 SWS/10,5 h		
2.	Group sizes				
	Lecture: unlimited Exercise: 20				
3.	Qualification and program goals/ /Competences				
	This course covers special aspects of astroparticle physics and astrophysics, thereby presenting the newest experimental methods and results. The course provides the students with advanced knowledge that will help in completing an experimental master’s thesis in a related research area.				
4.	Course content				
	Depending on interest of the lecturer, the emphasis will be put on nuclear- or astrophysical aspects of the following subjects: • Cosmology (early universe, nucleosynthesis, dark components), • Stars (formation, energy production and development stages) or • Cosmic radiation (origin, acceleration mechanisms, etc.).				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
	Knowledge on the level of the module Experimental Physics 5b "Nuclear and Particle Physics" is strongly recommended.				
7.	Entry requirements				
8.	Mode and duration of examinations				
	8.1. Active participation				
	successful completion of the exercises				
	8.2.Course achievements				
	8.3. Module examination				
	Written exam (90-180 Min.) or oral examination (30 Min.)				
9.	Weighting of the achievement in the overall grade				
	6/120				

Module Advanced Course: „Advanced Astroparticle- and Astrophysics“	
10.	Frequency of the module offering
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. L. Köpke Lecturers: Prof. S. Böser, Apl Prof. Dr. Egelhoff, Apl Prof. Dr. Kabuss, Prof. Dr. Köpke, Prof. Dr. Oberlack, Prof. Dr. Wurm
12.	Auxiliary Information Course language: German or English on request Literature: C. Grupen, Astroteilchenphysik E. Rolfs und W. Rodney, Cauldrons in the Cosmos

Module Advanced Course: „Advanced Accelerator Physics“

ID number 08.128.816	Workload	Duration of Course	Designated term	Credit Points
	180 h	1 Semester	2. Semester	6 LP

1. Courses/Teaching methods	Contact time	Self-study	Credit Points
Lecture with excercises „Advanced Accelerator Physics“ (WP)		138 h	6 LP
Lectures (WP)	3 SWS/31.5 h		
Excercises (WP)	1 SWS/10.5 h		

2. Group sizes

Lecture: unlimited
Excercise: 20

3. Qualification and program goals/ /Competences

The first objective of the course is to understand spin-polarized ensembles. Later-on, we will discuss their behavior under the conditions of relativistic motion in macroscopic external fields. This regime is governed by the Thomas-BMT equation. The spin dynamics in spin rotators, recirculating linear accelerators, but also in particular for synchrotrons and storage rings will be discussed.
The second part is devoted to the realization of spin-sensitive experiments at accelerators which are of course based on the interaction of spins with microscopic fields. Information on these interactions may be obtained by measuring spin sensitive observables, e.g. the analysing power of the process. The presentation of experimental techniques such as polarized sources and polarimeters concludes the course. The course provides the background successfully complete amaster's thesis in the groups at MAMI that deal with experiments based on spin-polarized beams.

4. Course content

The course will provide knowledge and competence with respect to the following subjects:
Spin polarized ensembles, density matrix, Dirac' equation, spin precession in the lab frame (Thomas BMT equation), single pass spin rotators, sibirian snakes, intrinsic and imperfection resonances in storage rings,
Sokolov-Ternov effect, spinstable solutions, depolarization by synchrotron radiation, spin equilibrium, spin polarized sources, spin sensitive observables (analyzing powers), polarimetry parity violating observable
Parity violation experiments at accelerators, double polarization experiments with polarized targets at collider facilities.

5. Applicable to the following programs

MSc. Physics

6. Recommended prerequisites

7. Entry requirements

8. Mode and duration of examinations

Module Advanced Course: „Advanced Accelerator Physics“	
	8.1. Active participation
	successful completion of the exercises
	8.2.Course achievements
	8.3. Module examination
	Written exam (90-180 Min.) or oral examination (30 Min.)
9.	Weighting of the achievement in the overall grade
	6/120
10.	Frequency of the module offering
	Every summer semester
11.	Persons responsible for this module and full-time lecturers
	Responsible: Prof. Dr. K. Aulenbacher Lecturers: Docents representing the area
12.	Auxiliary Informations
	Course language: 12. German or English on request Literature:

4.5 RESEARCH PHASE

Module Specialization					
ID number M.08.128.660		Workload	Duration of Course	Designated term	Credit Points
		420 h	1 Semesters	3. Semester	14 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Specialization (P)		60 h	360 h	14 LP
2.	Group sizes				
3.	Qualification and program goals/ /Competences				
	Within a working group the lecture intends to provide the student with • the special knowledge necessary to successfully complete a master's thesis and the • necessary methods to successfully complete a master's thesis and to work independently on a specific scientific topic.				
4.	Course content				
	A preliminary topic of the master's thesis from the research project of an experimental or theoretical working group will be specified which the student will then begin to work on.				
5.	Applicable to the following programs				
	MSc. Physics				
6.	Recommended prerequisites				
7.	Entry requirements				
	All teaching units of the master's courses from the 1st and 2nd semester, with the possible exception of the Special Lecture II, the Advanced Lecture and Seminar II.				
8.	Mode and duration of examinations				
	8.1. Active participation				
	Working on the research project with at least one weekly supervising discussion.				
	8.2.Course achievements				
	8.3. Module examination				
	A concluding presentation to the working group.				
9.	Weighting of the achievement in the overall grade				
	0/120 (the module does not enter in the overall grade)				
10.	Frequency of the module offering				
	Year round				
11.	Persons responsible for this module and full-time lecturers				
	Responsible: Prof. Dr. M. Ostrick Lecturers: All lecturers in physics				
12.	Auxiliary Information				
	Course language: - German or English				

Module Methodological Knowledge				
ID number M.08.128.670	Workload	Duration of Course	Designated term	Credit Points

Module Methodological Knowledge					
		450 h	1 Semesters	3. Semester	15 LP
25.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Methodological Knowledge (P)		60 h	390 h	15 LP

26. Group sizes

27. Qualification and program goals/ /Competences

Within a working group the lecture intends to provide the student with

- the special knowledge necessary to successfully complete a master's thesis and the
- methods necessary to successfully complete a master's thesis and to work independently on a specific scientific topic.

28. Course content

For the topic of the master's thesis from the research project of an experimental or theoretical working group, the student will become familiar with the methods necessary to complete the master's thesis.

29. Applicable to the following programs

MSc. Physics

30. Recommended prerequisites

31. Entry requirements

Module „Specialization"

32. Mode and duration of examinations

8.1. Active participation

Learning the methods in addition to at least one weekly supervising discussion

8.2.Course achievements

8.3. Module examination

Based on a concluding presentation to the working group or creating a portfolio

33. Weighting of the achievement in the overall grade

15/120

34. Frequency of the module offering

Year round

35. Persons responsible for this module and full-time lecturers

Responsible: Prof. Dr. M. Ostrick
Lecturers: All lecturers in physics

36. Auxiliary Information

Course language:
- German or English

Module Master's Thesis					
ID number M.08.128.960		Workload	Duration of Course	Designated term	Credit Points
		450 h	1 Semester	4. Semester	15 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points

Module Master's Thesis				
	a) Master's Thesis (P) ***b) Final Colloquium (P)***	112 h 2 h	788 h 28 h	30 LP 1 LP
2.	Group sizes			
3.	Qualification and program goals/ /Competences			
4.	Course content For the topic of the master's thesis from the research project of an experimental or theoretical working group, the student will develop new results at the frontiers of knowledge.			
5.	Applicable to the following programs MSc. Physics			
6.	Recommended prerequisites			
7.	Entry requirements Module „Specialization“ and „Methodological Knowledge“ of the research phase			
8.	Mode and duration of examinations *8.1. Active participation* Developing the new results at the frontiers of knowledge with at least one weekly supervising discussion *8.2.Course achievements* Written master's exam *8.3. Module examination* Final colloquium in front of the working group or a wider audience			
9.	Weighting of the achievement in the overall grade 30/120 (see § 16 of the PO)			
10.	Frequency of the module offering Year round			
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Ostrick Lecturers: All lecturers in physics			
12.	Auxiliary Information Course language: - German or English			

4.6 Subsidiary Subjects

Currently only the lectures from the Economics subject are always in English. For the other subsidiary subjects it is up to the lecturer to decide about the course language. The description of the individual courses (in German) can be found in the German version of this document for now until they are fully translated.