Modules and Courses

Master of Science
in
Physics

6. April 2021

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1 List of Modules and Courses

1.1 Overview of the Modules

Module	**SWS**	**CP**
	required modules	
Experimental Physics	3 V + 1 Ü	6
Theoretical Physics	4 V + 2 Ü	9
Seminars	4 S	8
Advanced laboratory course	8 P	10
sum		**33**
	Research Phase	
Specialization	F	15
Methodological Knowledge	F	15
Master thesis	F	30
sum		**60**
	Elective Modules	
Topical Courses	6 V + 2 Ü	12
Advanced Course	3 V + 1 Ü	6
Research Module	4 V	6
to choose		**12-18**
	Subsidiary Subject	
Subsidiary Subject (cf. chapter 1.4)		9-15
to choose		**9-15**
Total		**120**

1.2 List of Topical Courses

Only the following courses can be chosen in the “Topical Courses” module:

- Condensed Matter Physics
  - Selected Topics in Condensed Matter Physics
  - Modern Experimental Methods in Condensed Matter Physics
  - Materials Science
  - Introduction to Advanced Materials - from soft matter to hard matter
  - Quantum Spintronics
  - Superconductivity
  - Nonequilibrium phenomena in quantum matter
  - Introduction to Condensed Matter Theory
  - Selected Chapters of Condensed Matter Theory
  - Theory of Soft Matter I
  - Modern Computational Techniques in Condensed/Soft Matter Physics
  - Computer Simulations in Statistical Physics
  - Soft Materials at Interfaces
  - Biophysics
  - Advanced theoretical solid state 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
  - Theoretical Nuclear 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

1.3 List of Advanced Courses

Every topical course (cf. 1.2) can also be chosen as an advanced course. In addition the following courses can be chosen:

- Condensed Matter Physics
  - Theory of Soft Matter II
- Nuclear and Particle Physics
  - Advanced Particle Physics
  - Advanced Chapters on Subatomic Physics
  - Advanced Astroparticle- and Astrophysics
  - Advanced Accelerator Physics

1.4 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
Computer Science IV	4 V + 4 Ü + 2 S	16
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 I	4 V + 4 S + 2 Ü	15
History of Natural Science II	2 HS + 2 S	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
Stochastics 2	8 V	15
Basic numerics	4 V + 2 Ü	9
Basic numerics (with numerical methods of ordinary differential equations)	8 V + 2 Ü	15
Numerics of differential equations	4 V + 2 Ü	9
Numerics of differential equations (with partial differential equations)	8 V + 2 Ü	15
Algebra	4 V + 2 Ü	9
Algebra (with “Fields, Rings, Modules”)	8 V + 2 Ü	15
Topology	4 V + 2 Ü	9
Topology (with “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
Differential Geometry and Manifolds	4 V + 2 Ü	9
Function Theory	4 V + 2 Ü	9
Number Theory	4 V + 2 Ü	9
Functional Analysis	8 V + 2 Ü	15
Basics of Numerical Mathematics (with laboratory)	4 V + 2 Ü + 2 P	15

Subsidiary Subject	SWS	CP
Complex Differential Geometry	8 V + 2 Ü	15
Algebraic Geometry	8 V	15
In-depth module Analysis	8 V + 2 Ü	15
In-depth module Gauge Theory	8 V + 2 Ü	15
Meteorology		
Atmospheric Chemistry and Trace Gas Dynamics	5 V + 2 Ü	10
Atmospheric Modelling	6 V + 4 Ü	14
Atmospheric Radiation	4 V + 2 Ü	9
Large-scale Atmospheric Dynamics	4 V + 2 Ü + 1 P	11
Fundamentals of Atmospheric Hydrodynamics	4 V + 3 Ü	10
Philosophy		
Modern Philosophy	6 S	15
Interdisciplinary Courses		
History of Natural Science I	3 V	3
History of Natural Science II	3 V	3

1.4.1 Further Subsidiary Subjects

It is also possible to choose “Physics” as subsidiary subject which allows for advanced courses as well as additional theoretical or experimental physics courses.

Upon request additional subsidiary subjects can be added from other faculties of the university. Those need to be approved by the corresponding commitee („Fachausschusses für Studium und Lehre Physik“) and a dedicated contract has to be established with the faculty. The proposed subsidiary subject should be related to either natural sciences or mathematics. It is therefore advised to consult the head of the exams commitee before filing such a request.

2 Important Remarks

2.1 General Remarks

1. The language of all physics courses is English unless all participants are proficient in German and there is a consent to hold the course in German.

2. 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.

3. Before completion of the master studies either

   a) all three experimental physics courses (Ex-5a, Ex-5b, Ex-5c) and 5 main courses in theoretical physics

   b) or at least two of the three experimental physics courses and 6 main course 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.

4. 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.

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

6. 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.

7. 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.

8. Upon request, the second course of the "Topical Courses I/II" module may be replaced with a 4 hour main course in theoretical physics.

9. Each course in the "Topical Courses I/II" module can be chosen instead of a course in the "Advanced lectures" module 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 "Topical Courses I/II" or the "Advanced Lectures" module.

10. The interdisciplinary course (3 CP) 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. The credit points are added to the points for the subsidiary subject and in total a maximum of 15 credit points can be obtained.

11. 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 "Advanced Lectures" module.

12. Courses with only two hours per week cannot be credited towards the degree. They can be listed in the transcript of records under the category "other achievements" in case there is a course assessment.

2.2 Rules and regulations

The academic rules and regulations of the MSc program in physics at the Johannes Gutenberg University Mainz are summarized in the so-called "Prüfungsordnung" – or in short – "PO" (see https://www.studium.fb08.uni-mainz.de/downloadcenter-physik/). As a legal document, it needs to be formulated in German. However, we are summarizing some important points (and pit-falls) below in English.

2.2.1 Introductory remarks

- If you have questions, you should first contact the student advisor ("Studienberater") or the manager of studies ("Studienmanager") via our contact form http://helpdesk.fb08.uni-mainz.de/?l=1 . The office of student affairs ("Studienbüro", Staudingerweg 7, room 05 430, 10-12 pm Mondays to Thursday) is responsible for transcripts and certification documents, maintains recognized achievements in Jogustine and accepts applications to the Examination Board.

- A module may comprise several courses, such as teaching classes, exercises and labs. In the MSc program, a module typically consists of lecture sessions and exercise classes.

- All modules in the MSc program are graded based either on written exams, oral exams, presentations, reports on projects, or laboratory work.

- German grades are on a scale of 1.0 (best possible grade) to 4.0 (lowest passing grade). 5.0 is a failing grade. A popular formula to translate your grade into that of the German system is the so-called modified Bavarian formula

$$\frac{N_{max} - N}{N_{max} - N_{min}} \cdot 3 + 1.$$

  Where N_{max} is the highest possible grade in your home country's grading system, N_{min} is lowest possible passing grade in your home country's grading system and N the grade you want to convert.

2.2.2 How to register for a class and an exam?

At the JGU, we offer – with a few exceptions – a two-step registration process.

- At the end of the preceding term, in the week before the term starts and during the first week of lectures, students register their classes via Jogustine https://www.info.jogustine.uni-mainz.de/anmeldephasen/lehrveranstaltungsanmeldephasen/. You may drop out of a class without problems.

- Around mid-term, however, Jogustine will allow you for two weeks to register for the exam if you opt for this. The registration periods can be found here: https://www.info.jogustine.

uni-mainz.de/anmeldephasen/pruefungsanmeldephasen/. Such a registration is binding! Note that our department allows you retract from your registration, as long as you do it 1 week (1pm) before the exam is scheduled.

- After expiry of the registration or de-registration deadlines, a withdrawal is only possible in justified individual cases. This applies, for example, if you have been sick and this fact is proven by a medical certificate.

2.2.3 What happens if you fail an exam and have to repeat?

- Failed *compulsory* and *elective* module examinations may be repeated at most twice. An oral supplementary examination may, however, be approved by the examination committee following a written application to the examination board. A grade of 4.0 will be given in case the supplementary exam has been passed.

- It is not allowed to repeat an exam that was passed before.

- Students who have not passed a compulsory elective module examination may switch to a different elective module after having failed one, twice or three times. For the new elective module, the student receives three more attempts to successfully complete the exam.

- The registration for the first repetition of a module examination or partial module examination should take place within six months after the failure and the second repetition of the exam should take place within twelve months of the failure of the first repetition; the registration.

- The registrations are performed automatically by the examination office, unless the exam has been passed in the mean-time.

- Only in justified cases, longer deadlines may be granted for the first and a second repetition. However, the time period may not exceed one year and nine months. If the deadlines to repeat the examinations have been missed, the exams are considered failed.

- If an examination can no longer be repeated, the Master's program is considered failed and the continuation of studies in the same master's program is no longer possible in a German University.

2.2.4 What happens if you fail to participate in an exam or withdraw from the exam?

- If the candidate does not appear to a duly established and notified appointment without good reasons or he or she steps back from the exam without valid reasons, the grade is rated as "not sufficient" (5,0).

- Exams are also considered failed if the candidate did not complete the exam or file a written report (e.g. the Master's thesis) within the prescribed time limits.

- If you disagree with the decision, the reasons for the failure or withdrawal need to be promptly notified in writing to the examination board and made credible. Should the Examining Board recognize the reasons, the exam will be re-scheduled.

- If the candidates fails to appear or withdraws from the exam because of illness, this must be proven by a medical certificate at the latest by the third day after the exam date.

2.3 Recognition of achievements

Achievements obtained in other study programs in Mainz or abroad can be recognized if there is no significant difference with respect to corresponding achievements within the MSc in physics in Mainz. Within the recognition achievements can be combined or split in order to match the formal criteria on e.g. needed credict points. Each case will be looked at individually and discussed with the applicant. The corresponding recognition form to be filled out can be found here:
http://www.studium.fb08.uni-mainz.de/downloadcenter-physik/

2.4 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. This change has to be done 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 this form[1]. The “Studienbüro” will then take care of the actual enrolment inside Jogustine.

6. A master’s thesis outside the department of 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 “Studienbüro”.

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

[1] https://www.blogs.uni-mainz.de/fb08-studium/files/2017/08/PHY_MSc_Anmeldeformular_2-seitig.pdf

2.5 Example for Module Sequence

The following table showes an example for the module sequence for students starting in the winter or in the summer term:

Module Sequence

Term						**Credit points**
4	**Master Thesis** Thesis 29 LP Colloquium 1 LP					30 LP
3	**Methodological Knowledge** 15 LP					30 LP
	Specialization 15 LP					
2	**Advanced Course** 3V + 1 Ü 6 LP	**Advanced Laboratory** Teil 1 4 P 5 LP Teil 2 4 P 5 LP	**Topical Courses** Topical course 2 3 V + 1 Ü 6 LP	**Seminars** Seminar 2 2S 4 LP	**Subsidiary Subject** e.g. Chemistry Laboratory 5 P 5 LP	31 LP 23 SWS
1	**Experimental Physics** 3V + 1 Ü 6 LP	**Theoretical Physics** 4V + 2 Ü 9 LP	Topical course 1 3 V + 1 Ü 6 LP	Seminar 1 2S 4 LP	Nuclear Chemistry 2 V + 1 Ü 4 LP	29 LP 19 SWS
						120 LP

3 Detailed description of the Modules and Courses

3.1 Experimental Physics

<table>
<tr><th colspan="6">Atomic and Quantum Physics</th></tr>
<tr><td colspan="2">ID number
(JOGU-StINe)
08.128.050</td><td>Workload
(workload)
180 h</td><td>Course Duration
(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
6 LP</td></tr>
<tr><td>1.</td><td colspan="2">Courses/Teaching methods
Lecture with excercises “Atomic and Quantum Physics” (WP)
Lecture (WP)
Excercises (WP)</td><td>Contact time

3 SWS/31.5 h
1 SWS/10.5 h</td><td>Self-study
138 h</td><td>Credit Points
6 LP</td></tr>
<tr><td>2.</td><td colspan="5">Group sizes
Lecture: unlimited
Excercises: 20</td></tr>
<tr><td>3.</td><td colspan="5">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</td></tr>
<tr><td>4.</td><td colspan="5">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</td></tr>
<tr><td>5.</td><td colspan="5">Applicable to the following programs
BSc. Physics, MSc. Physics, MSc. Mathematics</td></tr>
<tr><td>6.</td><td colspan="5">Recommended prerequisites</td></tr>
<tr><td>7.</td><td colspan="5">Entry requirements</td></tr>
</table>

Atomic and Quantum Physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.050	180 h	1	1	6 LP

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.	Module frequency 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

Nuclear and Particle Physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.055	180 h	1	1	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
Excercises: 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

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. Module frequency

Every semester

Nuclear and Particle Physics					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.055		180 h	1	1	6 LP
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Schott, Prof. Dr. W. Gradl 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				

Condensed Matter Physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.060	180 h	1	1	6 LP

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

2. Group sizes

Lecture: unlimited
Excercises: 20

3. Qualification and program goals / Competences

The „Condensed Matter Physics“ module 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 course 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

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. Module frequency

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

Condensed Matter Physics				
ID number (JOGU-StINe) 08.128.060	Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP

12.	Auxiliary Information Course language: German or English on request Literature:

3.2 Theoretical Physics

Advanced Quantum Mechanics					
ID number (JOGU-StINe) 08.128.151		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises "Advanced Quantum Mechanics" (WP) Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207	Credit Points 9 LP
2.	Group sizes Lecture: unlimited Excercises: 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 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.	Module frequency Every semester				

Advanced Quantum Mechanics				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.151	270 h	1	1	9 LP

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: 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

Relativistic Quantum Field Theory

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.165	270 h	1	1	9 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Relativistic Quantum Field Theory” (WP)		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		

2. Group sizes
Lecture: unlimited
Excercises: 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 is aimed at theoretical interested students who would like to make a 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. 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. Module frequency
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 und D.V. Schroeder, An Introduction to Quantum Field Theory.
- M.D. Schwartz, Quantum Field Theory and the Standard Model

Advanced Statistical Physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.170	270 h	1	1	9 LP

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

2. Group sizes

Lecture: unlimited
Excercises: 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

- Basic concepts in a statistical description of complex systems at equilibrium and non-equilibrium, linear response and transport, stochastic processes, structure and scattering;
- 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;
- Phase transitions, mean-field approaches, Landau theory, fluctuations and critical exponents, scale invariance and renormalization, and (possibly) basic concepts of statistical field theory;
- 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

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.)

Advanced Statistical Physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.170	270 h	1	1	9 LP

9.	Weighting of the achievement in the overall grade 9/120
10.	Module frequency At least once per year
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. F. Schmid Lecturers: All lecturers in theoretical physics
12.	Auxiliary Information Course language: English 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

Theoretical quantum optics and many body physics					
ID number (JOGU-StINe) 08.128.175		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises „ Theoretical quantum optics and many body physics” (WP) Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
2.	Group sizes Lecture: unlimited Excercises: 20				
3.	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.				
4.	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, 4He), 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.				
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				

Theoretical quantum optics and many body physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.175	270 h	1	1	9 LP

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.	Module frequency Annually in winter term
11.	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
12.	Auxiliary Information Course language: 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.

Theoretical solid state physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.180	270 h	1	1	9 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises "Theoretical solid state physics" (WP)		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		

2. Group sizes

Lecture: unlimited
Excercises: 20

3. Qualification and program goals / Competences

Students will get acquainted with basic and advanced concepts and methods of theoretical solid state physics. They will learn fundamentals concepts of the atomic and electronic structure theory of solids that explain the stability of matter, how the symmetries of crystals govern many properties of matter, the dynamics and transport of electrons in solids, the basic optical properties of solid matter, and the basic concepts behind broken symmetry ordered states of solid matter such as magnetism and superconductivity. The class will provide the basic knowledge to prepare students for more advanced classes in solid state theory and for conducting a master thesis in Condensed Matter Theory or Experiment.

4. Course content

Basic Drude and Summerfeld theory of metals, Crystal symmetries, Reciprocal lattice, Theory of experimental determination of crystals, Crystal binding, Phonons, Free Electron gas, Bloch's theorem and the band structure of solids, Methods for calculating band structure, Fermi surface, Classification of conductors and semiconductors, Effects of electron-electron interactions, basic theory of transport and optical properties of solids, Introduction to basic ordered phases of solids such as magnetism and superconductivity.

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

9. Weighting of the achievement in the overall grade

9/120

10. Module frequency

At least once per year

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

Responsible: Prof. Dr. J. Sinova
Lecturers: All lecturers in theoretical solid state physics

Theoretical solid state physics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.180	270 h	1	1	9 LP

12. Auxiliary Information

Course language: English

Literature:

- Charles Kittel: Introduction to Solid State Physics, Wiley
- Michael P. Marder, Condensed Matter Physics, Wiley
- Neil W. Ashcroft and N. David Mermin: Solid State Physics, Saunders College

3.3 Laboratory Courses and Seminars

Advanced Laboratory Course					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.128.620		300 h	1	2	10 LP
1.	Courses/Teaching methods a) Advanced Laboratory Part 1 (P) b) Advanced Laboratory Part 2 (P)		Contact time 4 SWS/42 h 4 SWS/42 h	Self-study 108 h 108 h	Credit Points 5 LP 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.	Module frequency Every semester				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. W. Gradl Lecturers: All lecturers in physics				
12.	Auxiliary Information Course language: English Literature: Manuals of experiments with special references				

Seminars

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.128.630	240 h	2	1	8 LP

1.	Courses/Teaching methods a) Seminar 1 (P) b) Seminar 2 (P)	Contact time 2 SWS/21 h 2 SWS/21 h	Self-study 99 h 99 h	Credit Points 4 LP 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.	Module frequency Every semester
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. W. Gradl Lecturers: All lecturers in physics
12.	Auxiliary Information Course language: English

3.4 Topical and Advanced Courses

3.4.1 Modules

Module "Topical Courses"					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.128.640		360 h	1	1	12 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture with excercises "Topical Course I" (WP)			138 h	6 LP
	Lecture (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
	Lecture with excercises "Topical Course II" (WP)			138 h	6 LP
	Lecture (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
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 12/120				

Module "Advanced Course"					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.128.650		180 h	1	1	6 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture with excercises "Topical Course I" (WP)			138 h	6 LP
	Lecture (WP)		3 SWS/31.5 h		
	Excercises (WP)		1 SWS/10.5 h		
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.), oral examination (30 Min.), term paper or presentation				
9.	Weighting of the achievement in the overall grade 6/120				

3.4.2 Condensed Matter Physics

<table>
<tr><th colspan="6">Module Topical Courses: “Selected topics in Condensed Matter Physics”</th></tr>
<tr><td colspan="2">ID number
(JOGU-StINe)
08.128.720</td><td>Workload
(workload)
180 h</td><td>Course Duration
(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
6 LP</td></tr>
<tr><td>1.</td><td colspan="2">Courses/Teaching methods
Lecture with excercises “Selected topics in Condensed Matter Physics” (WP)
Lecture (WP)
Excercises (WP)</td><td>Contact time

3 SWS/31.5 h
1 SWS/10.5 h</td><td>Self-study
138 h</td><td>Credit Points
6 LP</td></tr>
<tr><td>2.</td><td colspan="5">Group sizes
Lecture: unlimited
Excercises: 20</td></tr>
<tr><td>3.</td><td colspan="5">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.</td></tr>
<tr><td>4.</td><td colspan="5">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</td></tr>
<tr><td>5.</td><td colspan="5">Applicable to the following programs
MSc. Physics</td></tr>
<tr><td>6.</td><td colspan="5">Recommended prerequisites
Knowledge of experimental physics on the level of the module Experimental Physics “Physics of Condensed Matter”</td></tr>
<tr><td>7.</td><td colspan="5">Entry requirements</td></tr>
<tr><td>8.</td><td colspan="5">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</td></tr>
<tr><td>9.</td><td colspan="5">Weighting of the achievement in the overall grade
6/120</td></tr>
<tr><td>10.</td><td colspan="5">Module frequency
Each summer semester</td></tr>
<tr><td>11.</td><td colspan="5">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</td></tr>
</table>

Module Topical Courses: "Selected topics in Condensed Matter Physics"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.720	180 h	1	1	6 LP

12.	Auxiliary Information Course language: English Literature: will be provided by the lecturer

Module Topical Courses: " Modern Experimental Methods in Condensed Matter Physics"					
ID number (JOGU-StINe) 08.128.721		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Modern Experimental Methods in Condensed Matter Physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 Modul Experimentalphysik "Physik kondensierter Materie"				
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.	Module frequency Every winter 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				

Module Topical Courses: " Modern Experimental Methods in Condensed Matter Physics"				
ID number (JOGU-StINe) 08.128.721	Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP

12.	Auxiliary Information Course language: English Literature:

Module Topical Courses: “ Materials Science”

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.722	180 h	1	1	6 LP

1.	Courses/Teaching methods Lecture with excercises “Materials Science” (WP) Lecture (WP) Excercises (WP)	Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 “Physik kondensierter Materie”			
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.	Module frequency 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: English Literature:			

Modul Spezialvorlesung I und II: „Introduction to Advanced Materials - from soft matter to hard matter“					
ID number (JOGU-StINe) 08.128.7012		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Vorlesung mit Übung „Introduction to Advanced Materials - from soft matter to hard matter“ (WP) Vorlesung (WP) Übung (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Vorlesung: unbegrenzt Übungen: 20				
3.	Qualification and program goals / Competences Den Studierenden sollen die Grundlagen der Physik und Chemie harter und weicher Materie nahe gebracht werden. Insbesondere soll ein Verständnis darüber erzielt werden, wie die Größe, die nanoskopische Anordnung sowie die Wechselwirkungsenergie der atomaren, molekularen und makromolekularen bzw. kolloidalen Bausteine die Materialeigenschaften bestimmt. Als universelle Analysemethode wird Streuung eingeführt, was sich sowohl zur Untersuchung von harter, als auch von weicher Materie eignet. Für die weiche Materie erfolgt überdies eine Einführung in die Rheologie. An einem oder an mehreren speziellen Themen soll ein vertieftes Verständnis für ein forschungsnahes Spezialgebiet der kondensierten Materie entstehen, das eine gute Grundlage darstellt, eine Masterarbeit erfolgreich durchführen zu können.				
4.	Course content • Einführung in Kristallstrukturen, Gitterschwingungen und Gitterdefekte • Einführung in weiche Materie inklusive Polymere • Einführung in Streuung mit Photonen, Neutronen und Elektronen zur Untersuchung von Kristallen, Polymeren und magnetischen Systemen • Einführung in die Rheologie von Polymeren • Einführung in den Magnetismus				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites Kenntnisse auf dem Niveau des Moduls Experimentalphysik „Physik kondensierter Materie“				
7.	Entry requirements				
8.	Mode and duration of examinations *8.1 Active participation* Vorab Bearbeitung der online bereitgestellten e-Learning Materialien, insbes. der Fragen darin. *8.2 Course achievements* *8.3 Module examination* Gemeinsame mündliche Prüfung (30-45 Min.) über beide Spezialvorlesungen				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Module frequency In der Regel jährlich				

Modul Spezialvorlesung I und II: „Introduction to Advanced Materials - from soft matter to hard matter“

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7012	180 h	1	1	6 LP

11.	Persons responsible for this module and full-time lecturers Modulbeauftragte: Prof. Dr. M. Kläui Lehrende: Dozenten und Dozentinnen aus dem Bereich der experimentellen kondensierten Materie und der Chemie
12.	Auxiliary Information Sprache: Englisch Literatur: C. Kittel: Einführung in die Festkörperphysik, R. Gross: Festkörperphysik, R. A. J. Jones: Soft Condensed Matter, M. Rubinstein & R. H. Colby: Polymer Physics; S. Blundell: Magnetism in Condensed Matter

Modul Spezialvorlesung I und II: „Quantum Spintronics“

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7014	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Vorlesung mit Übung „Quantum Spintronics“ (WP)		138 h	6 LP
	Vorlesung (WP)	3 SWS/31.5 h		
	Übung (WP)	1 SWS/10.5 h		

2. Group sizes
Vorlesung: unbegrenzt
Übungen: 20

3. Qualification and program goals / Competences
Den Studierenden sollen die physikalischen Grundlagen des Magnetismus von klassischen makroskopischen Beschreibungen bis zum quantenmechanischen Einzelspin nahe gebracht werden. Insbesondere soll ein Verständnis erzielt werden, wie einzelne Elektronen im Festkörper durch die Austauschkopplung zu einer makroskopischen Magnetisierung führen. Die Dynamik von Spins wird klassisch als auch quantenmechanisch besprochen und Methoden zur Messung werden erklärt. Auf der Anwendungsseite wird energiesparende Magnetoelektronik für Speicher, Sensorik und Logik eingeführt und Spin-basierte Qubits werden erklärt. Studenten werden die Konzepte von emergenten Phänomenen und den Übergang von klassischen und quantenmechanischen Effekten im Beispiel des Spin verstehen und das Anwendungspotential abschätzen können. An einem oder an mehreren speziellen Themen soll ein vertieftes Verständnis für ein forschungsnahes Spezialgebiet der kondensierten Materie entstehen, das eine gute Grundlage darstellt, eine Masterarbeit erfolgreich durchführen zu können.

4. Course content
Einzel-Spins und resultierende magnetische Momente, Spin Ensembles und thermodynamische Effekte, Kopplung von Spins, Spindynamik, Mikromagnetismus, Spin Torque Effekte, Spin Transport und Magnetowiderstandseffekte, Realisierung von QuBits mit Spins, Messmethoden für Spins, Anwendungen von Spin.

5. Applicable to the following programs
MSc. Physics

6. Recommended prerequisites
Kenntnisse auf dem Niveau des Moduls Experimentalphysik „Physik kondensierter Materie“

7. Entry requirements

8. Mode and duration of examinations
8.1 Active participation
Erfolgreiches Bearbeiten der Übungsaufgaben
8.2 Course achievements

8.3 Module examination
Gemeinsame mündliche Prüfung (30-45 Min.) über beide Spezialvorlesungen

9. Weighting of the achievement in the overall grade
6/120

10. Module frequency
In der Regel jährlich

11. Persons responsible for this module and full-time lecturers
Modulbeauftragte: Prof. Dr. M. Kläui
Lehrende: Dozenten und Dozentinnen aus dem Bereich der experimentellen kondensierten Materie

Modul Spezialvorlesung I und II: „Quantum Spintronics“				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7014	180 h	1	1	6 LP

12.	Auxiliary Information Sprache: Englisch Literatur: Speziellere Lehrbücher der kondensierten Materie, Lehrbücher zu Magnetismus, S. Blundell: Magnetism in Condensed Matter, J. M. D. Coey: Magnetism and Magnetic Materials, J. Stöhr & H. c. Siegmann: Magnetism – from fundamentals to nanoscale dynamics, speziellen Materialien, Sommerschulprogramme, Forschungsnahe Veröffentlichungen

Module Topical Courses: "Superconductivity"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7013	180 h	1	1	6 LP

1.	Courses/Teaching methods Lecture with excercises "Superconductivity" (WP) Lecture (WP) Excercises (WP)	Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP

2.	Group sizes Lecture: unlimited Excercises: 20
3.	Qualification and program goals / Competences The students should get acquainted with the physical foundations of superconductivity. In particular they should understand how the independent individual electrons in a solid condense into a macroscopic quantum state, what is the symmetry of the order parameter, and how the order parameter is determined. An understanding of the transport properties of the superconducting ground state shall be achieved with respect to the possibilities of dissipation free transport and the realization of superconducting quantum phenomena as ultrasensitive sensors or qubits. In one or several special topics a deeper understanding of a subfield of current research in solid state physics shall be achieved forming the foundation to successfully prepare a master thesis on these topics.
4.	Course content Electrons in solids, BCS-theory for Cooper pair formation and condensation in the ground state, phase transition and transport properties Ginzburg-Landau description, type I and type II superconductors, the Josephson effect and its applications in ultra sensitive sensors and as voltage normal, critical currents in superconductors, superconducting magnets, superconducting qubits, high temperature superconductivity, transport in two-dimensional systems, related quantum effects as Quantum Hall effect.
5.	Applicable to the following programs MSc. Physics
6.	Recommended prerequisites Knowledge at the level of the module in experimental physics: "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.	Module frequency Generally every year
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. G. Jakob, Prof. Dr. M. Jourdan Lecturers: All lecturers in experimental condensed matter physics

Module Topical Courses: "Superconductivity"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7013	180 h	1	1	6 LP

12.	Auxiliary Information Course language: English Literature: Specialized textbooks of condensed mmatter physics, textbooks of superconductivity, Tinkham: Introduction to Superconductivity; Kleiner+Buckel: Superconductivity, specialized materials, summer school lectures, research papers

Module Topical Courses: "Nonequilibrium phenomena in quantum matter"					
ID number (JOGU-StINe) 08.128.752		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Nonequilibrium phenomena in quantum matter" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 20				
3.	Qualification and program goals / Competences This lecture addresses non-equilibrium phenomena in advanced solids, with focus on systems exhibiting low temperature macroscopic quantum states like superconductivity, charge/spin density waves, ferro- and anti-ferromagnetism. These states can be studied and manipulated by femtosecond optical pulses using the so-called "pump-probe" approach. Femtosecond technology and spectroscopy have experienced major developments in the recent two decades, providing means to femtosecond switching of magnetization, observations of Higgs modes in superconductors and light-induced enhancement of superconductivity, or making molecular movies, just to mention a few. After introducing the general principle of the "pump-probe" spectroscopy, we will address several case studies, where different experimental techniques (THz spectroscopy, ultrafast electron diffraction, time-resolved ARPES, etc.) will be applied to study one of the above-mentioned macroscopic quantum states. This way we will learn the basics of non-linear optics, the novel laser-based techniques (used both in the lab and at large-scale facilities) and address physics of different material classes with fascinating functional properties. The course should provide a broad overview of techniques and nonequilibrium phenomena in correlated solids, and thus present solid grounds for MSc work in several areas of research in solid state physics.				
4.	Course content Basics of nonlinear optics & ultrafast lasers; Principles of femtosecond real-time spectroscopy and modulation techniques; Femtosecond thermo-modulation in metals; Terahertz generation and THz time-domain spectroscopy; Basics of superconductivity; Electrodynamics of systems with broken symmetry ground states; Dynamics of the superconducting gap; Microwave enhancement of superconductivity; Collective (Higgs) modes in superconductors; Basics of Charge and Spin density waves; Time-resolved photoelectron spectroscopy; Femtosecond X-ray and electron diffraction – making molecular movies; Magnetization dynamics and switching				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites Knowledge at the level of the module in experimental physics: "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				

Module Topical Courses: "Nonequilibrium phenomena in quantum matter"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.752	180 h	1	1	6 LP

9.	Weighting of the achievement in the overall grade 6/120
10.	Module frequency Normally every third semester
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. J. Demsar Lecturers: All lecturers in experimental condensed matter physics
12.	Auxiliary Information Course language: English Literature: B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics, Wiley, 1991; Kittel: Introduction to Solid State physics; M. Dressel and G. Grüner: Electrodynamics of Solids; S. Blundell: "Magnetism in Condensed Matter"; Oxford Master Series in Physics; M. Tinkham: Introduction to Superconductivity; G. Grüner: Density waves in solids; selected scientific publications & reviews

<table>
<tr><th colspan="6">Module Topical Courses: “Introduction to Condensed Matter Theory”</th></tr>
<tr><td colspan="2">ID number
(JOGU-StINe)
08.128.723</td><td>Workload
(workload)
180 h</td><td>Course Duration
(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
6 LP</td></tr>
<tr><td>1.</td><td colspan="2">Courses/Teaching methods
Lecture with excercises “Introduction to Condensed Matter Theory” (WP)
Lecture (WP)
Excercises (WP)</td><td>Contact time

3 SWS/31.5 h
1 SWS/10.5 h</td><td>Self-study
138 h</td><td>Credit Points
6 LP</td></tr>
<tr><td>2.</td><td colspan="5">Group sizes
Lecture: unlimited
Excercises: 20</td></tr>
<tr><td>3.</td><td colspan="5">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.</td></tr>
<tr><td>4.</td><td colspan="5">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.</td></tr>
<tr><td>5.</td><td colspan="5">Applicable to the following programs
MSc. Physics</td></tr>
<tr><td>6.</td><td colspan="5">Recommended prerequisites
Knowledge at the level of the courses Theoretical Physics 1-5 of the Bachelor’s degree program</td></tr>
<tr><td>7.</td><td colspan="5">Entry requirements</td></tr>
<tr><td>8.</td><td colspan="5">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</td></tr>
<tr><td>9.</td><td colspan="5">Weighting of the achievement in the overall grade
6/120</td></tr>
<tr><td>10.</td><td colspan="5">Module frequency
Every summer semester</td></tr>
<tr><td>11.</td><td colspan="5">Persons responsible for this module and full-time lecturers
Responsible: Prof. Dr. P. van Dongen
Lecturers: All lecturers in theoretical “hard” condensed matter physics</td></tr>
<tr><td>12.</td><td colspan="5">Auxiliary Information
Course language: English
Literature:</td></tr>
</table>

Module Topical Courses: "Selected Chapters of Condensed Matter Theory"					
ID number (JOGU-StINe) 08.128.724		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Selected Chapters of Condensed Matter Theory" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 *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.	Module frequency 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				

Module Topical Courses: "Selected Chapters of Condensed Matter Theory"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.724	180 h	1	1	6 LP

12. Auxiliary Information

Course language: English

Literature:

- J. P. Hansen, I. R. McDonald, Theory of Simple Liquids, Academic Press, London 2006;
- J. Yeomans, Statistical Mechanics of Phase Transitions, Clarendon Press, Oxford, 1992;
- A. Onuki, Phase Transition Dynamics, Cambridge University Press, Cambridge, 2002;
- K. Binder, W. Kob, Glassy Materials and Disordered Solids. An Introduction to Their Statistical Mechanics, World Scientific, Singapore, 2005;
- W. Paul, J. Baschnagel, Stochastic Processes, From Physics to Finance, Springer, Berlin, 2000;
- A. Auerbach, Interacting Electrons and Quantum Magnetism, Springer (1994);
- P. Fulde, Electron Correlations in Molecules and Solids, Springer (1995);
- L. Kantorovich, Quantum Theory of the Solid State: An Introduction, Kluwer (2004);
- D.C. Mattis, The Theory of Magnetism Made Simple: An Introduction to Physical Concepts and to Some Useful Mathematical Methods, World Scientific, 2006;

Module Topical Courses: "Theory of Soft Matter I"					
ID number (JOGU-StINe) 08.128.725		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Theory of Soft Matter I" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 *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.	Module frequency 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				

Module Topical Courses: "Theory of Soft Matter I"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.725	180 h	1	1	6 LP

12.	Auxiliary Information Course language: English 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 Computational Techniques in Condensed/Soft Matter Physics"					
ID number (JOGU-StINe) 08.128.745		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Modern Computational Techniques in Condensed/Soft Matter Physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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				
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.	Module frequency 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: English Literature: To be announced in class				

Module Topical Courses: "Computer Simulations in Statistical Physics"					
ID number (JOGU-StINe) 08.128.801		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Computer Simulations in Statistical Physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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				
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.	Module frequency 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				

Module Topical Courses: "Computer Simulations in Statistical Physics"				
ID number (JOGU-StINe) 08.128.801	Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP

12.	Auxiliary Information Course language: English 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 Topical Courses: "Soft Materials at Interfaces"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7010	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises "Soft Materials at Interfaces" (WP) Lecture (WP) Excercises (WP)	 3 SWS/31.5 h 1 SWS/10.5 h	138 h	6 LP

2. Group sizes

Lecture: unlimited
Excercises: 20

3. Qualification and program goals / Competences

The course gives an introduction to the physical principles to understand the structure and dynamics of soft condensed matter adjacent to solid, liquid, and vapor interfaces. Soft matter interfaces are ubiquitous in life and technology, see for example, OLED displays on smartphones, soap bubbles, many biological tissues.

Particular emphasis is given to the links connecting intermolecular forces with molecular scale structure and physical materials properties. The course further introduces the experimental techniques required to study soft matter interfaces on the relevant time and length scales. Focus is set to scattering and scanning probe techniques, providing complementary information in real and reciprocal space.

The course will enable the students to understand numerous physical phenomena surrounding us in everyday live while also providing them with the basic knowledge for improving the performance of modern soft materials for specific applications. Examples help to develop a deeper understanding and to explore links to other branches of physics.

4. Course content

Topics may vary depending on the preferences of the lecturers. Typical topics are

- Thermodynamics of interfaces
- Surface tension
- Self-organization of soft matter thin films
- Charged solid/liquid interfaces and Helmholtz double layer
- Interfacial forces and colloidal stability
- Interface induced phase transitions
- Adsorption and wetting
- Surfactants and Emulsions
- Interfacial freezing and premelting
- Liquids in nanoporous materials
- X-ray scattering and spectroscopy
- Scanning probe techniques and force measurements

5. Applicable to the following programs

MSc. Physics

6. Recommended prerequisites

7. Entry requirements

Module Topical Courses: "Soft Materials at Interfaces"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.7010	180 h	1	1	6 LP

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.	Module frequency Annually
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. Hans-Jürgen Butt, Prof. Dr. Thomas Palberg, Prof. Dr. F. Schmid Lecturers: All lecturers in condensed matter physics
12.	Auxiliary Information Course language: English Literature: • Metin Tolan, "X-Ray Scattering from Soft-Matter Thin Films", Springer (1999). • Jens Als-Nielsen, Des McMorrow, "Elements of Modern X-ray Physics", 2nd Edition, Wiley (2011). • Peter S. Pershan , Mark Schlossman, "Liquid Surfaces and Interfaces : Synchrotron X-ray Methods", Cambridge University Press (2012). • Hans-Jürgen Butt, Karlheinz Graf, Michael Kappl, "Physics and Chemistry of Interfaces", 3rd Edition, Wiley (2013).

Module Topical Courses: "Biophysics"					
ID number (JOGU-StINe) 08.128.753		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Biophysics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 20				
3.	Qualification and program goals / Competences The course gives an introduction to phenomena in biological matter using concepts from theoretical physics in order to expose and understand common physical principles. Students will learn about the elementary molecular components of a cell, as well as the interactions of these components and the formation of hierarchical functional structures. The course will enable students to understand and approach phenomena in biological systems from a physics perspective. Particular attention is given to the application of established concepts from soft matter physics and their application to living matter.				
4.	Course content There will be an introduction to living matter (tissue, bacteria, cells, etc.) and its organization, as well as the molecular players (proteins, polymers, enzymes). Further topics may vary depending on the preferences of the lecturers. Typical topics include: • Stochastic dynamics, diffusion, and single molecule dynamics • Basics of non-equilibrium thermodynamics and information theory • Physical limits to sensing • Biochemical networks and criticality • Mechanochemical coupling, molecular motors and force generation • Collective behavior and phase behavior • Self-organization and structure formation • X-ray scattering and the structure of proteins • Membranes and their theoretical description				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites A working knowledge of statistical physics (Theoretical Physics 4) is 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* Common oral examination (30 – 45 Min.) covering two topical courses				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Module frequency irregular				

Module Topical Courses: "Biophysics"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.753	180 h	1	1	6 LP

11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. Thomas Speck, Prof. Dr. Friederike Schmid Lecturers: All lecturers in condensed matter physics
12.	Auxiliary Information Course language: English Literature: • William Bialek, Biophysics: Searching for Principles, Princeton University Press (2013).

Module Topical Courses: “Advanced theoretical solid state physics”

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.754	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Advanced theoretical solid state physics” (WP) Lecture (WP) Excercises (WP)	 3 SWS/31.5 h 1 SWS/10.5 h	138 h	6 LP

2.	Group sizes Lecture: unlimited Excercises: 20
3.	Qualification and program goals / Competences Students shall get acquainted with basic and advanced concepts and methods of theoretical solid state physics. They will learn fundamentals concepts of electronic structure theory that explain the stability of matter, of symmetries that govern many structural properties of matter, of transport mechanisms, and of the role of excitations and defects for many material properties in solid matter. The class will provide basic knowledge to prepare them for more advanced classes in solid state theory and for conducting a master thesis in Condensed Matter Theory or Experiment.
4.	Course content Crystal symmetries, Reciprocal lattice, Phonons, Electron gas, Band structure, Methods for calculating Band Structure, Fermi surface, Conductors and Semiconductors, Quasiparticles concepts, Defects and Disordered systems, Transport, Optical properties, Magnetism, Superconductivity
5.	Applicable to the following programs MSc. Physics
6.	Recommended prerequisites Quantum mechanics, Statistical Physics Knowledge of condensed matter at the level of the class “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.	Module frequency Each summer semester
11.	Persons responsible for this module and full-time lecturers Module responsible: Prof. Dr. J. Sinova Lecturers:Lecturers in theoretical solid state physics

Module Topical Courses: "Advanced theoretical solid state physics"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.754	180 h	1	1	6 LP

12. Auxiliary Information

Course language: English

Literature:

- Ashcroft, Mermin: Solid State Physics, Saunders College
- Kittel: Quantum Theory of Solids, Wiley
- Jones, March, Theoretical Solid State Physics, Vol 1,2, John Wiley
- Ziman, Principles of the Theory of Solids, Cambridge University Press

Module Advanced Course: "Theory of Soft Matter II"					
ID number (JOGU-StINe) 08.128.800		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 2	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Theory of Soft Matter II" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 Theory 1-5, in particular 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* Written exam (90-180 Min.) or oral examination (30 Min.)				
9.	Weighting of the achievement in the overall grade 6/120				
10.	Module frequency				
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				

Module Advanced Course: “Theory of Soft Matter II”

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.800	180 h	1	2	6 LP

12.	Auxiliary Information Course language: English 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

3.4.3 Quantum, Atomic and Neutron Physics

Module Topical Courses: "Quantum Optics (Q-Ex-1)"					
ID number (JOGU-StINe) 08.128.729		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Quantum Optics" (WP), frequently joint theoretical-experimental course Lecture (WP) Excercises (WP)	Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP	
2.	Group sizes Lecture: unlimited Excercises: 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				

Module Topical Courses: "Quantum Optics (Q-Ex-1)"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.729	180 h	1	1	6 LP

10.	Module frequency 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: English Literature: Textbooks on quantum optics and light-atom interaction, • Introductory quantum optics, Gerry & Knight • The Quantum theroy 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 (JOGU-StINe) 08.128.803		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Photonics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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", 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.	Module frequency Annually in summer term				

Module Topical Courses: "Photonics (Q-Ex-2)"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.803	180 h	1	1	6 LP

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: 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 und M.C. Teich • publications close to current research.

<table>
<tr><th colspan="6">Module Topical Courses: “Quantum Information (Q-Ex-3)”</th></tr>
<tr><td colspan="2">ID number
(JOGU-StINe)
08.128.804</td><td>Workload
(workload)
180 h</td><td>Course Duration
(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
6 LP</td></tr>
<tr><td>1.</td><td colspan="2">Courses/Teaching methods
Lecture with excercises “Quantum Information ” (WP), frequently joint theoretical-experimental course
Lecture (WP)
Excercises (WP)</td><td>Contact time

3 SWS/31.5 h
1 SWS/10.5 h</td><td>Self-study
138 h</td><td>Credit Points
6 LP</td></tr>
<tr><td>2.</td><td colspan="5">Group sizes
Lecture: unlimited
Excercises: 20</td></tr>
<tr><td>3.</td><td colspan="5">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.</td></tr>
<tr><td>4.</td><td colspan="5">Course content
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.</td></tr>
<tr><td>5.</td><td colspan="5">Applicable to the following programs
MSc. Physics</td></tr>
<tr><td>6.</td><td colspan="5">Recommended prerequisites
Experimental Physics 5a “Atomic and Quantum Physics”, Theoretical Physics 3 “Quantum Mechanics”</td></tr>
<tr><td>7.</td><td colspan="5">Entry requirements</td></tr>
</table>

Module Topical Courses: "Quantum Information (Q-Ex-3)"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.804	180 h	1	1	6 LP

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.	Module frequency 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: English Literature: Text books on quantum optics and quantum information processing, e.g. • 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 (JOGU-StINe) 08.128.805		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Precision fundamental physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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				
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.	Module frequency Annually in winter term				

Module Topical Courses: "Precision fundamental physics (Q-Ex-4)"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.805	180 h	1	1	6 LP

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: English Literature: • Textbooks in atomics physics • proceedings of summer-schools • publications close to current research.

3.4.4 Nuclear and Particle Physics

Module Topical Courses: “Statistics, Data Analysis and Simulation”					
ID number (JOGU-StINe) 08.128.730		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Statistics, Data Analysis and Simulation” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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.	Module frequency Every summer semester				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Schott Lecturers: All lecturers in experimental nuclear and particle physics				

Module Topical Courses: "Statistics, Data Analysis and Simulation"					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.730		180 h	1	1	6 LP
12.	Auxiliary Information Course language: English 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 (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.731	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Particle Detectors” (WP)		138 h	6 LP
	Lecture (WP)	3 SWS/31.5 h		
	Excercises (WP)	1 SWS/10.5 h		

2. Group sizes

Lecture: unlimited
Excercises: 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. Module frequency

Every winter semester

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

Responsible: Prof. Dr. M. Schott
Lecturers: All lecturers in experimental nuclear and particle physics

Module Topical Courses: "Particle Detectors"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.731	180 h	1	1	6 LP

12.	Auxiliary Information Course language: English Literature: • K. Kleinknecht, Detectors for particle radiation • C. Grupen, B. Shwartz, Particle Detectors

Module Topical Courses: “Cosmology and General Relativity”					
ID number (JOGU-StINe) 08.128.732		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Cosmology and General Relativity” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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				
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.	Module frequency				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Neubert Lecturers: Häusling, Neubert, Papadopoulos, Reuter, Spiesberger, Weinzierl				
12.	Auxiliary Information Course language: English Literature: e.g. Carroll, Wald, Kolb & Turner, Dodelson				

Module Topical Courses: “Symmetries in Physics”					
ID number (JOGU-StINe) 08.128.733		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Symmetries in Physics” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 20				
3.	Qualification and program goals / Competences The lectures’ program goal is to provide a basic understanding of group theory and its’ applications in physics.				
4.	Course content Group theory, representations, unitary symmetries, Lie groups, applications and exercises in particle and nuclear 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* 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.	Module frequency				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Neubert Lecturers: Neubert, Scherer, Spiesberger, Weinzierl				
12.	Auxiliary Information Course language: English Literature: e.g. Georgi, Tung				

Module Topical Courses: “Modern Methods in Theoretical High Energy, Particle and Nuclear Physics”					
ID number (JOGU-StINe) 08.128.734		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Modern Methods in Theoretical High Energy, Particle and Nuclear Physics” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 20				
3.	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 masters’s thesis.				
4.	Course content Concerning to the lecturer the focus is put on a current scientifical topic from the following research areas: electroweak and strong interactions, lattice gauge theory, effective field theories, mathematical aspects of perturbation theory, functional integration in 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.				
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.	Module frequency				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Neubert, Prof. Dr. H. Wittig Lecturers: All lecturers in theoretical nuclear and particle physics				
12.	Auxiliary Information Course language: English Literature: various textbooks, publications close to science				

Module Topical Courses: “Accelerator Physics”

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.735	180 h	1	1	6 LP

No.	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Accelerator Physics” (WP)		138 h	6 LP
	Lecture (WP)	3 SWS/31.5 h		
	Excercises (WP)	1 SWS/10.5 h		

2. Group sizes
Lecture: unlimited
Excercises: 20

3. 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.

4. 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.

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. Module frequency
Every winter semester

11. Persons responsible for this module and full-time lecturers
Responsible: Prof. Dr. K. Aulenbacher
Lecturers: Prof. Dr. K. Aulenbacher

12. Auxiliary Information
Course language: English
Literature:
- H. Wiedemann, Particle Accelerator Physics Bd. 1&2

Module Topical Courses: “Astroparticle Physics”					
ID number (JOGU-StINe) 08.128.737		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Astroparticle Physics” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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* 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				

Module Topical Courses: "Astroparticle Physics"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.737	180 h	1	1	6 LP

10.	Module frequency Every summer semester
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. U. Oberlack Lecturers: Prof. S. Böser, Apl Prof. Dr. Egelhoff, Apl Prof. Dr. Kabuss, Prof. U. Oberlack, Prof. M. Wurm.
12.	Auxiliary Information Course language: English 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 (JOGU-StINe) 08.128.738		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Particle Physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 The 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 Knowledge equivalent to module Experimental Physics 5b "Nuclear and 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.	Module frequency Every semester				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. M. Schott Lecturers: All lecturers in experimental nuclear and particle physics				

Module Topical Courses: "Particle Physics"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.738	180 h	1	1	6 LP

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 (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.809	180 h	1	1	6 LP

1.	Courses/Teaching methods Lecture with excercises “Theoretical Particle Physics” (WP) Lecture (WP) Excercises (WP)	Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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			
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.	Module frequency 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: English Literature: Peskin & Schroeder, Ryder, Schwartz, Zee			

Module Topical Courses: “Theoretical Nuclear Physics”

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.751	180 h	1	1	6 LP

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

2.	Group sizes Lecture: unlimited Excercises: 20
3.	Qualification and program goals / Competences The aim of this course is to provide students with a survey of nuclear theory at the graduate level, as well as an introduction to modern nuclear theories and topics. While the focus is on theoretical aspects of nuclear physics, when possible, the subject will be linked to recent experimental progress and applications, e.g. to astrophysics.
4.	Course content Introduction to nuclei and nuclear forces, Theory for alpha, beta and gamma decays, Types of nuclear spectra and EM transitions, Few-body methods for nuclei, Many-body methods for nuclei, Nuclear reactions, Nuclear astrophysics and formation of the elements.
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.	Module frequency Winter semester
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. S. Bacca Lecturers: Prof. Dr. S. Bacca and Prof. Dr. P. Capel
12.	Auxiliary Information Course language: English Literature: Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nuclear Physics. • Carlos A. Bertulani, Nuclear Physics in a Nutshell. • Kenneth S. Krane, Introductory Nuclear Physics.

Module Topical Courses: “Introduction to Lattice Gauge Theory”					
ID number (JOGU-StINe) 08.128.746		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Introduction to Lattice Gauge Theory” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 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.	Module frequency 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				

Module Topical Courses: “Introduction to Lattice Gauge Theory”

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.746	180 h	1	1	6 LP

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.

<table>
<tr><th colspan="6">Module Topical Courses: “Introduction to String Theory”</th></tr>
<tr><td colspan="2">ID number
(JOGU-StINe)
08.128.760</td><td>Workload
(workload)
180 h</td><td>Course Duration
(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
6 LP</td></tr>
<tr><td>1.</td><td colspan="2">Courses/Teaching methods
Lecture with excercises “Introduction to String Theory” (WP)
Lecture (WP)
Excercises (WP)</td><td>Contact time

3 SWS/31.5 h
1 SWS/10.5 h</td><td>Self-study
138 h</td><td>Credit Points
6 LP</td></tr>
<tr><td>2.</td><td colspan="5">Group sizes
Lecture: unlimited
Excercises: 20</td></tr>
<tr><td>3.</td><td colspan="5">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.</td></tr>
<tr><td>4.</td><td colspan="5">Course content
Classical bosonic string, quantisation (lightcone, covariant, path integral, BRST formalism), D-branes, superstrings, introduction to conformal field theory, string amplitudes.</td></tr>
<tr><td>5.</td><td colspan="5">Applicable to the following programs
MSc. Physics</td></tr>
<tr><td>6.</td><td colspan="5">Recommended prerequisites
Recommended, but not required: Theoretical Physics 6 (Quantum Field Theory), Cosmology and General Relativity</td></tr>
<tr><td>7.</td><td colspan="5">Entry requirements</td></tr>
<tr><td>8.</td><td colspan="5">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</td></tr>
<tr><td>9.</td><td colspan="5">Weighting of the achievement in the overall grade
6/120</td></tr>
<tr><td>10.</td><td colspan="5">Module frequency
Irregular</td></tr>
<tr><td>11.</td><td colspan="5">Persons responsible for this module and full-time lecturers
Responsible: Prof. Dr. G. Honecker
Lecturers: All professors of theoretical high energy physics</td></tr>
</table>

Module Topical Courses: “Introduction to String Theory”				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.760	180 h	1	1	6 LP

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 (JOGU-StINe) 08.128.766		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Effective Field Theories" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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.	Module frequency 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				

Module Topical Courses: “Effective Field Theories”				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.766	180 h	1	1	6 LP

12. Auxiliary Information

Course language: English

Literature:

- Lecture notes Ëffective Field Theory"by A. Pich
- Lecture notes Ëffective Field Theories"by A. Manohar
- Lecture notes Ëffective Field Theories and Heavy Quark Physics"by M. Neubert

Module Topical Courses: “Theoretical Astroparticle Physics”					
ID number (JOGU-StINe) 08.128.762		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises “Theoretical Astroparticle Physics” (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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.	Module frequency 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 (JOGU-StINe) 08.128.764		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Amplitudes and Precision Physics at the LHC" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 6/120				
10.	Module frequency 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				

<table>
<tr><th colspan="6">Module Topical Courses: “Functional Methods and Exact Renormalization Group”</th></tr>
<tr><td colspan="2">ID number
(JOGU-StINe)
08.128.747</td><td>Workload
(workload)
180 h</td><td>Course Duration
(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
6 LP</td></tr>
<tr><td>1.</td><td colspan="2">Courses/Teaching methods
Lecture with excercises “Functional Methods and Exact Renormalization Group” (WP)
Lecture (WP)
Excercises (WP)</td><td>Contact time

3 SWS/31.5 h
1 SWS/10.5 h</td><td>Self-study
138 h</td><td>Credit Points
6 LP</td></tr>
<tr><td>2.</td><td colspan="5">Group sizes
Lecture: unlimited
Excercises: 20</td></tr>
<tr><td>3.</td><td colspan="5">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.</td></tr>
<tr><td>4.</td><td colspan="5">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.</td></tr>
<tr><td>5.</td><td colspan="5">Applicable to the following programs
MSc. Physics</td></tr>
<tr><td>6.</td><td colspan="5">Recommended prerequisites
Theoretical Physics 6 (Quantum Field Theory)</td></tr>
<tr><td>7.</td><td colspan="5">Entry requirements</td></tr>
<tr><td>8.</td><td colspan="5">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</td></tr>
</table>

Module Topical Courses: “Functional Methods and Exact Renormalization Group”				
ID number (JOGU-StINe) 08.128.747	Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP

9.	Weighting of the achievement in the overall grade 6/120
10.	Module frequency 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 (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.806	180 h	1	2	6 LP

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

2. Group sizes

Lecture: unlimited
Excercises: 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 Topical 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. Module frequency

irregular

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

Responsible: Prof. Dr. M. Schott
Lecturers: All lecturers in experimental particle physics

Module Advanced Course: "Advanced Particle Physics"				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.806	180 h	1	2	6 LP

12. Auxiliary Information

Course language: English

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 (JOGU-StINe) 08.128.807		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 2	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Advanced Chapters on Subatomic Physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 20				
3.	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 research topics will be presented. The lecture will provide the essential knowledge necessary to successfully complete an experimental master's thesis in related fields.				
4.	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.				
5.	Applicable to the following programs MSc. Physics				
6.	Recommended prerequisites Knowledge at the level of Experimental Physics 5 "Nuclear and 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.	Module frequency				
11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. A. Denig Lecturers: from the field of experimental nuclear and particle physics				
12.	Auxiliary Information Course language: English Literature: Several text books, e.g. • B. Povh et al., Teilchen und Kerne • D. H. Perkins, High Energy Physics • W. Thomas und W. Weise, The Structure of the Nucleon				

Module Advanced Course: "Advanced Astroparticle- and Astrophysics"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.808	180 h	1	2	6 LP

No.	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises "Advanced Astroparticle- and Astrophysics" (WP) Lecture (WP) Excercises (WP)	 3 SWS/31.5 h 1 SWS/10.5 h	138 h	6 LP

2. Group sizes

Lecture: unlimited
Excercises: 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

10. Module frequency

irregular

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

Responsible: Prof. Dr. U. Oberlack
Lecturers: Prof. S. Böser, Apl Prof. Dr. Egelhoff, Apl Prof. Dr. Kabuss, Prof. Dr. Oberlack, Prof. Dr. Wurm

12. Auxiliary Information

Course language: English
Literature:

- C. Grupen, Astroteilchenphysik
- E. Rolfs und W. Rodney, Cauldrons in the Cosmos

Module Advanced Course: "Advanced Accelerator Physics"					
ID number (JOGU-StINe) 08.128.816		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 2	Credit Points (LP) 6 LP
1.	Courses/Teaching methods Lecture with excercises "Advanced Accelerator Physics" (WP) Lecture (WP) Excercises (WP)		Contact time 3 SWS/31.5 h 1 SWS/10.5 h	Self-study 138 h	Credit Points 6 LP
2.	Group sizes Lecture: unlimited Excercises: 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 to successfully complete a master'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 *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.	Module frequency Every summer semester				

Module Advanced Course: "Advanced Accelerator Physics"

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
08.128.816	180 h	1	2	6 LP

11.	Persons responsible for this module and full-time lecturers Responsible: Prof. Dr. K. Aulenbacher Lecturers: Docents representing the area
12.	Auxiliary Information Course language: English Literature: • D. Barber: Introduction to Spin polarisation in accelerators and storage rings • B.W. Montague Physics Reports 113 (1984) 1-96 • A. Lehrach: Strahl und Spin-Dynamik von Hadronenstrahlen in Mittelenergiespeicherringen. Schriften des Forschungszentrums Jülich, Reihe Schlüsseltechnologien, Jülich 2008 ISBN 978-3-89336-548-7

3.5 Research Phase

Specialization					
ID number (JOGU-StINe) M.08.128.660		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 3	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Specialization (P)		Contact time 60 h	Self-study 390 h	Credit Points 15 LP
2.	Group sizes				
3.	Qualification and program goals / Competences Within a working group the course 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 Topical Course II, the Advanced Course 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.	Module frequency Every semester				
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: English				

Methodological Knowledge				
ID number (JOGU-StINe) M.08.128.670	Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 3	Credit Points (LP) 15 LP
1. Courses/Teaching methods Methodological Knowledge (P)		Contact time 60 h	Self-study 390 h	Credit Points 15 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 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.				
5. Applicable to the following programs MSc. Physics				
6. Recommended prerequisites				
7. Entry requirements Module "Specialization"				
8. 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				
9. Weighting of the achievement in the overall grade 15/120				
10. Module frequency Every semester				
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: English				

Master Thesis					
ID number (JOGU-StINe) A.08.128.969		Workload (workload) 900 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 4	Credit Points (LP) 30 LP
1.	Courses/Teaching methods Master thesis (P) Final Colloquium (P)		Contact time 110 h 2 h	Self-study 760 h 28 h	Credit Points 29 LP 1 LP
2.	Group sizes				
3.	Qualification and program goals / Competences				
4.	Course content For the topic of the master 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 thesis *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.	Module frequency Every semester				
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: English				

3.6 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.

3.6.1 Chemistry

Nuclear Chemistry					
ID number (JOGU-StINe) M.09.032.1005		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture “Einführung in die Kernchemie” (WP)		2 SWS	39 h	2 LP
	Excercises “Einführung in die Kernchemie” (WP)		1 SWS	49.5 h	2 LP
	Kernchemisches Praktikum I (WP)		5 SWS	97.5 h	5 LP
8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* *8.3 Module examination* Oral examination (30-45 Min.)				
12.	Auxiliary Information Course language: German Further details can be found in the module handbooks of the Chemistry programs.				

Nuclear Chemistry (with one additional advanced course)					
ID number (JOGU-StINe) M.09.032.1006		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 12 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture “Einführung in die Kernchemie” (WP)		2 SWS	39 h	2 LP
	Excercises “Einführung in die Kernchemie” (WP)		1 SWS	49.5 h	2 LP
	Kernchemisches Praktikum I (WP)		5 SWS	97.5 h	5 LP
	Spezialvorlesung I (WP)		2 SWS	69 h	3 LP
8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* *8.3 Module examination* Oral examination (30-45 Min.)				
12.	Auxiliary Information Course language: German Further details can be found in the module handbooks of the Chemistry programs.				

Nuclear Chemistry (with two additional advanced courses)

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.09.032.1007	270 h	2	1	15 LP

No.	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture “Einführung in die Kernchemie” (WP)	2 SWS	39 h	2 LP
	Excercises “Einführung in die Kernchemie” (WP)	1 SWS	49.5 h	2 LP
	Kernchemisches Praktikum I (WP)	5 SWS	97.5 h	5 LP
	Spezialvorlesung I (WP)	2 SWS	69 h	3 LP
	Spezialvorlesung II (WP)	2 SWS	69 h	3 LP

8. Mode and duration of examinations

8.1 Active participation

successful completion of the exercises

8.2 Course achievements

8.3 Module examination

Oral examination (30-45 Min.)

12. Auxiliary Information

Course language: German

Further details can be found in the module handbooks of the Chemistry programs.

Introduction to Theoretical Chemistry

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.09.032.1010	270 h	1	1	9 LP

No.	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture/Excercises “Einführung in die Theoretische Chemie” (WP)	5 SWS	127 h	6 LP
	Lab course “Computerchemie” (WP)	5 SWS	37 h	3 LP

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 min) or oral examination (30 min)

12. Auxiliary Information

Course language: German

Further details can be found in the german version of the module handbook

Theoretical Chemistry

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.09.032.1011	360 h	2	1	12 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture/Excercises “Theoretische Chemie 1” (WP)	3 SWS	88 h	4 LP
	Lab course “Theoretische Chemie 1” (WP)	5 SWS	7 h	2 LP
	Lecture/Excercises “Theoretische Chemie 2” (WP)	3 SWS	88 h	4 LP
	Lab course “Computerchemie” (WP)	5 SWS	7 h	2 LP

8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* Kolloquium zum Praktikum Computerchemie *8.3 Module examination* Written exam (120 min) or oral examination (30 min)
12.	Auxiliary Information Course language: German Further details can be found in the german version of the module handbook

3.6.2 Computer Science

Remarks:

The introductory courses „Einführung in die Programmierung“, „Einführung in die Softwareentwicklung“, as well as „Technische Informatik“ cannot be chosen as part of these modules.

Courses belonging to the theoretical foundation („Theoretische Grundlagen der Informatik I + II“, „Datenstrukturen u. effiziente Algorithmen“) as well as the ones belonging to the focus subjects can be chosen.

The following courses are regularly offered: Computergrafik (Computergrafik Teil I + II, Echtzeitbildverarbeitung, 3D Computer Vision) Informationssysteme (Datenbanken Teil I + II) Datenanalyse (Datenwarehouse + Data-Mining) Modellbildung + Simulation Clientseitige Webanwendungen + Serverseitige Webanwendungen Datenstrukturen u. effiziente Algorithmen Betriebssysteme + verteilte Systeme Kommunikationsnetze Software-Technik.

Computer Science I					
ID number (JOGU-StINe) M.08.079.xx1		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Course A (WP)		2 SWS/21 h	69 h	3 LP
	Excercises to Course A (WP)		1 SWS/10,5 h	79.5 h	3 LP
	Lab course A (WP)		2 SWS/21 h	69 h	3 LP
8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* succesfull completion of the lab course *8.3 Module examination* Written exam (120 min) or oral examination (30 min)				
12.	Auxiliary Information Course language: German Further details can be found in the module handbooks of the Computer Science programs.				

Computer Science II					
ID number (JOGU-StINe) M.08.079.xx2		Workload (workload) 360 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 12 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Course A (WP)		2 SWS/21 h	69 h	3 LP
	Excercises to Course A (WP)		1 SWS/10,5 h	79.5 h	3 LP
	Course B (WP)		2 SWS/21 h	69 h	3 LP
	Excercises to Course B (WP)		1 SWS/10,5 h	79.5 h	3 LP
8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* Written exam (120 min) or oral examination (30 min) for each of the two courses *8.3 Module examination* Average of the two course achievements				

Computer Science II					
ID number (JOGU-StINe) M.08.079.xx2		Workload (workload) 360 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 12 LP
12.	Auxiliary Information Course language: German Further details can be found in the module handbooks of the Computer Science programs.				

Computer Science III					
ID number (JOGU-StINe) M.08.079.xx3		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Course A (WP) Excercises to Course A (WP) Course B (WP) Excercises to Course B (WP) Lab course A or B (WP)		Contact time 2 SWS/21 h 1 SWS/10,5 h 2 SWS/21 h 1 SWS/10,5 h 2 SWS/21 h	Self-study 69 h 79.5 h 69 h 79.5 h 69 h	Credit Points 3 LP 3 LP 3 LP 3 LP 3 LP
8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* Written exam (120 min) or oral examination (30 min) for each of the two courses Succesfull completion of the lab course *8.3 Module examination* Average of the course achievements				
12.	Auxiliary Information Course language: German Further details can be found in the module handbooks of the Computer Science programs.				

Computer Science IV					
ID number (JOGU-StINe) M.08.079.xx4		Workload (workload) 480 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 16 LP
1.	Courses/Teaching methods Course A (WP) Excercises to Course A (WP) Course B (WP) Excercises to Course B (WP) Lab course A or B (WP)		Contact time 2 SWS/21 h 1 SWS/10,5 h 2 SWS/21 h 1 SWS/10,5 h 2 SWS/21 h	Self-study 69 h 79.5 h 69 h 79.5 h 99 h	Credit Points 3 LP 3 LP 3 LP 3 LP 4 LP
8.	Mode and duration of examinations *8.1 Active participation* successful completion of the exercises *8.2 Course achievements* Written exam (120 min) or oral examination (30 min) for each of the two courses Seminar presentation *8.3 Module examination* Average of the course achievements				

Computer Science IV				
ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.079.xx4	480 h	1	1	16 LP

12.	Auxiliary Information Course language: German Further details can be found in the module handbooks of the Computer Science programs.

3.6.3 Economics

Within the subsidiary subject Economics one out of the following three branches can be selected: „International Economics & Public Policy“, „Finance & Accounting“ and „Marketing, Management & Operations“. In each branch two modules must be succesfully completed.

- Branch 1: „International Economics & Public Policy“
  - International Trade
  - Mikroökonomie II
  - Öffentliche Finanzen
  - Wirtschaftspolitik
  - Intertemporale Optimierung
  - Mikroökonometrie
  - Exchange Rates
  - Makroökonomie II
  - Zeitreihenanalyse
- Branch 2: „Finance & Accounting“
  - Rechnungslegung
  - Steuern
  - Finanzen
  - Controlling
  - Banken
  - Zeitreihenanalyse
- Branch 3: „Marketing, Management & Operations“
  - Organisation
  - Wirtschaftsinformatik
  - Marketing
  - Logistikmanagement

International Trade

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4140	180 h	1	1	6 LP

1.	Courses/Teaching methods	Contact time	Self-study	Credit Points
	a) Lecture: International Trade: Theory and Policy	2 SWS/21 h	99 h	4 LP
	b) Exercises: International Trade: Theory and Policy	1 SWS/10,5 h	49,5 h	2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)			
12.	Auxiliary Information Language: English Further details can be found in the german version of the module handbook			

Mikroökonomie II

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4105	180 h	1	1	6 LP

1.	Courses/Teaching methods	Contact time	Self-study	Credit Points
	a) Lecture: Mikroökonomie II	2 SWS/21 h	99 h	4 LP
	b) Exercises: Mikroökonomie II	1 SWS/10,5 h	49,5 h	2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)			
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook			

Öffentliche Finanzen

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4115	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Öffentliche FInanzen	2 SWS/21 h	99 h	4 LP
	b) Exercises: Öffentliche FInanzen	1 SWS/10,5 h	49,5 h	2 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Written exam (120 min)

12. Auxiliary Information

Language: German

Further details can be found in the german version of the module handbook

Wirtschaftspolitik

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4120	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Wirtschaftspolitik	2 SWS/21 h	99 h	4 LP
	b) Exercises: Wirtschaftspolitik	1 SWS/10,5 h	49,5 h	2 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Written exam (120 min)

12. Auxiliary Information

Language: German

Further details can be found in the german version of the module handbook

Intertemporale Optimierung

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4145	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Intertemporale Optimierung b) Exercises: Intertemporale Optimierung	2 SWS/21 h 1 SWS/10,5 h	99 h 49,5 h	4 LP 2 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Written exam (120 min)

12. Auxiliary Information

Language: German

Further details can be found in the german version of the module handbook

Micro Econometrics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4405	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Micro Econometrics b) Exercises: Micro Econometrics	2 SWS/21 h 1 SWS/10,5 h	99 h 49,5 h	4 LP 2 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Written exam (120 min)

12. Auxiliary Information

Language: English

Further details can be found in the german version of the module handbook

Exchange Rates and International Capital Markets					
ID number (JOGU-StINe) M.03.184.4125		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods a) Lecture: Exchange Rates and International Capital Markets b) Exercises: Exchange Rates and International Capital Markets		Contact time 2 SWS/21 h 1 SWS/10,5 h	Self-study 99 h 49,5 h	Credit Points 4 LP 2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)				
12.	Auxiliary Information Language: English Further details can be found in the german version of the module handbook				

Makroökonomie II					
ID number (JOGU-StINe) M.03.184.4110		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods a) Lecture: Makroökonomie II b) Exercises: Makroökonomie II		Contact time 2 SWS/21 h 1 SWS/10,5 h	Self-study 99 h 49,5 h	Credit Points 4 LP 2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)				
12.	Auxiliary Information Language: English Further details can be found in the german version of the module handbook				

Zeitreihenanalyse

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4410	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Zeitreihenanalyse	2 SWS/21 h	99 h	4 LP
	b) Exercises: Zeitreihenanalyse	1 SWS/10,5 h	49,5 h	2 LP

8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

Rechnungslegung nach HGB

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4205	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Rechnungslegung nach HGB	2 SWS/21 h	99 h	4 LP
	b) Exercises: Rechnungslegung nach HGB	1 SWS/10,5 h	49,5 h	2 LP

8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

Steuern					
ID number (JOGU-StINe) M.03.184.4210		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods a) Lecture: Steuern b) Exercises: Steuern		Contact time 2 SWS/21 h 1 SWS/10,5 h	Self-study 99 h 49,5 h	Credit Points 4 LP 2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Finanzierung					
ID number (JOGU-StINe) M.03.184.4220		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods a) Lecture: Finanzierung b) Exercises: Finanzierung		Contact time 2 SWS/21 h 1 SWS/10,5 h	Self-study 99 h 49,5 h	Credit Points 4 LP 2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Controlling

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4215	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Controlling	2 SWS/21 h	99 h	4 LP
	b) Exercises: Controlling	1 SWS/10,5 h	49,5 h	2 LP

8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

Banken

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4225	180 h	1	1	6 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	a) Lecture: Banken	2 SWS/21 h	99 h	4 LP
	b) Exercises: Banken	1 SWS/10,5 h	49,5 h	2 LP

8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

Banken

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4310	180 h	1	1	6 LP
1. Courses/Teaching methods		Contact time	Self-study	Credit Points
a) Lecture: Organisation		2 SWS/21 h	99 h	4 LP
b) Exercises: Organisation		1 SWS/10,5 h	49,5 h	2 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Written exam (120 min)

12. Auxiliary Information

Language: German

Further details can be found in the german version of the module handbook

Wirtschaftsinformatik

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.03.184.4320	180 h	1	1	6 LP
1. Courses/Teaching methods		Contact time	Self-study	Credit Points
a) Lecture: Wirtschaftsinformatik		2 SWS/21 h	99 h	4 LP
b) Exercises: Wirtschaftsinformatik		1 SWS/10,5 h	49,5 h	2 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Written exam (120 min)

12. Auxiliary Information

Language: German

Further details can be found in the german version of the module handbook

Marketing					
ID number (JOGU-StINe) M.03.184.4305		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods a) Lecture: Marketing b) Exercises: Marketing		Contact time 2 SWS/21 h 1 SWS/10,5 h	Self-study 99 h 49,5 h	Credit Points 4 LP 2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Logistikmanagement					
ID number (JOGU-StINe) M.03.184.4315		Workload (workload) 180 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 6 LP
1.	Courses/Teaching methods a) Lecture: Logistikmanagement b) Exercises: Logistikmanagement		Contact time 2 SWS/21 h 1 SWS/10,5 h	Self-study 99 h 49,5 h	Credit Points 4 LP 2 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

3.6.4 History of Natural Sciences

History of Natural Science I					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.275.060		450 h	2	1	15 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	a) Vorlesung: Geschichte der Naturwissenschaft I (P)		2 SWS/21 h	69 h	3 LP
	b) Seminar: Einführung in das wissenschaftshistorische Arbeiten (P)		2 SWS/21 h	69 h	3 LP
	c) Vorlesung: Geschichte der Naturwissenschaft II (P)		2 SWS/21 h	69 h	3 LP
	d) Lektürekurs (P)		2 SWS/21 h	69 h	3 LP
	e) Übungen (P)		2 SWS/21 h	69 h	3 LP
8.	Mode and duration of examinations *8.1 Active participation* Participation in all seminars *8.2 Course achievements* d) Presentation e) Essays and/or Exercises *8.3 Module examination* Oral examination (20-30 Min)				
12.	Auxiliary Information Course language: German (maybe English) Further details can be found in the german version of the module handbook				

History of Natural Science II					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.275.070		270 h	2	1	9 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	a) Vorlesung: Geschichte der Naturwissenschaft I (P)		2 SWS/21 h	129 h	5 LP
	b) Lektürekurs (P)		2 SWS/21 h	99 h	4 LP
8.	Mode and duration of examinations *8.1 Active participation* Participation in all seminars *8.2 Course achievements* a) Presentation and written term paper b) Presentation and report *8.3 Module examination* Oral examination (20-30 Min)				
12.	Auxiliary Information Course language: German (maybe English) Further details can be found in the german version of the module handbook				

3.6.5 Mathematics

Functional Analysis					
ID number (JOGU-StINe) M.08.105.1300		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises “Funktionalanalysis I” Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Functional Analysis (with Functional Analysis II)					
ID number (JOGU-StINe) M.08.105.1310		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Lecture with excercises “Functional Analysis I” Lecture (WP) Excercises (WP) Lecture “Funktionalanalysis II”		Contact time 4 SWS/42 h 2 SWS/21 h 4 SWS/42 h	Self-study 207 h 138 h	Credit Points 9 LP 6 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Partial differential equations					
ID number (JOGU-StINe) M.08.105.1320		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises "Partial differential equations I" Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Partial differential equations (with partial differential equations II)					
ID number (JOGU-StINe) M.08.105.1330		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Lecture with excercises "Partial differential equations I" Lecture (WP) Excercises (WP) Lecture "Partial differential equations II"		Contact time 4 SWS/42 h 2 SWS/21 h 4 SWS/42 h	Self-study 207 h 138 h	Credit Points 9 LP 6 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Fundamentals in Stochastics					
ID number (JOGU-StINe) M.08.105.1340		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises "Introduction to Stochastics" Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Fundamentals in Stochastics					
ID number (JOGU-StINe) M.08.105.1350		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Lecture with excercises "Introduction to Stochastics" Lecture (WP) Excercises (WP) Lecture "Stochastics I"		Contact time 4 SWS/42 h 2 SWS/21 h 4 SWS/42 h	Self-study 207 h 138 h	Credit Points 9 LP 6 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Stochastics I

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.1360	270 h	1	1	9 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Stochastics I”		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		

8. Mode and duration of examinations

8.1 Active participation

Successful completion of the exercises and oral presentation of own solutions.

8.2 Course achievements

8.3 Module examination

Oral examination (20-30 min) or written exam (120 min)

12. Auxiliary Information

Language: German
Further details can be found in the german version of the module handbook

Stochastics I (with Stochastics II)

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.1370	450 h	2	1	15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Stochastics I”		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		
	Lecture “Stochastics II”	4 SWS/42 h	138 h	6 LP

8. Mode and duration of examinations

8.1 Active participation

Successful completion of the exercises and oral presentation of own solutions.

8.2 Course achievements

8.3 Module examination

Oral examination (20-30 min) or written exam (120 min)

12. Auxiliary Information

Language: German
Further details can be found in the german version of the module handbook

Stochastics 2

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.580	450 h	2	1	15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture “Stochastics II”	4 SWS/42 h	120 h	6 LP
	Lecture “Stochastics III”	4 SWS/42 h	120 h	6 LP
	Oral exam		90 h	3 LP

Stochastics 2				
ID number (JOGU-StINe) M.08.105.580	Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP

8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

Basic Numerics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.1380	270 h	1	1	9 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Basic Numerics”		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		

8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

Basic Numerics

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.1390	450 h	1	1	15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Grundlagen der Numerik”		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		
	Lecture “Numerik gewöhnlicher Differentialgleichungen”	4 SWS/42 h	138 h	6 LP

8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

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(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
9 LP</td></tr>
<tr><td>1.</td><td>Courses/Teaching methods
Lecture with excercises “Numerics of ordinary differential equations”
Lecture (WP)
Excercises (WP)</td><td>Contact time

4 SWS/42 h
2 SWS/21 h</td><td>Self-study
207 h</td><td>Credit Points
9 LP</td></tr>
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8.1 Active participation
Successful completion of the exercises and oral presentation of own solutions.
8.2 Course achievements

8.3 Module examination
Oral examination (20-30 min) or written exam (120 min)</td></tr>
<tr><td>12.</td><td colspan="4">Auxiliary Information
Language: German
Further details can be found in the german version of the module handbook</td></tr>
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(laut Studienverlaufsplan)
1</td><td>Designated term
(laut Studienverlaufsplan)
1</td><td>Credit Points
(LP)
15 LP</td></tr>
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Lecture (WP)
Excercises (WP)
Lecture “Numerics of partial differential equations”</td><td>Contact time

4 SWS/42 h
2 SWS/21 h
4 SWS/42 h</td><td>Self-study
207 h

138 h</td><td>Credit Points
9 LP

6 LP</td></tr>
<tr><td>8.</td><td colspan="4">Mode and duration of examinations
8.1 Active participation
Successful completion of the exercises and oral presentation of own solutions.
8.2 Course achievements

8.3 Module examination
Oral examination (20-30 min) or written exam (120 min)</td></tr>
<tr><td>12.</td><td colspan="4">Auxiliary Information
Language: German
Further details can be found in the german version of the module handbook</td></tr>
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Algebra					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.1420		270 h	1	1	9 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture with excercises “Computeralgebra”			207 h	9 LP
	Lecture (WP)		4 SWS/42 h		
	Excercises (WP)		2 SWS/21 h		
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Algebra					
ID number (JOGU-StINe)		Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.1430		450 h	1	1	15 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture with excercises “Computeralgebra”			207 h	9 LP
	Lecture (WP)		4 SWS/42 h		
	Excercises (WP)		2 SWS/21 h		
	Lecture “Körper, Ringe, Moduln”		4 SWS/42 h	138 h	6 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Topology					
ID number (JOGU-StINe) M.08.105.1440		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises “Topology” Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Topology (with lecture “Algebraic curves and Riemannian surfaces”)					
ID number (JOGU-StINe) M.08.105.1450		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Lecture with excercises “Topology” Lecture (WP) Excercises (WP) Lecture “Algebraic curves and Riemannian surfaces”		Contact time 4 SWS/42 h 2 SWS/21 h 4 SWS/42 h	Self-study 207 h 138 h	Credit Points 9 LP 6 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Computer algebra					
ID number (JOGU-StINe) M.08.105.1460		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises "Computer algebra" Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Computer algebra (with Number Theory)					
ID number (JOGU-StINe) M.08.105.1470		Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP
1.	Courses/Teaching methods Lecture with excercises "Computer algebra" Lecture (WP) Excercises (WP) Lecture "Number Theory"		Contact time 4 SWS/42 h 2 SWS/21 h 4 SWS/42 h	Self-study 207 h 138 h	Credit Points 9 LP 6 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Differential Geometry and Manifolds					
ID number (JOGU-StINe) M.08.105.10050		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises “Differential Geometry and Manifolds” Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Function Theory					
ID number (JOGU-StINe) M.08.105.10040		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods Lecture with excercises “Function Theory” Lecture (WP) Excercises (WP)		Contact time 4 SWS/42 h 2 SWS/21 h	Self-study 207 h	Credit Points 9 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Number Theory

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.140	270 h	1	1	9 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises "Number Theory" Lecture (WP) Excercises (WP)	 4 SWS/42 h 2 SWS/21 h	207 h	9 LP

8. Mode and duration of examinations

8.1 Active participation

Successful completion of the exercises and oral presentation of own solutions.

8.2 Course achievements

8.3 Module examination

Oral examination (20-30 min) or written exam (120 min)

12. Auxiliary Information

Language: German

Further details can be found in the german version of the module handbook

Vertiefungsmodul Analysis

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.650	450 h	2	1	15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture "Vertiefungsmodul Analysis I" Lecture "Vertiefungsmodul Analysis II" Module examination	4 SWS/42 h 4 SWS/42 h	138 h 138 h 90 h	6 LP 6 LP

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Oral examination (20-30 min)

12. Auxiliary Information

Language: German

Further details can be found in the module handbooks of the Mathematics programs

Functional Analysis

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.560	450 h	2	1	15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture “Functional Analysis II”	4 SWS/42 h	138 h	6 LP
	Lecture “Funktionalanalysis III”	4 SWS/42 h	138 h	6 LP
	Module examination		90 h	

8. Mode and duration of examinations

8.1 Active participation

Successful completion of the exercises and oral presentation of own solutions.

8.2 Course achievements

8.3 Module examination

Oral examination (20-30 min)

12. Auxiliary Information

Language: German
Further details can be found in the german version of the module handbook

Vertiefungsmodul Eichtheorie

ID number (JOGU-StINe)	Workload (workload)	Course Duration (laut Studienverlaufsplan)	Designated term (laut Studienverlaufsplan)	Credit Points (LP)
M.08.105.625	450 h	2	1	15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture “Eichtheorie I”	4 SWS/42 h	138 h	6 LP
	Lecture “Eichtheorie II”	4 SWS/42 h	138 h	6 LP
	Module examination		90 h	

8. Mode and duration of examinations

8.1 Active participation

8.2 Course achievements

8.3 Module examination

Oral examination (20-30 min)

12. Auxiliary Information

Language: German
Further details can be found in the module handbooks of the Mathematics programs

Basic Numerics				
ID number (JOGU-StINe) M.08.105.070	Workload (workload) 360 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 12 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture with excercises “Basic Numerics”		207 h	9 LP
	Lecture (WP)	4 SWS/42 h		
	Excercises (WP)	2 SWS/21 h		
		2 SWS/21 h	69 h	3 LP
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min) or written exam (120 min)			
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook			

Complex Differential Geometry				
ID number (JOGU-StINe) M.08.105.540	Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture “Complex Differential Geometry I”	4 SWS/42 h	138 h	6 LP
	Lecture “Complex Differential Geometry II”	4 SWS/42 h	138 h	6 LP
	Module examination		90 h	
8.	Mode and duration of examinations *8.1 Active participation* Successful completion of the exercises and oral presentation of own solutions. *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min)			
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook			

Algebraic Geometry				
ID number (JOGU-StINe) M.08.105.500	Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP

	Courses/Teaching methods	Contact time	Self-study	Credit Points
1.	Lecture “Algebraic Geometry I”	4 SWS/42 h	120 h	6 LP
	Lecture “Algebraic Geometry II”	4 SWS/42 h	120 h	6 LP
	Oral exam		90 h	3 LP

Algebraic Geometry				
ID number (JOGU-StINe) M.08.105.500	Workload (workload) 450 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 15 LP

8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 min)
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook

3.6.6 Meteorology

Atmospheric Chemistry and Trace Gas Dynamics					
ID number (JOGU-StINe) M.08.110.550		Workload (workload) 300 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 10 LP
1.	Courses/Teaching methods		Contact time	Self-study	Credit Points
	Lecture with excercises "Atmospheric Chemistry"			157.5 h	7 LP
	Lecture		3 SWS/31.5 h		
	Excercises		2 SWS/21 h		
	Lecture "Trace Gas Dynamics"		2 SWS/21 h	69 h	3 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Written exam (90 Min.) or oral examination (30 Min.). The successful completion of the exercises is a prerequisite for the examination.				
12.	Auxiliary Information Course language: German or English Further details can be found in the german version of the module handbook				

Atmospheric Modelling					
ID number (JOGU-StINe) M.08.110.520		Workload (workload) 420 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 14 LP
1.	Courses/Teaching methods	Contact time		Self-study	Credit Points
	a) Lecture with excercises "Modelling" (WP)			157.5 h	7 LP
	Lecture (WP)	3 SWS/31.5 h			
	Excercises (WP)	2 SWS/21 h			
	b) Lecture with excercises "Application of Models" (WP)			157.5 h	7 LP
	Lecture (WP)	3 SWS/31.5 h			
	Excercises (WP)	2 SWS/21 h			
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 Min.) or oral examination (30 Min.)				
12.	Auxiliary Information Course language: German or English Further details can be found in the german version of the module handbook				

Atmospheric Radiation					
ID number (JOGU-StINe) M.08.110.530		Workload (workload) 270 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 9 LP
1.	Courses/Teaching methods	Contact time		Self-study	Credit Points
	a) Lecture with excercises "Theory of Radiation" (WP)			138 h	6 LP
	Lecture (WP)	2 SWS/21 h			
	Excercises (WP)	2 SWS/21 h			
	b) Lecture "Applied Radiation" (WP)	2 SWS/21 h		69 h	3 LP
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 Min.) or oral examination (30 Min.)				
12.	Auxiliary Information Course language: German or English Further details can be found in the german version of the module handbook				

Large-scale Atmospheric Dynamics					
ID number (JOGU-StINe) M.08.110.1060		Workload (workload) 330 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 11 LP
1.	Courses/Teaching methods Lecture with excercises and lab course "Large-scale Atmospheric Dynamics" (WP) Lecture (WP) Excercises (WP) Lab course (WP)		Contact time 4 SWS/42 h 2 SWS/10.5 h 1 SWS/10.5 h	Self-study 256.5 h	Credit Points 11 LP
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 Min.) or oral examination (30 Min.)				
12.	Auxiliary Information Course language: German or English Further details can be found in the german version of the module handbook				

ID number (JOGU-StINe) M.08.110.20031		Workload (workload) 300 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 4	Credit Points (LP) 10 LP
1.	Courses/Teaching methods Lecture with excercises "Fundamentals of Atmospheric Hydrodynamics" Lecture Excercises		Contact time 4 SWS/42 h 3 SWS/31,5 h	Self-study 226,5 h	Credit Points 10 LP
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 Min.) or oral examination (30 Min.				
12.	Auxiliary Information Course language: German or English Further details can be found in the german version of the module handbook				

3.6.7 Philosophy

Basismodul (historisch) - Philosophie der Neuzeit					
ID number (JOGU-StINe) M.05.127.061		Workload (workload) 150 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 5 LP
1.	Courses/Teaching methods a) Oberseminar: Philosophie der Neuzeit Modul examination		Contact time 2 SWS/21 h	Self-study 99 h 30 h	Credit Points 4 LP 1 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Seminar paper (8-10 pages) or Presentation (+ written report of 5 pages) or written exam (90 Min.) or oral exam (20 Min.) in a)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Aufbaumodul (historisch) - Philosophie der Neuzeit					
ID number (JOGU-StINe) M.05.127.063		Workload (workload) 150 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 2	Credit Points (LP) 5 LP
1.	Courses/Teaching methods a) Oberseminar: Philosophie der Neuzeit Modul examination		Contact time 2 SWS/21 h	Self-study 99 h 30 h	Credit Points 4 LP 1 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Seminar paper (8-10 pages) or Presentation (+ written report of 5 pages) or written exam (90 Min.) or oral exam (20 Min.) in a)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

Vertiefungsmodul (historisch) - Philosophie der Neuzeit					
ID number (JOGU-StINe) M.05.127.065		Workload (workload) 150 h	Course Duration (laut Studienverlaufsplan) 1	Designated term (laut Studienverlaufsplan) 3	Credit Points (LP) 5 LP
1.	Courses/Teaching methods a) Oberseminar: Philosophie der Neuzeit Modul examination		Contact time 2 SWS/21 h	Self-study 99 h 30 h	Credit Points 4 LP 1 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Seminar paper (8-10 pages) or Presentation (+ written report of 5 pages) or written exam (90 Min.) or oral exam (20 Min.) in a)				
12.	Auxiliary Information Language: German Further details can be found in the german version of the module handbook				

3.7 interdisciplinary Courses

History of Natural Science I					
ID number (JOGU-StINe) 08.275.130		Workload (workload) 90 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 3 LP
1.	Courses/Teaching methods Lecture: Geschichte der Naturwissenschaft I		Contact time 2 SWS/21 h	Self-study 69 h	Credit Points 3 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 Min)				
12.	Auxiliary Information Course language: German (maybe English) Further details can be found in the german version of the module handbook				

History of Natural Science II					
ID number (JOGU-StINe) 08.275.140		Workload (workload) 90 h	Course Duration (laut Studienverlaufsplan) 2	Designated term (laut Studienverlaufsplan) 1	Credit Points (LP) 3 LP
1.	Courses/Teaching methods Lecture: Geschichte der Naturwissenschaft II		Contact time 2 SWS/21 h	Self-study 69 h	Credit Points 3 LP
8.	Mode and duration of examinations *8.1 Active participation* *8.2 Course achievements* *8.3 Module examination* Oral examination (20-30 Min)				
12.	Auxiliary Information Course language: German (maybe English) Further details can be found in the german version of the module handbook				