# **Modules and Courses**

# Master of Science in Physics

1. Juni 2022

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# 1 List of Modules and Courses

# 1.1 Overview of the Modules

Module	SWS	CP
required mod	lules	
Experimental Physics	$3 \mathrm{V} + 1 \mathrm{\ddot{U}}$	6
Theoretical Physics	$4 \mathrm{V} + 2 \mathrm{\ddot{U}}$	9
Seminars	4 S	8
Advanced laboratory course	8 P	10
sum		33
Research Ph	ase	
Specialization	$\mathbf{F}$	15
Methodological Knowledge	$\mathbf{F}$	15
Master thesis	$\mathbf{F}$	30
sum		60
Compulsory Election	ve Modules	
Topical Courses	3  V + 1  Ü	6
Advanced Theoretical Physics	$4 \mathrm{V} + 2 \mathrm{\ddot{U}}$	9
to choose		12-27
Elective Mod	lules	
Focus Courses	2	3
Research Module	$4 \mathrm{V}$	6
Subsidiary Subject (cf. chapter 1	.3)	9-15
to choose	,	0-15
Total		120

# 1.2 List of Topical Courses

Here is a list of topical courses that are offered regularly. You will find the actual list for each semester in Jogustine.

- 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
  - Theory of Soft Matter II
- Quantum, Atomic and Neutron Physics
  - Quantum Optics (Q-Ex-1)
  - Photonics (Q-Ex-2)
  - Quantum Information (Q-Ex-3)
  - Precision Fundamental Physics (Q-Ex-4)
- Nuclear and Particle Physics
  - Statistics, Data Analysis and Simulation
  - Particle Detectors
  - Accelerator Physics
  - Particle Physics
  - Astroparticle Physics
  - Cosmology and General Relativity
  - Symmetries in Physics
  - Modern Methods in Theoretical High Energy, Particle and Nuclear Physics
  - Theoretical Particle Physics
  - 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
- Advanced Particle Physics
- Advanced Chapters on Subatomic Physics
- Advanced Astroparticle- and Astrophysics
- Advanced Accelerator Physics

# **1.3 Subsidiary Subjects**

Subsidiary Subject	SWS	CP
Chemistry		
Nuclear Chemistry	$2 V + 1 \ddot{U} + 5 P$	9
Nuclear Chemistry (with 1 additional advanced lecture)	$4 \text{ V} + 1 \ddot{\text{U}} + 5 \text{ P}$	12
Nuclear Chemistry (with 2 additional advanced lectures)	$6 \text{ V} + 1 \ddot{\text{U}} + 5 \text{ P}$	$12 \\ 15$
Introduction in Theoretical Chemistry	$4 \text{ V} + 1 \ddot{\text{U}} + 5 \text{ P}$	9
Theoretical Chemistry	$4 V + 2 \ddot{U} + 10P$	12
•	1 1 1 2 0 1 101	
Computer Science		-
Computer Science I	$2 \text{ V} + 2 \ddot{\text{U}} + 2 \text{ P}$	9
Computer Science II	$4 \text{ V} + 4 \ddot{\text{U}}$	12
Computer Science III	$4 \text{ V} + 4 \ddot{\text{U}} + 2 \text{ P}$	15
Computer Science IV	$4 \mathrm{V} + 4 \mathrm{\ddot{U}} + 2 \mathrm{S}$	16
Economics		
International Economics & Public Policy	$6 \text{ V} + \ddot{\text{U}}$	12
Finance & Accounting	$6 \text{ V} + \ddot{\text{U}}$	12
Marketing, Management & Operations	$6 \text{ V} + \ddot{\text{U}}$	12
History of Natural Science		
History of Natural Science I	$4 \text{ V} + 4 \text{ S} + 2 \ddot{\text{U}}$	15
History of Natural Science II	2  HS + 2  S	9
·		0
Mathematics		0
Functional Analysis	$4 \text{ V} + 2 \ddot{\text{U}}$	9
Functional Analysis (with Functional Analysis II)	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Partial differential equations	$4 \text{ V} + 2 \ddot{\text{U}}$	9
Partial differential equations (with partial differential equations II)	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Fundamentals in stochastics	$4 \text{ V} + 2 \ddot{\text{U}}$	9
Fundamentals in stochastics (with stochastics I)	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Stochastics I	$4 \text{ V} + 2 \ddot{\text{U}}$	9
Stochastics I (with stochastics II)	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Stochastics 2	8 V	15
Basic numerics	4  V + 2  U	9
Basic numerics (with numerical methods of ordinary differential equa-	$8 \text{ V} + 2 \ddot{\text{U}}$	15
tions)		0
Numerics of differential equations	$4 \text{ V} + 2 \ddot{\text{U}}$	9 15
Numerics of differential equations (with partial differential equations)	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Algebra	$4 \text{ V} + 2 \ddot{\text{U}}$	9 15
Algebra (with "Fields, Rings, Modules")	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Topology	$4 V + 2 \ddot{U} 8 V + 2 \ddot{U}$	9 15
Topology (with "Algebraic curves and Riemannian surfaces")	8 V + 2 U 4 V + 2 Ü	15
Computer algebra	4 V + 2 U 8 V + 2 Ü	9 15
Computer algebra (with Number Theory) Differential Commetty and Manifolds		15
Differential Geometry and Manifolds	$4 V + 2 \ddot{U} 4 V + 2 \ddot{U}$	9 0
Function Theory		9
Number Theory	4 V + 2 Ü 8 V + 2 Ü	9 15
Functional Analysis Basics of Numerical Mathematics (with laboratory)	8 V + 2 U 4 V + 2 Ü + 2 P	$15 \\ 15$
Basics of Numerical Mathematics (with laboratory)	4 v + 2 U + 2 P	15

Subsidiary Subject	SWS	CP
Complex Differential Geometry	$8 \text{ V} + 2 \ddot{\text{U}}$	15
Algebraic Geometry	8 V	15
In-depth module Analysis	$8 \mathrm{V} + 2 \mathrm{\ddot{U}}$	15
In-depth module Gauge Theory	8  V + 2  Ü	15
Meteorology		
Clouds and Aerosols		15
Dynamics of Weather and Climate		15
Modelling		14
Composition of the Atmosphere		13
Philosophy		
Modern Philosophy	6 S	15
Interdisciplinary Courses		
History of Natural Science I	3 V	3
History of Natural Science II	3 V	3

### 1.3.1 Further Subsidiary Subjects

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. If you choose a subsidiary subject then you have to obtain at least 9 credit points in this subject. 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. 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 topical course has to be taken.
- 6. Equivalent courses taken at other universities may be recognised with the credit points awarded for the corresponding course in Mainz. Moderate additional requirements may be imposed.
- 7. 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.

## 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 Important Remarks

### 2.2.1 Introductory remarks

- If you have questions, you should first contact the student advisor ("Studienfachberater") 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. The grade of Focus Courses do not enter the overall grade of the MSc.
- 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: <a href="https://www.info.jogustine.uni-mainz.de/anmeldephasen/pruefungsanmeldephasen/">https://www.info.jogustine.uni-mainz.de/anmeldephasen/pruefungsanmeldephasen/</a>. 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

 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.

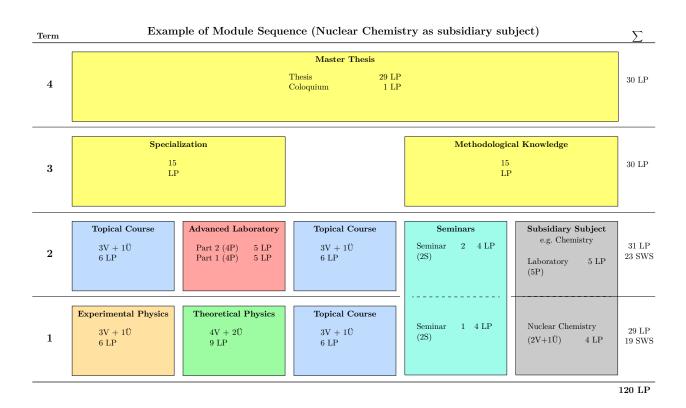
### 2 Important Remarks

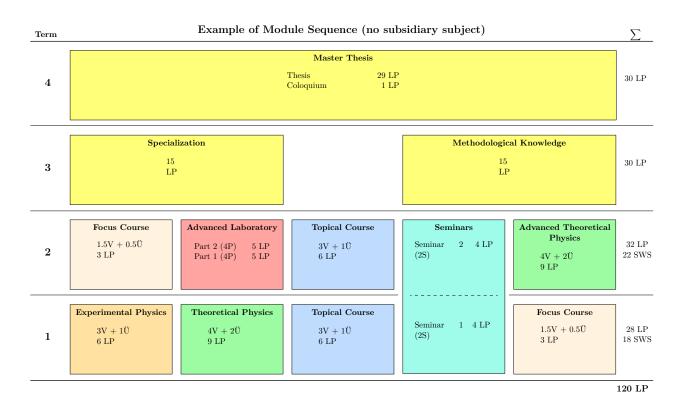
- 2. Students are allowed to enrol into the research phase if at most one of the required courses to reach the 60 CP is missing (e.g. a Topical Course, a Focus Course or one of the two seminars). The start of the master thesis is 6 month after the start of the research phase. At this point in time, at 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<sup>1</sup>. 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.

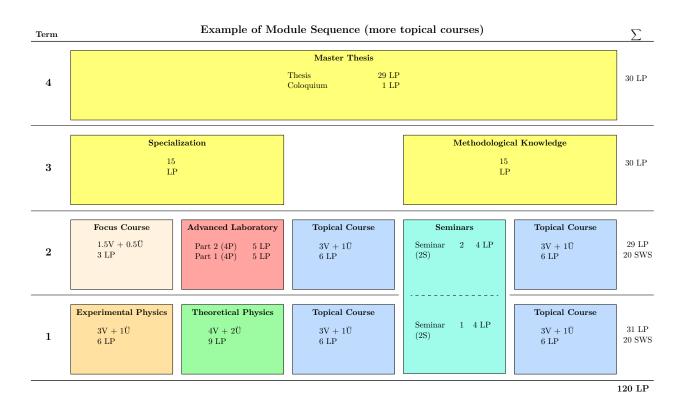
<sup>&</sup>lt;sup>1</sup>https://www.blogs.uni-mainz.de/fb08-studium/files/2017/08/PHY\_MSc\_Anmeldeformular\_2-seitig.pdf

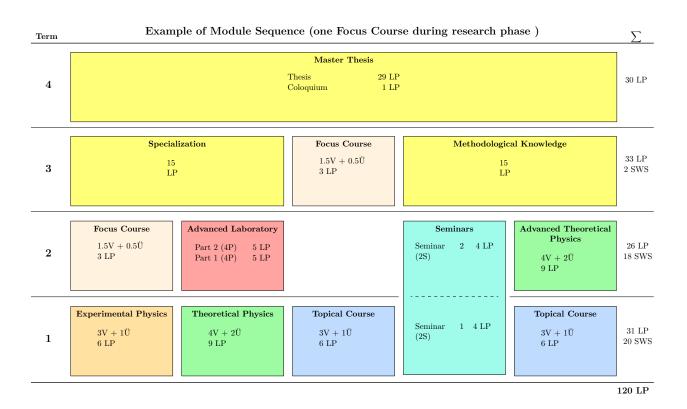
## 2.5 Examples for Module Sequence

The following tables show examples for the module sequence for students starting in the winter or in the summer term:









# 3.1 Experimental Physics

	Atomic and Quantum Physics         08.128.05			128.050		
Compulsory or elective module	WP					
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Atomic and Quantum Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3  SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving ad	chievements mus	t be made:			
Presence						
Active participation	accor	ding to §5 subsection	ion 3			
Course achievements	succe	essful completion of	exercises or	projects		
Module examination	Writt	ten exam (120-180	Min.) or oral	examinatio	n (30 Mi	n.)
Qualification and program goals /	Comp	etences				
<ul><li>understand the structure of atoms and</li><li>apply quantum mechanical approached</li></ul>	d simpl es to p	oractical examples	l as their inte and thus dee	epen their u	nderstan	ding, achieve
• understand the structure of atoms and	d simpl es to p	le molecules as well practical examples	l as their inte and thus dee	epen their u	nderstan	ding, achieve
<ul> <li>understand the structure of atoms and</li> <li>apply quantum mechanical approached insights into modern experimental tech systems by coherent radiation</li> <li>Course content</li> <li>Profound introduction to the experiment</li> </ul>	d simples to puniques tal qua ral qua rlink in lowing	le molecules as well practical examples s in atomic physics, antum physics of a n this field is detai set of topics:	and thus dee spectroscopy toms and mo led and can h	epen their u and the ma	nderstan nipulatio their inte l by the o	ding, achieve n of quantum eraction with embedding of
<ul> <li>understand the structure of atoms and</li> <li>apply quantum mechanical approached insights into modern experimental tech systems by coherent radiation</li> <li>Course content</li> <li>Profound introduction to the experiment light. The strong experiment-theory integuest lectures. The lectures cover the fol</li> <li>relativistic effects and Dirac equation f fields</li> </ul>	d simples to p aniques tal qua rlink in lowing for the l	le molecules as well practical examples s in atomic physics, antum physics of a n this field is detai set of topics: hydrogen atom, inf	and thus dee spectroscopy toms and mo led and can b luences of the	epen their u	nderstan nipulatio their inte l by the e leus, atom	ding, achieve n of quantum eraction with embedding o
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<ul> <li>understand the structure of atoms and</li> <li>apply quantum mechanical approached insights into modern experimental tech systems by coherent radiation</li> <li>Course content</li> <li>Profound introduction to the experiment light. The strong experiment-theory integuest lectures. The lectures cover the fol</li> <li>relativistic effects and Dirac equation ffields</li> <li>atoms in laser fields – light-atom inter</li> <li>many electron systems, fundamentals</li> <li>manipulation and trapping of neutral</li> <li>as well as Bose Einstein condensation</li> </ul>	d simples to p miques tal qua erlink in lowing for the l caction, of laser atoms,	le molecules as well practical examples s in atomic physics, antum physics of a n this field is detai set of topics: hydrogen atom, inf , coherent and spor r spectroscopy on a , molecules and ion	and thus dee spectroscopy toms and mo led and can h luences of the ntaneous scat atoms and mo s, Ramsey m	epen their u and the ma	nderstan nipulation their inte l by the e leus, atom	ding, achieve n of quantum eraction with embedding o ns in externa
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<ul> <li>understand the structure of atoms and</li> <li>apply quantum mechanical approached insights into modern experimental tech systems by coherent radiation</li> <li>Course content</li> <li>Profound introduction to the experiment light. The strong experiment-theory integuest lectures. The lectures cover the fol</li> <li>relativistic effects and Dirac equation f fields</li> <li>atoms in laser fields – light-atom inter</li> <li>many electron systems, fundamentals</li> <li>manipulation and trapping of neutral</li> <li>as well as Bose Einstein condensation</li> <li>Literature</li> <li>Physics of Atoms and Molecules, B.H.</li> <li>Atom- und Quantenphysik, H. Haken</li> </ul>	d simples to p miques tal qua erlink in lowing for the l caction, of laser atoms, . Brans & H.C	le molecules as well practical examples s in atomic physics, antum physics of a n this field is detai set of topics: hydrogen atom, inf , coherent and spor r spectroscopy on a , molecules and ion sden & C.J. Joacha 2. Wolf	as their interaction of the spectroscopy toms and model and can be and can be an and model and can be atoms and model atoms at	epen their u and the ma	nderstan nipulation their inte l by the e leus, atom	ding, achieve n of quantum eraction with embedding of ns in externa
<ul> <li>understand the structure of atoms and</li> <li>apply quantum mechanical approached insights into modern experimental tech systems by coherent radiation</li> <li>Course content</li> <li>Profound introduction to the experiment light. The strong experiment-theory integuest lectures. The lectures cover the fol</li> <li>relativistic effects and Dirac equation fields</li> <li>atoms in laser fields – light-atom inter</li> <li>many electron systems, fundamentals</li> <li>manipulation and trapping of neutral</li> <li>as well as Bose Einstein condensation</li> <li>Literature</li> <li>Physics of Atoms and Molecules, B.H.</li> <li>Atom- und Quantenphysik, H. Haken</li> <li>Experimental Physics 3: Atoms, Molecules</li> </ul>	d simples to p miques tal qua erlink in lowing for the l caction, of laser atoms, . Brans & H.C	le molecules as well practical examples s in atomic physics, antum physics of a n this field is detai set of topics: hydrogen atom, inf , coherent and spor r spectroscopy on a , molecules and ion sden & C.J. Joacha 2. Wolf	as their interaction in the spectroscopy toms and model and can be and can be an and model and can be atoms and model atoms at	epen their u and the ma	nderstan nipulation their inte l by the e leus, atom	ding, achieve n of quantum eraction with embedding of ns in externa
<ul> <li>understand the structure of atoms and</li> <li>apply quantum mechanical approached insights into modern experimental tech systems by coherent radiation</li> <li>Course content</li> <li>Profound introduction to the experiment light. The strong experiment-theory integuest lectures. The lectures cover the fol</li> <li>relativistic effects and Dirac equation fields</li> <li>atoms in laser fields – light-atom inter</li> <li>many electron systems, fundamentals</li> <li>manipulation and trapping of neutral</li> <li>as well as Bose Einstein condensation</li> <li>Literature</li> <li>Physics of Atoms and Molecules, B.H.</li> <li>Atom- und Quantenphysik, H. Haken</li> <li>Experimental Physics 3: Atoms, Molecules</li> </ul>	d simples to p miques tal qua erlink in lowing for the l caction, of laser atoms, . Brans & H.C	le molecules as well practical examples s in atomic physics, antum physics of a n this field is detai set of topics: hydrogen atom, inf , coherent and spor r spectroscopy on a , molecules and ion sden & C.J. Joacha 2. Wolf	as their interaction in the spectroscopy toms and model and can be and can be an and model and can be atoms and model atoms at	epen their u and the ma	nderstan nipulation their inte l by the e leus, atom	ding, achieve n of quantum eraction with embedding of ns in externa

Modul 050	Atomic and Quant	08.128.050		
Weighting of the achievement in th	e overall grade	6/120		
Module frequency		Winter semester		
Reasons for compulsory attendance	9			
Persons responsible for this module	e	Prof. Dr. F. Schmidt-Kaler, Prof. Dr. K. Wendt		
Applicable to the following program	BSc. Physics, MSc. Physics, MSc. Mathematics			
Miscellaneous		Course language: German quest	or English on re-	

### 3.1 Experimental Physics

Modul 055	Nuclear and Particle Physics         08.128.055					
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Kern- und Ele- mentarteilchenphysik" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:		1	
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements		essful completion of		projects		
Module examination		ten exam (120-180			n (30 Min.	)
Qualification and program goals /		``````````````````````````````````````	)		(	/
<ul> <li>a basic understanding of the physics compound systems (mesons, baryons effective interactions as well as</li> <li>an exemplary understanding of the im</li> </ul>	and r	nucleons) as well a	s an underst	anding of the	heir funda	mental and
• an exclupion y understanding of the mini- systems and perturbative calculations As a result of the course, students shou well as key experiments.	(Feyn:	man diagrams).				-
Course content						
<ul><li>The course covers the following subjects</li><li>properties, stability, structure, shape,</li></ul>		citations of nuclei	as well as the	e forces betw	veen nucleo	ons,
• elastic, inelastic and deep-inelastic sca	ttering	g reactions,				
• strong, weak and electro-weak interaction	tions a	nd an introduction	to the stand	ard model o	f particle j	physics,
• ep, pp und e+e- reactions,						
• bound systems (quarkonia, mesons, ba	aryons)	),				
• essential symmetries used to classify p	article	s and important se	election rules	governing pa	article read	ctions.
Literature						
• Povh, Rith, Scholz "Teilchen und Kerr	ne" (D	OI: 10.1007/978-3-	642-37822-5)			
• Other books on nuclear and particle p		,	,			
Entry requirements						
Recommended prerequisites						
Language				guage Englis on language		
Weighting of the achievement in th	e ove	rall grade	6/120	0.01	<u> </u>	
Module frequency			Every seme	ester		
Reasons for compulsory attendance	9		Ť			
Persons responsible for this module			Prof. Dr. M	I. Schott, Pr	of. Dr. W	Gradl
Applicable to the following program				cs, MSc. Phy		
Miscellaneous			Course lan quest	guage: Germ	nan or Eng	glish on re-

Iodul 060 Condensed Matte			Physics		08.12	28.060
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Condensed Matter Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination	Writt	ten exam (120-180	Min.) or oral	examinatio	on (30 Min	.)
Qualification and program goals /	Comp	etences	,			,
<ul><li>well as with</li><li>the capability to use the basic element describe the many body nature of con The lecture course provides a solid four</li></ul>	densed	matter phenomen	a.			
<ul> <li>the capability to use the basic element describe the many body nature of com The lecture course provides a solid foun and a key to grasp the numerous effects</li> <li>Course content</li> </ul>	densed dation behind	l matter phenomen for a comprehensi l technical applicat	a. ive understan ions of mode	ding of mat rn condense	erial scien	ce problem
• the capability to use the basic eleme describe the many body nature of con The lecture course provides a solid foun and a key to grasp the numerous effects	densed dation behind system odels,	l matter phenomen for a comprehense l technical applicat ns, nucleation and	a. ive understan ions of mode growth, glass	ding of mat rn condense transition	terial scien d matter I	ce problem physics.
<ul> <li>the capability to use the basic element describe the many body nature of com The lecture course provides a solid foun and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron mathematical electron elec</li></ul>	densed dation behind system odels, uction	a matter phenomen for a comprehension of technical application is, nucleation and free electron gas,	a. ive understan ions of mode growth, glass band model,	ding of mat rn condense transition	terial scien d matter I	ce problem physics.
<ul> <li>the capability to use the basic element describe the many body nature of com The lecture course provides a solid foun and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron m metals, anharmonic effects, heat conditioned</li> </ul>	densed dation behind system odels, uction ercondu	a matter phenomen for a comprehension l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm	a. ive understan ions of mode growth, glass band model,	ding of mat rn condense transition	terial scien d matter I	ce problem physics.
<ul> <li>the capability to use the basic element describe the many body nature of comon The lecture course provides a solid four and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat conders</li> <li>Correlated electrons: magnetism, super</li> <li>Applications: surfaces, spectroscopic metals</li> </ul>	densed dation behind system odels, uction ercondu	a matter phenomen for a comprehension l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm	a. ive understan ions of mode growth, glass band model,	ding of mat rn condense transition	terial scien d matter I	ce problem physics.
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<ul> <li>the capability to use the basic elemendescribe the many body nature of comon The lecture course provides a solid four and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat conder</li> <li>Correlated electrons: magnetism, super</li> <li>Applications: surfaces, spectroscopic metals</li> <li>Recommended prerequisites</li> <li>Language</li> </ul>	densed dation behind system odels, uction ercondu nethod	l matter phenomen for a comprehensi l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm s	a. ive understan ions of mode growth, glass band model, nions Course lang Examinatio	ding of mat rn condense transition	erial scien ad matter p actors, spec	ce problem physics.
<ul> <li>the capability to use the basic elemendescribe the many body nature of comon the lecture course provides a solid four and a key to grasp the numerous effects.</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat condered electrons: magnetism, supersesses of surfaces, spectroscopic metals, applications: surfaces, spectroscopic metals.</li> <li>Applications: surfaces, spectroscopic metals.</li> <li>Recommended prerequisites</li> <li>Language</li> <li>Weighting of the achievement in the spectrum of the section.</li> </ul>	densed dation behind system odels, uction ercondu nethod	l matter phenomen for a comprehensi l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm s	a. ive understan ions of mode growth, glass band model, nions Course lang Examinatio 6/120	ding of mat rn condense transition semi-condu guage Englis	erial scien ad matter p actors, spec	ce problem physics.
<ul> <li>the capability to use the basic elemendescribe the many body nature of comon The lecture course provides a solid four and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat conditions</li> <li>Correlated electrons: magnetism, super</li> <li>Applications: surfaces, spectroscopic metals</li> <li>Recommended prerequisites</li> <li>Language</li> <li>Weighting of the achievement in the Module frequency</li> </ul>	densed dation behinc system odels, uction ercondu nethod	l matter phenomen for a comprehensi l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm s	a. ive understan ions of mode growth, glass band model, nions Course lang Examinatio	ding of mat rn condense transition semi-condu guage Englis	erial scien ad matter p actors, spec	ce problem physics.
<ul> <li>the capability to use the basic elemendescribe the many body nature of comon the lecture course provides a solid four and a key to grasp the numerous effects.</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat condered electrons: magnetism, supersesses of surfaces, spectroscopic metals, applications: surfaces, spectroscopic metals.</li> <li>Applications: surfaces, spectroscopic metals.</li> <li>Recommended prerequisites</li> <li>Language</li> <li>Weighting of the achievement in the spectrum of the section.</li> </ul>	densed dation behinc system odels, uction ercondu nethod	l matter phenomen for a comprehensi l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm s	a. ive understan ions of mode growth, glass band model, nions Course lang Examinatio 6/120 Every seme	ding of mat rn condense transition semi-condu guage Englis on language ster	sh English	ce problem ohysics.
<ul> <li>the capability to use the basic elemendescribe the many body nature of comon The lecture course provides a solid four and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat conditions</li> <li>Correlated electrons: magnetism, super</li> <li>Applications: surfaces, spectroscopic metals</li> <li>Recommended prerequisites</li> <li>Language</li> <li>Weighting of the achievement in the Module frequency</li> </ul>	densed dation behinc system odels, uction ercondu nethod	l matter phenomen for a comprehensi l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm s	a. ive understan ions of mode growth, glass band model, nions Course lang Examinatic 6/120 Every seme Prof. Dr. 7 hense	ding of mat rn condense transition semi-condu guage Englis on language ester Th. Palberg,	sh English , Prof. Dr.	ce problem physics. cific heat of . G. Schön
<ul> <li>the capability to use the basic elemendescribe the many body nature of comon The lecture course provides a solid four and a key to grasp the numerous effects</li> <li>Course content</li> <li>Processes of structural change: model</li> <li>Electrons in solids: single electron metals, anharmonic effects, heat conditions: surfaces, spectroscopic metals, applications: surfaces, spectroscopic metals</li> <li>Applications: surfaces, spectroscopic metals</li> <li>Recommended prerequisites</li> <li>Language</li> <li>Weighting of the achievement in the Module frequency</li> <li>Reasons for compulsory attendance</li> </ul>	densed dation behinc system odels, uction ercondu nethod	l matter phenomen for a comprehensi l technical applicat ns, nucleation and free electron gas, nctivity, heavy ferm s	a. ive understan ions of mode growth, glass band model, nions Course lang Examinatio 6/120 Every seme Prof. Dr. 7 hense BSc. Physic tics	ding of mat rn condense transition semi-condu guage Englis on language ster	sh English , Prof. Dr. ysics, MSc	ce problem physics.

## **3.2 Theoretical Physics**

Modul 151	Advanced Quantum Mechanics     08.128.151			8.151		
Compulsory or elective module	WP					
Credit points and workload	9 LP = 270 h					
<b>Duration</b> according to the study plan	1					
	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	$\mathbf{term}$	obligation	$\mathbf{time}$	study	points
Lecture with excercises "Advanced Quantum Mechanics" (WP)		1	Р		207	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2  SWS		
To complete the module, the follow	ing ad	chievements mus	st be made:		•	
Presence						
Active participation	according to §5 subsection 3					
Course achievements	successful completion of exercises or projects					
Module examination	Writt	en exam (120-180	Min.) or oral	examination	n (30 Min.)	)
Qualification and program goals /	Comp	etences				

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.

#### 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.
- $\bullet~Additional~in-depth~topics$  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.

#### 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

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	9/120
Module frequency	Every semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. S. Weinzierl
Applicable to the following programs	BSc. Physics, MSc. Physics
Miscellaneous	Course language: German or English on re- quest

Modul 165	Relativistic Quantum Field Theory     08.128.165					
Compulsory or elective module	WP					
Credit points and workload	9  LP = 270  h					
<b>Duration</b> according to the study plan	1					
	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Relativistic Quantum Field Theory" (WP)		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2  SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			·
Presence						
Active participation	according to §5 subsection 3					
Course achievements	successful completion of exercises or projects					
Module examination	Writt	en exam (120-180	Min.) or oral	examination	n (30 Min.)	)
Qualification and program goals /	Comp	etences				

#### 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.

#### 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.

#### 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

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	9/120
Module frequency	Every semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. S. Weinzierl
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 170	Adv	anced Statistic	al Physics		08.128	8.170
Compulsory or elective module	WP					
Credit points and workload	9 LF	P = 270  h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Advanced Sta- tistical Physics" (WP)		1	Р		207 h	9 LP
Lecture (WP)	V			4  SWS		
Excercises (WP)	Ü			2  SWS		
To complete the module, the follow	ving a	chievements mus	st be made:		•	·
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination	Writt	en exam (120-180	Min.) or oral	examination	n (30 Min.)	
Qualification and program goals /	Comp	etences	•			

#### 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.

#### **Course content**

• Basic concepts in a statistical description of complex systems at equilibrium and non-equilibrium, linear response and transport, stochastic processes, structure, correlations, and scattering;

- Modeling concepts, symmetries and conservation laws, coarse-graining concepts (reduction of degrees of freedom);
- Phase transitions, mean-field approaches, Landau theory, fluctuations and critical exponents, scale invariance and renormalization, and (possibly) basic concepts of statistical field theory;

Other topics are selected based on the preferences of the lecturers. Possibilities are: Non-equilibrium thermodynamics, stochastic thermodynamics, disordered systems and glasses, hydrodynamics at low Reynolds numbers, statistical physics of complex soft matter (e.g., polymers, 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.

#### 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.

Entry requirements	
Recommended prerequisites	
Language	Course language English
	Examination language English or German
Weighting of the achievement in the overall grade	9/120
Module frequency	At least once per year
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. F. Schmid

Modul 170	Advanced Statistic	al Physics	08.128.170
Applicable to the following program	ns	MSc. Physics	
Miscellaneous		Course language: English	

Modul 175		oretical quant y physics	um optics	and mar	ny 08.12	8.175
Compulsory or elective module	WP				I	
Credit points and workload	9 LF	P = 270  h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	$\mathbf{term}$	obligation	$\mathbf{time}$	study	points
Lecture with excercises " Theoretical quantum optics and many body physics" (WP)		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination	Writt	en exam (120-180	Min.) or oral	examinatio	n (30 Min.	)
Qualification and program goals /	Comp	etences				
After this course, the students should an	nongst	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.

#### **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.

	heoretical quantum optics an ody physics	d many 08.128.175
Literature		
• F. Schwabl, Quantenmechanik für Fortg	schrittene, Springer-Verlag, Berlin, 199	7.
• J. J. Sakurai, Advanced Quantum Mech	nics, Addison Wesley, Reading, 1967.	
• S. M. Barnett, P.M. Radmore, Methods	n Theoretical Quantum Optics, Oxford	l Univ. Press, Oxford, 2002.
• M. Fox, Quantum Optics, Oxford Univ.	Press, Oxford, 2006.	
• M. A. Nielsen, I. L. Chuang, Quantur Cambridge, 2000.	Computation and Quantum Informat	tion, Cambridge Univ. Press,
• M. Lewenstein, A. Sanpera, V. Ahufing 2012.	er, Ultracold atoms in optical lattices,	Oxford Univ. Press, Oxford,
• J. W. Negele, H. Orland, Quantum Mar	-particle Systems, Perseus Books, New	York, 1994.
• R. Loudon, The Quantum Theory of Lig	nt, Oxford Univ. Press, Oxford, 2000.	
Entry requirements		
Recommended prerequisites		
Language	Course languag Examination la	ge English anguage English or German
Weighting of the achievement in the	overall grade 9/120	
Module frequency	Annually in wi	nter term
Reasons for compulsory attendance		
Persons responsible for this module	Prof. Dr. P. va Loock	an Dongen, Prof. Dr. P. van
Applicable to the following programs	MSc. Physics	
Miscellaneous	Course languag	ge: English

Modul 180	The	oretical solid s	tate physic	S	08.12	28.180
Compulsory or elective module	WP					
Credit points and workload	9 LF	P = 270 h				
<b>Duration</b> according to the study plan	1					
Courses and tooshing methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	$\mathbf{term}$	obligation	time	study	points
Lecture with excercises "Theoretical so- lid state physics" (WP)		1	Р		207 h	9 LP
Lecture (WP)	V			4  SWS		
Excercises (WP)	Ü			2 SWS		
To complete the module, the follow	ving a	chievements mu	st be made:		•	- <b>·</b>
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion o	f exercises or	projects		
Module examination	Writt	en exam (120-180	Min.) or oral	examinatio	n (30 Min.	.)

#### 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.

#### **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.

#### 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

Entry requirements	
Recommended prerequisites	
Language	Course language English
	Examination language English or German
Weighting of the achievement in the overall grade	9/120
Module frequency	At least once per year
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. J. Sinova
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

# **3.3 Laboratory Courses and Seminars**

Modul 620	Adv	anced Laborat	ory		M.08	8.128.620
Compulsory or elective module	WP					
Credit points and workload	10 L	P = 300 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and reaching methods	ре	term	obligation	time	study	points
a) Laboratory Project 1 (P)	Pr	2	Р	4  SWS	108 h	5  LP
b) Laboratory Project 2 (P)	Pr	2	Р	4  SWS	108 h	5  LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence	Pr					
Active participation						
Course achievements						
Module examination	Portf	olio of the projects	s in part 1 res	spectively pa	art 2	
Qualification and program goals /	Comp	etences				
Compared to the bachelor advanced lab actual research.	porator	y course there is	a stronger en	nphasis on i	ndepender	nt work an
Course content The format of these projects is quite flex be approved by the course convenor. Mar does not exceed 60h of lab work, and th other project in this module.	rible windatory	there is the	a stronger en c, implementa the topic incl werlap neithe	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t pachelor th	nt work an ever it mus the duratio assis nor th
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Man does not exceed 60h of lab work, and th other project in this module.	cible windatory at their	there is the	a stronger en c, implementa the topic incl werlap neithe	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t pachelor th	nt work an ever it mus the duratio assis nor th
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Mar does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi-	cible windatory at their	there is the	a stronger en c, implementa the topic incl werlap neithe	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t pachelor th	nt work an ever it mus the duratio assis nor th
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Man does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi Literature Specific literature and manuals from the	tible ward there is a constraint of the second seco	ty course there is ith respect to topicy requests are that re is no thematic of s with a focus on m	a stronger en c, implementa the topic incl werlap neithe	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t pachelor th	nt work an ever it mus the duratio assis nor th
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Man does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi Literature Specific literature and manuals from the Entry requirements	tible ward there is a constraint of the second seco	ty course there is ith respect to topicy requests are that re is no thematic of s with a focus on m	a stronger en c, implementa the topic incl werlap neithe	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t pachelor th	nt work an ever it mus the duratio assis nor th
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Man does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi Literature Specific literature and manuals from the Entry requirements	tible ward there is a constraint of the second seco	ty course there is ith respect to topicy requests are that re is no thematic of s with a focus on m	a stronger en c, implementa the topic incl werlap neithe	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t pachelor th	nt work an ever it mus the duration tesis nor th
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Man does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi Literature Specific literature and manuals from the Entry requirements Recommended prerequisites	tible ward there is a constraint of the second seco	ty course there is ith respect to topicy requests are that re is no thematic of s with a focus on m	a stronger en	nphasis on i ution and tin udes modern r with the b	ndepender ning. How a physics, t bachelor th at external an/English	ever it must the duration the duration institution
Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Mar does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi Literature Specific literature and manuals from the Entry requirements Recommended prerequisites Language	cible windatory at their groups ible.	ty course there is ith respect to topic y requests are that re is no thematic of s with a focus on m et organizer	a stronger en	nphasis on i ation and tin udes modern r with the b s. Research a guage Germ	ndepender ning. How a physics, t bachelor th at external an/English	ever it must the duration the duration institution
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Compared to the bachelor advanced lab actual research. Course content The format of these projects is quite flex be approved by the course convenor. Man does not exceed 60h of lab work, and th other project in this module. Projects can be performed in all research (e.g. major research institutions) is possi Literature Specific literature and manuals from the Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency	tible w. ndatory at ther groups ible. project	ty course there is ith respect to topic y requests are that re is no thematic of s with a focus on m et organizer	a stronger en c, implementa the topic incl werlap neithe odern physics Course lang Examinatic 10/120	nphasis on i ntion and tir udes modern r with the b s. Research a guage Germ on language	ndepender ning. How a physics, t bachelor th at external an/English	ever it musthe duration institution
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Modul 630	Sem	linars			M.08	.128.630
Compulsory or elective module	WP					
Credit points and workload		P = 240  h				
<b>Duration</b> according to the study plan	2					
~ · · · · ·	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	time	study	points
a) Seminar 1 (P)	HS	1	Р	2 SWS	99 h	4 LP
b) Seminar 2 (P)	HS	1	Р	2 SWS	99 h	4 LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence	HS					
Active participation	accor	ding to §5 subsect:	ion 3			
Course achievements						
Module examination	The s	students's presenat	ions are grade	ed both for s	seminar 1 a	and semina
Qualification and program goals /	Comp	etences				
Seminar 2 should include a deepened ex	aminat	ion and discussion	of up-to-date	e questions i	n physics 1	esearch.
Course content a) Student presentations of topics from	1	1	· ·	. 1 1.1		•
<ul> <li>a) Student presentations of topics from</li> <li>b) Student presentations on up-to-date the physics institutes. Usually, severa condensed matter, nuclear and partice</li> <li>Entry requirements</li> </ul>	e topics d subje	s relevant to the e ects will be offered	experimental	or theoretic	cal working	g groups
Recommended prerequisites						
Language				guage Englis m language		
	ne over	rall grade	8/120			
Weighting of the achievement in th			<b>D</b>			
			Every seme	ster		
Module frequency	e		Every seme	ster		
Module frequency Reasons for compulsory attendance			Prof. Dr. W			
Weighting of the achievement in the Module frequency Reasons for compulsory attendance Persons responsible for this module Applicable to the following program	e			V. Gradl		

# 3.4 Topical Courses

# 3.4.1 Condensed Matter Physics

		dule Topical C in Condensed			08.12	28.720
Compulsory or elective module	WP				•	
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Selected topics		1	Р		138 h	6 LP
in Condensed Matter Physics" (WP)		1	P		130 II	0 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			$1 \ \mathrm{SWS}$		
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation	accor	ding to §5 subsection	ion 3			
Course achievements	succe	essful completion of	exercises or	projects		
Module examination	Writt	ten exam (120-180	Min.), oral e	xamination (	(30 Min.),	term paper
	or pr	esentation				
solid background when dealing with resea correlated dynamics of electrons in solids Surface Science is essential for an in dep techniques. Soft Matter shows fascinatin field of applications. Its fundamental sci	and p oth und ng stru	rovide the basis of a lerstanding of mini ctural and dynami	modern electraturized devi c properties a	conics and in ces as well a and nurtures	formation as for nove a rapidly	technology. l diagnostic
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course with fermions, applied solid state physics, sur <b>Literature</b>	of one f Cond ill focu	or more of these t ensed Matter Phys s on specific topics	opics, the co ics. , such as mag	urse will pro	ovide a sol	v, chemistry id basis for
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course wi fermions, applied solid state physics, sur	of one f Cond ill focu	or more of these t ensed Matter Phys s on specific topics	opics, the co ics. , such as mag	urse will pro	ovide a sol	v, chemistry id basis for
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course wi fermions, applied solid state physics, sur <b>Literature</b>	of one f Cond ill focu	or more of these t ensed Matter Phys s on specific topics	opics, the co ics. , such as mag	urse will pro	ovide a sol	v, chemistry id basis for
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course wifermions, applied solid state physics, sur <b>Literature</b> will be provided by the lecturer	of one f Cond ill focu	or more of these t ensed Matter Phys s on specific topics	opics, the co ics. , such as mag	urse will pro	ovide a sol	v, chemistry id basis for
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course with fermions, applied solid state physics, sur <b>Literature</b> will be provided by the lecturer <b>Entry requirements</b>	of one f Cond ill focu	or more of these t ensed Matter Phys s on specific topics	opics, the co ics. , such as mag r physics Course lang	urse will pro	er conduct	v, chemistry id basis for ivity, heavy
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course with fermions, applied solid state physics, sur <b>Literature</b> will be provided by the lecturer <b>Entry requirements</b> <b>Recommended prerequisites</b>	of one f Cond ill focu face sc	or more of these t ensed Matter Phys s on specific topics ience or soft matte	opics, the co ics. , such as mag r physics Course lang	guage Englis	er conduct	v, chemistry id basis for ivity, heavy
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course with fermions, applied solid state physics, sur <b>Literature</b> will be provided by the lecturer <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b>	of one f Cond ill focu face sc	or more of these t ensed Matter Phys s on specific topics ience or soft matte	opics, the co ics. , such as mag r physics Course lang Examination 6/120	guage Englis	er conduct	v, chemistry id basis for ivity, heavy
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course wi fermions, applied solid state physics, sur Literature will be provided by the lecturer Entry requirements Recommended prerequisites Language Weighting of the achievement in the	of one f Cond ill focu face sc	or more of these t ensed Matter Phys s on specific topics ience or soft matte	opics, the co ics. , such as mag r physics Course lang Examination 6/120	guage Englis	er conduct	v, chemistry id basis for ivity, heavy
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course with fermions, applied solid state physics, sur Literature will be provided by the lecturer Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency	of one f Cond ill focu face sc ne over	or more of these t ensed Matter Phys s on specific topics ience or soft matte	opics, the co ics. , such as mag r physics Course lang Examinatic 6/120 Each summ	guage Englis	by ide a sol	z, chemistry id basis for ivity, heavy German
and medicine. By an depth treatment of conducting a master thesis in the area of <b>Course content</b> Depending on the lecturer, the course with fermions, applied solid state physics, sur Literature will be provided by the lecturer <b>Entry requirements</b> <b>Recommended prerequisites</b> Language Weighting of the achievement in the Module frequency Reasons for compulsory attendance	of one f Cond ill focu face sc he over	or more of these t ensed Matter Phys s on specific topics ience or soft matte	opics, the co ics. , such as mag r physics Course lang Examinatic 6/120 Each summ	guage Englis on language I er semester	by ide a sol	z, chemistry id basis for ivity, heavy German

Modul 721	peri ter 1	lule Topical Co mental Methoo Physics"		8.721		
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Modern Expe- rimental Methods in Condensed Matter Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ing a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		ten exam (120-180 esentation	Min.), oral e	xamination (	(30 Min.),	term paper
Qualification and program goals /	Comp	etences				
Students shall be guided towards both methods in material science. The cours approaches. Examples may include spec- well as application related characterizat Dealing with one or more of such topics, area of expertise in Condensed Matter P in Condensed Matter Physics in this or a	e will troscop ion of the co hysics.	therefore present i pic methods, scatte novel materials, sa urse will develop a It will further pro-	mportant and ering technique mple prepara n enhanced u	d state of thues, scanning ation and con nderstanding	ne art tech g probe te nditioning g of a resea	nniques and chniques as techniques. arch related
Course content						
Depending on the lecturers, the course techniques, modern microscopy technique techniques or methods for material chara	ies, sca	nning probe techn	iques, synthe	esis strategie		
Entry requirements						
Recommended prerequisites						
Language				guage Englis on language l		German
Weighting of the achievement in th	e over	rall grade	6/120			
Module frequency			Every wint	er semester		
	9		1			
Reasons for compulsory attendance						
Reasons for compulsory attendance Persons responsible for this module			Prof. Dr. T	. Palberg, P	rof. Dr. M	. Kläui
	e		Prof. Dr. T MSc. Physi	<b>.</b>	rof. Dr. M	. Kläui

Modul 722		lule Topical ( nce"	Courses: "	Materia	ls 08.12	28.722
Compulsory or elective module	WP				•	
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} {f study}$	Credit points
Lecture with excercises "Materials Science" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			$1 \ \mathrm{SWS}$		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	essful completion o	f exercises or	projects		
Module examination		ten exam (120-180 esentation	Min.), oral ex	kamination (	(30 Min.),	term paper
Students shall be guided towards the ess of processes in novel materials on the ate						
of processes in novel materials on the ato example, the structure and properties of functionalized surfaces, formation of and as concepts and fundamentals of novel r or more of such topics, the course will do in Condensed Matter Physics. It will fur	omic an f funct d trans nateria evelop	physics of Material and the nano-scale. ional materials, na itions within solid an enhanced under	Topics of inte anomaterials, s, modern me development a rstanding of a	rest covered fluids and s ethods of ma and applicat research rel	by the cou oft materi terial scie- ion. Dealin ated area	urse are, for als, glasses, nce, as well ng with one of expertise
of processes in novel materials on the ato example, the structure and properties of functionalized surfaces, formation of and as concepts and fundamentals of novel r or more of such topics, the course will de	omic an f funct d trans nateria evelop	physics of Material and the nano-scale. ional materials, na itions within solid an enhanced under	Topics of inte anomaterials, s, modern me development a rstanding of a	rest covered fluids and s ethods of ma and applicat research rel	by the cou oft materi terial scie- ion. Dealin ated area	urse are, for als, glasses, nce, as well ng with one of expertise
of processes in novel materials on the ato example, the structure and properties of functionalized surfaces, formation of and as concepts and fundamentals of novel r or more of such topics, the course will do in Condensed Matter Physics. It will fur Matter Physics in this or a related area.	omic an f funct l trans nateria evelop rther p rill focu alized s	physics of Material and the nano-scale. ional materials, na itions within solid is including their an enhanced under provide a solid basis	Topics of inter- anomaterials, s, modern me development a standing of a s for conduct s like e.g. fun	rest covered fluids and s ethods of ma and applicat research rel ing a master ctional mate	by the cou oft materi terial scie ion. Dealin ated area r thesis in erials, nan	urse are, for als, glasses, nce, as well ng with one of expertise Condensed o materials,
of processes in novel materials on the ato example, the structure and properties of functionalized surfaces, formation of and as concepts and fundamentals of novel r or more of such topics, the course will de in Condensed Matter Physics. It will fur Matter Physics in this or a related area. <b>Course content</b> Depending on the lecturer, the course w soft matter materials, glasses, functional transitions or materials for specific applit <b>Entry requirements</b>	omic an f funct l trans nateria evelop rther p rill focu alized s	physics of Material and the nano-scale. ional materials, na itions within solid is including their an enhanced under provide a solid basis	Topics of inter- anomaterials, s, modern me development a standing of a s for conduct s like e.g. fun	rest covered fluids and s ethods of ma and applicat research rel ing a master ctional mate	by the cou oft materi terial scie ion. Dealin ated area r thesis in erials, nan	urse are, for als, glasses, nce, as well ng with one of expertise Condensed o materials,
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Modul 7012	Moo	dule Topical Co	ourses: " I	ntroductio	n   08.12	8.7012
	to A	dvanced Mater	ials - from	soft matte	er	
	to h	ard matter"				
Compulsory or elective module	WP					
Credit points and workload		P = 180 h				
<b>Duration</b> according to the study plan	1		-		~ • •	
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
	pe	term	obligation	time	study	points
Lecture with excercises "Introduction			D		1001	6 J D
to Advanced Materials - from soft mat-		1	Р		138 h	6 LP
ter to hard matter" (WP)	17			9 GMG		
Lecture (WP)	V Ü			3 SWS		
Excercises (WP)	Ū	1. ,		1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation		ding to §5 subsect				
Course achievements		essful completion of				
Module examination		ten exam (120-180	Min.), oral e	xamination (	30 Min.),	term paper
	-	esentation				
Qualification and program goals /						
Students will be introduced to the fund						
an understanding of how the size, nanc	scodic a	arrangement and 11	iteraction en	ergy of the a	tomic mo	
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		lule Topical atronics"	Courses: "	Quantu	m 08.12	28.7014
Compulsory or elective module	WP				I	
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Quantum Spintronics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			$1 \; \mathrm{SWS}$		
To complete the module, the follow	ing a	chievements mu	st be made:		•	
Presence						
Active participation	accor	ding to §5 subsect	tion 3			
Course achievements	succe	ssful completion o	f exercises or	projects		
Module examination	Writt	en exam (120-180	Min.), oral e	xamination (	(30 Min.),	term pape
	or pr	esentation				
Qualification and program goals /	Comp	etences				
criptions to quantum mechanical single solid lead to macroscopic magnetisation	spin. In throug	n particular, an u gh exchange coupl	nderstanding ing is to be a	of how indiv chieved. The	ridual elec e dynamic	trons in the s of spins i
criptions to quantum mechanical single solid lead to macroscopic magnetisation discussed classically as well as quantum r cation side, energy-saving magnetoelectro are explained. Students will understand and quantum mechanical effects in the er or more specific topics, students will gain	spin. In throug mechar onics fo the co xample n a dee	n particular, an ur gh exchange coupl nically and method or memory, sensing oncepts of emergen e of spin and be ab oper understanding	nderstanding ing is to be a ls for measure g and logic are at phenomena- le to assess th g of a research	of how indiv chieved. The ment are exp introduced and the tra- ne application -related spec-	vidual elec e dynamic plained. O and spin-h ansition from n potentia	trons in th s of spins i on the appli- based qubit om classica l. Using on
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Modul 7013	Module Topical Courses: "Superconduc- tivity"					08.128.7013	
Compulsory or elective module	WP				I		
Credit points and workload	6 LF	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching matheda	Ty-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	time	study	points	
Lecture with excercises "Superconductivity" (WP)		1	Р		138 h	6 LP	
Lecture (WP)	V			3 SWS			
Excercises (WP)	Ü			1 SWS			
To complete the module, the follow	ving a	chievements mu	st be made:		•		
Presence							
Active participation	accor	ding to §5 subsect	ion 3				
Course achievements	succe	essful completion o	f exercises or	projects			
Module examination		ten exam (120-180 esentation	Min.), oral e	xamination	(30 Min.),	term paper	
is the symmetry of the order parameter transport properties of the superconduct dissipation free transport and the realiz or qubits. In one or several special topic physics shall be achieved forming the for <b>Course content</b> Electrons in solids, BCS-theory for Coop and transport properties Ginzburg-Land and its applications in ultra sensitive set conducting magnets, superconducting qu systems, related quantum effects as Qua <b>Literature</b> Specialized textbooks of condensed mma Superconductivity; Kleiner+Buckel: Sup papers	ting g ation o s a dee indationer pair au des nsors a ibits, h ntum l atter p	round state shall of of superconducting eper understanding on to successfully p formation and con- cription, type I an nd as voltage norm- high temperature s Hall effect.	be achieved v quantum ph g of a subfield prepare a mas indensation in d type II sup- nal, critical co- uperconduction of superconduction	vith respect enomena as d of current ster thesis or the ground s erconductors urrents in su vity, transpo	to the po ultrasensi research in a these top state, phas s, the Jose uperconductor ort in two-	ssibilities of tive sensors a solid state bics. se transition phson effect ttors, super- dimensional coduction to	
Entry requirements							
Recommended prerequisites							
Language				guage Englis on language		German	
Weighting of the achievement in th	e ove	rall grade	6/120				
Module frequency			Generally e	every year			
Reasons for compulsory attendance	Э						
Persons responsible for this module			D ( D (	I Jakob Dr			
			Prot. Dr. 🤆	<b>i.</b> Jakob, 1 10	of. Dr. M.	Jourdan	
	$\mathbf{ns}$		Prof. Dr. C MSc. Physi		of. Dr. M.	Jourdan	
Applicable to the following program Miscellaneous	ns		MSc. Physi			Jourdan	

	Moo	lule Topical Co	ourses: "N	onequinor	ri-   08.12	10.102
	um phenomena in quantum matter"					
Compulsory or elective module	WP					
Credit points and workload		P = 180 h				
Duration according to the study plan	1	<b>_</b>	<b>D</b>	<b>a</b>	G 10	
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Nonequilibri- um phenomena in quantum matter" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			$1 \ \mathrm{SWS}$		
To complete the module, the follow	ving ac	chievements mus	t be made:			
Presence						
Active participation	accor	ding to §5 subsecti	ion 3			
Course achievements	succe	ssful completion of	exercises or	projects		
Module examination	1	ten exam (120-180 esentation	Min.), oral e	xamination	(30  Min.),	term paper
Qualification and program goals $/$	Comp	etences				
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in superconductors and light-induced ermention a few. After introducing the general principle of where different experimental techniques etc.) will be applied to study one of the basics of non-linear optics, the novel and address physics of different material. The course should provide a broad over and thus present solid grounds for MSc. <b>Course content</b> Basics of nonlinear optics & ultrafast latechniques; Femtosecond thermo-modula Basics of superconductivity; Electrodyna superconducting gap; Microwave enhance Basics of Charge and Spin density wave electron diffraction – making molecular in <b>Literature</b> B.E.A. Saleh, M.C. Teich: Fundamental M. Dressel and G. Grüner: Electrodyna Master Series in Physics; M. Tinkham: selected scientific publications & reviews <b>Entry requirements</b> <b>Recommended prerequisites</b>	o femto nhance (THz s e above laser-b l classes view o work ir asers; I tion in amics c ement c res; Tir movies; s of Ph umics o Introdus	second switching of ment of supercond "pump-probe" spec spectroscopy, ultrati- e-mentioned macro- based techniques (u s with fascinating fif f techniques and n n several areas of re- Principles of femtor metals; Terahertz of systems with bro- of superconductivity ne-resolved photoe ; Magnetization dy notonics, Wiley, 199 f Solids; S. Blunde uction to Supercon	of magnetizat luctivity, or i ctroscopy, we fast electron scopic quants sed both in t functional pro- onequilibriur esearch in sol second real-t generation ar oken symmetry; Collective electron spect- namics and s 91; Kittel: In ell: "Magnetis iductivity; G Course lang Examinatio 6/120	ion, observa making mole will addres diffraction, t um states. T he lab and a operties. n phenomen id state phy ime spectros ad THz time- ry ground st (Higgs) mod troscopy; Fe witching troduction t m in Conde . Grüner: De	ations of H ecular mov s several of time-resolv This way we this way we that large-scation a in correl sics. Scopy and -domain sp ates; Dyna es in super mtosecond to Solid St ensed Matter ensity way	Iiggs modes vies, just to ase studies, red ARPES, re will learn le facilities) lated solids, modulation pectroscopy; amics of the rconductors; l X-ray and ate physics; cer"; Oxford es in solids;
in superconductors and light-induced ermention a few. After introducing the general principle of where different experimental techniques etc.) will be applied to study one of the the basics of non-linear optics, the novel and address physics of different material. The course should provide a broad over and thus present solid grounds for MSc. <b>Course content</b> Basics of nonlinear optics & ultrafast la techniques; Femtosecond thermo-modula Basics of superconductivity; Electrodyna superconducting gap; Microwave enhance Basics of Charge and Spin density way electron diffraction – making molecular in <b>Literature</b> B.E.A. Saleh, M.C. Teich: Fundamental M. Dressel and G. Grüner: Electrodyna Master Series in Physics; M. Tinkham: selected scientific publications & reviews <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b> Weighting of the achievement in the	o femto nhance (THz s e above laser-b l classes view o work ir assers; I tion in amics o ement o res; Tir movies; s of Ph unics o Introdus	second switching of ment of supercond "pump-probe" spec spectroscopy, ultrati- e-mentioned macro- based techniques (u s with fascinating fif f techniques and n n several areas of re- Principles of femtor metals; Terahertz of systems with bro- of superconductivity ne-resolved photoe ; Magnetization dy notonics, Wiley, 199 f Solids; S. Blunde uction to Supercon	of magnetizat luctivity, or i ctroscopy, we fast electron scopic quants sed both in t functional pro- onequilibriur esearch in sol second real-t generation ar oken symmetry; Collective electron spect- namics and s 91; Kittel: In ell: "Magnetis iductivity; G Course lang Examinatio 6/120	ion, observa making mole e will addres diffraction, t im states. T he lab and a operties. n phenomen id state phy ime spectros ad THz time cy ground st (Higgs) mod troscopy; Fe witching troduction t m in Conde . Grüner: De guage Englis on language	ations of H ecular mov s several of time-resolv This way we this way we that large-scation a in correl sics. Scopy and -domain sp ates; Dyna es in super mtosecond to Solid St ensed Matter ensity way	Iiggs modes vies, just to ase studies, red ARPES, re will learn le facilities) lated solids, modulation pectroscopy; amics of the rconductors; l X-ray and ate physics; cer"; Oxford es in solids;

Modul 752	Module Topical Co um phenomena in o	ourses: "Nonequilibri- quantum matter"	08.128.752
Applicable to the following program	ns	MSc. Physics	
Miscellaneous		Course language: English	

Modul 723	Module Topical Courses: "Introduction08.128.723to Condensed Matter Theory"					8.723
Compulsory or elective module	WP					
Credit points and workload	6 LP = 180 h					
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Introduction to Condensed Matter Theory" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	essful completion of	exercises or	projects		
Module examination	Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation					
Qualification and program goals /	Comp	etences				
Building on the introductory courses on of of the description of crystalline solids sh concepts like the electronic structure (ele	all be	discussed. Starting	from lattice	periodicity a	and crystal	symmetry,

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.

#### **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.

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every summer semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. P. van Dongen
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 724	Mod	-	Courses:			8.724
	Cha	pters of Conde	ensed Matt	er Theory	."	
Compulsory or elective module	WP					
Credit points and workload	6 LP = 180 h					
<b>Duration</b> according to the study plan	1					
Courses and tenshing methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Selected Chap- ters of Condensed Matter Theory" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ing a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	successful completion of exercises or projects					
Module examination		en exam (120-180 esentation	Min.), oral e	xamination (	30 Min.), t	term paper
Qualification and program goals /	Comp	etences				

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.

#### **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.

- 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;

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every summer semester
Reasons for compulsory attendance	

Modul 724	Module Top Chapters of C		"Selected er Theory"	08.128.724
Persons responsible for this module	е	Prof. Dr. P.	van Dongen	
Applicable to the following program	ns	MSc. Physics		
Miscellaneous		Course lang	uage: English	

Modul 725	Module Topical Courses: "Theory of Soft Matter I"08.128.725					8.725
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	time	study	points
Lecture with excercises "Theory of Soft Matter I" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3  SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		en exam (120-180 esentation	Min.), oral e	xamination (	(30 Min.), 1	term paper
Qualification and program goals /	Comp	etences				

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.

#### **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 none-quilibrium matter.

- 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

Entry requirements	
Recommended prerequisites	
Language	Course language English
Language	Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Upon request
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. K. Kremer, Prof. Dr. F. Schmid
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 745		lule Topical nputational Te 'Soft Matter P	-	"Moder n Conder		28.745
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Modern Computational Techniques in Conden- sed/Soft Matter Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			$1 \ \mathrm{SWS}$		
To complete the module, the follow	ving a	chievements mu	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	essful completion o	f exercises or	projects		
Module examination	Written exam (120-180 Min.), oral examination (30 Min.), term pap or presentation					term paper
• •						
Qualification and program goals / O Students attending the course will lear computer simulations in the field of com-	Comp n the	etences use of advanced t		-	•	
Students attending the course will lear computer simulations in the field of cond These techniques will enable them to st solids, polymer melts etc.), conformations	Comp n the densed tudy p	etences use of advanced t and soft matter p henomena like pha	hysics, possib ase transitions	ly including s in a variet	molecular y of syste	biophysics. ms (liquids,
Students attending the course will lear computer simulations in the field of cond These techniques will enable them to st solids, polymer melts etc.), conformations <b>Course content</b>	Comp in the densed cudy pl al char	etences use of advanced to and soft matter p henomena like pha ages, chemical reac	hysics, possib ase transitions tions, non-equ	ly including s in a variet ilibrium or c	molecular y of syste driven phe	biophysics. ms (liquids, nomena etc.
Students attending the course will lear computer simulations in the field of cond These techniques will enable them to st solids, polymer melts etc.), conformationa <b>Course content</b> The topics of the course will be selected a sampling techniques, simulation of rare density functional theory, force-field opti	Comp n the densed tudy p al char ccordin events	etences use of advanced to and soft matter p henomena like pha ages, chemical reac ng to the docent an , critical phenome	hysics, possib ase transitions tions, non-equ id can include na, non-equili	ly including s in a variet ilibrium or c free energy c brium dyna	molecular y of syste driven phe calculation mics, coar	biophysics. ms (liquids, nomena etc. s, enhanced se-graining,
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Students attending the course will lear computer simulations in the field of cond These techniques will enable them to st solids, polymer melts etc.), conformational <b>Course content</b> The topics of the course will be selected a sampling techniques, simulation of rare density functional theory, force-field opti <b>Literature</b> To be announced in class	Comp n the densed tudy p al char ccordin events	etences use of advanced to and soft matter p henomena like pha ages, chemical reac ng to the docent an , critical phenome	hysics, possib ase transitions tions, non-equi- id can include na, non-equili- ce fields, long	ly including s in a variet ilibrium or o free energy o brium dyna range intera guage Englis	molecular y of syste driven phe calculation mics, coar actions, et	biophysics. ms (liquids, nomena etc. s, enhanced se-graining, c.
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Modul 801	Module Topical Courses: "Computer Si- mulations in Statistical Physics"				Si- 08.128.801	
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Computer Si- mulations in Statistical Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mu	st be made:			
Presence						
Active participation	accor	rding to §5 subsect	tion 3			
Course achievements	succe	essful completion o	f exercises or	projects		
Module examination		ten exam (120-180 resentation	Min.), oral e	xamination	(30 Min.)	, term pape
Qualification and program goals /	Comp	etences				
They will learn to appreciate the import riment.		rrectly and in an e f computer simula				
They will learn to appreciate the import riment.	ance o	of computer simula	tions in their	interaction	with theo	ry and exp
They will learn to appreciate the import riment.	ance o	of computer simula	tions in their chain Monte C	interaction Carlos, rando	with theo	ry and exp
They will learn to appreciate the import riment. Course content Molecular dynamics simulations, sympled analysis of time series, finite size effects	ance o	of computer simula	tions in their chain Monte C	interaction Carlos, rando	with theo	ry and exp
They will learn to appreciate the import riment. Course content Molecular dynamics simulations, sympled analysis of time series, finite size effects	ance o	of computer simula regrators, Markov of mulations in differen	tions in their chain Monte C ent thermodyn	interaction Carlos, rando namic ensen	with theo om numbe nbles.	ry and exp r generator
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature</li> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> </ul>	ance o ctic int and sin olecula	egrators, Markov of mulations in different ar Simulation – Fro	tions in their chain Monte C ent thermodyn om Algorithms	interaction Carlos, rando namic ensen s to Applica	with theo om numbe nbles. tions, Aca	ry and exp r generator demic Pres
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature</li> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to the series of the ser</li></ul>	ance o ctic int and sin olecula	egrators, Markov of mulations in difference ar Simulation – Fro te Carlo Simulation	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic	interaction Carlos, rando namic ensen s to Applica cal Physics,	with theo om numbe nbles. tions, Aca Cambridg	ry and exp r generator demic Pres
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature</li> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to Press, New York, 2005</li> </ul>	ance o ctic int and sin olecula > Mont r Simu	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation ilations of Liquids,	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford	with theo om numbe nbles. tions, Aca Cambridg l, 1987	ry and exp r generator demic Pres
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature</li> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to Press, New York, 2005</li> <li>M. P. Allen, D. J. Tildesley, Compute</li> <li>J. M. Haile, Molecular Dynamics Simu</li> </ul>	ance o ctic int and sin olecula > Mont r Simu	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation ilations of Liquids,	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford	with theo om numbe nbles. tions, Aca Cambridg l, 1987	ry and exp r generator demic Pres
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<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects analysis of time series, finite series,</li></ul>	ance o ctic int and sin olecula > Mont r Simu	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation ilations of Liquids,	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P ethods, Wiley Course lang Examinatic	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford	with theo om numbe nbles. tions, Aca Cambridg l, 1987 , 1997.	ry and exp r generator demic Pres ge Universi
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature</li> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to Press, New York, 2005</li> <li>M. P. Allen, D. J. Tildesley, Compute</li> <li>J. M. Haile, Molecular Dynamics Simu</li> <li>Entry requirements</li> <li>Recommended prerequisites</li> <li>Language</li> </ul>	ance o ctic int and sin olecula o Mont r Simu ulation	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation alations of Liquids, as – Elementary Ma	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P ethods, Wiley	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford , New York, guage Englis	with theo om numbe nbles. tions, Aca Cambridg l, 1987 , 1997.	ry and exp r generator demic Pres ge Universi
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects analysis of time series, finite size effects and the series, finite size effects and the series, so the series, finite size effects and the series, so the series, series, series, and the series, and the series, and the series, series, series, series, and series, and series a</li></ul>	ance o ctic int and sin olecula o Mont r Simu ulation	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation alations of Liquids, as – Elementary Ma	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P ethods, Wiley Course lang Examinatic	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford , New York, guage Englis on language	with theo om numbe nbles. tions, Aca Cambridg l, 1987 , 1997.	ry and exp r generator demic Pres ge Universi
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature <ul> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to Press, New York, 2005</li> <li>M. P. Allen, D. J. Tildesley, Compute</li> <li>J. M. Haile, Molecular Dynamics Simu</li> </ul> </li> <li>Entry requirements <ul> <li>Recommended prerequisites</li> <li>Language</li> </ul> </li> <li>Weighting of the achievement in the Module frequency</li> </ul>	ance o ctic int and sin olecula o Mont r Simu ulation	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation alations of Liquids, as – Elementary Ma	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P ethods, Wiley Course lang Examinatic 6/120	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford , New York, guage Englis on language	with theo om numbe nbles. tions, Aca Cambridg l, 1987 , 1997.	ry and exp r generator demic Pres ge Universi
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature <ul> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to Press, New York, 2005</li> <li>M. P. Allen, D. J. Tildesley, Compute</li> <li>J. M. Haile, Molecular Dynamics Simu</li> </ul> </li> <li>Entry requirements <ul> <li>Recommended prerequisites</li> </ul> </li> <li>Language</li> <li>Weighting of the achievement in the Module frequency</li> <li>Reasons for compulsory attendance</li> </ul>	ance o ctic int and sin olecula o Mont r Simu ulation	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation alations of Liquids, as – Elementary Ma	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P ethods, Wiley Course lang Examinatic 6/120	interaction Carlos, rando namic ensen s to Applica cal Physics, ress, Oxford , New York, guage Englis on language er semester	with theo om numbe nbles. tions, Aca Cambridg l, 1987 , 1997.	ry and exp r generator demic Pres ge Universi
<ul> <li>They will learn to appreciate the import riment.</li> <li>Course content</li> <li>Molecular dynamics simulations, sympled analysis of time series, finite size effects</li> <li>Literature</li> <li>D. Frenkel, B. Smit, Understanding M San Diego, 2002</li> <li>D. P. Landau, K. Binder, A Guide to Press, New York, 2005</li> <li>M. P. Allen, D. J. Tildesley, Compute</li> <li>J. M. Haile, Molecular Dynamics Simu</li> <li>Entry requirements</li> <li>Recommended prerequisites</li> <li>Language</li> </ul>	ance o ctic int and sin olecula o Mont r Simu ulation	of computer simula eggrators, Markov of mulations in different ar Simulation – Fro e Carlo Simulation alations of Liquids, as – Elementary Ma	tions in their chain Monte C ent thermodyn om Algorithms ns in Statistic Clarendon P ethods, Wiley Course lang Examinatic 6/120 Every wint	interaction Carlos, randonamic ensen s to Applica cal Physics, ress, Oxford , New York, guage Englis on language er semester	with theo om numbe nbles. tions, Aca Cambridg l, 1987 , 1997.	ry and exp r generator demic Pres ge Universi

Modul 7010	at Interfaces"					28.7010
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	study	points
Lecture with excercises "Soft Materials		1	D		190.1	CID
at Interfaces" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ing a	chievements mu	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	tion 3			
Course achievements		essful completion of		projects		
Module examination		ten exam (120-180		1 0	(30 Min )	term nane
wordule examination	1	esentation	willi, orar e	Aammation	(00 101111.),	term pape
Qualification and program goals /	-					
The course will enable the students to un while also providing them with the basic specific applications. Examples help to d physics.	c know	ledge for improvir	ng the perform	nance of mo	dern soft i	naterials fo
Course content						
<ul> <li>Topics may vary depending on the prefe</li> <li>Thermodynamics of interfaces</li> <li>Surface tension</li> <li>Self-organization of soft matter thin fi</li> <li>Charged solid/liquid interfaces and He</li> <li>Interfacial forces and colloidal stability</li> <li>Interface induced phase transitions</li> <li>Adsorption and wetting</li> <li>Surfactants and Emulsions</li> <li>Interfacial freezing and premelting</li> <li>Liquids in nanoporous materials</li> <li>X-ray scattering and spectroscopy</li> <li>Scanning probe techniques and force n</li> </ul>	lms elmholt y	tz double layer	ypical topics	are		
Literature						
• Metin Tolan, "X-Ray Scattering from	Soft-M	[atter Thin Films"				
			. Springer (19	999).		
- Iong Alg Nielson Des MeMorres "El	monta			· · · · · · · · · · · · · · · · · · ·	ilov (9011	)
<ul> <li>Jens Als-Nielsen, Des McMorrow, "Ele</li> <li>Peter S. Pershan, Mark Schlossman, "University Press (2012).</li> </ul>		of Modern X-ray	Physics", 2nd	Edition, W		

# Entry requirements

## Recommended prerequisites

Modul 7010	Module Topical Co at Interfaces"	Module Topical Courses: "Soft Materials at Interfaces"		
Language		Course language English	1:1 0	
		Examination language Eng	flish or German	
Weighting of the achievement in th	e overall grade	6/120		
Module frequency		Annually		
Reasons for compulsory attendance	9			
Demonstration and the feat this are ded	_	Prof. Dr. Hans-Jürgen Butt, Prof. Dr. Tho-		
Persons responsible for this module		mas Palberg, Prof. Dr. F. Schmid		
Applicable to the following program	ns	MSc. Physics		
Miscellaneous		Course language: English		

Modul 753	Module Topical Courses: "Biophysics" 08.128.753				8.753	
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} {f study}$	Credit points
Lecture with excercises "Biophysics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3  SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation	according to §5 subsection 3					
Course achievements	successful completion of exercises or projects					
Module examination	1	en exam (120-180 esentation	Min.), oral e	xamination (	30 Min.), 1	term paper
Qualification and program goals /	Comp	etences				
The course gives an introduction to phe order to expose and understand common components of a cell, as well as the inter structures. The course will enable stude a physics perspective. Particular attention physics and their application to living m	n physic actions ents to ion is g	cal principles. Stud of these component understand and approximation of the second statement of the se	lents will lear ats and the for oproach phen	n about the ormation of h comena in bio	elementary ierarchica ological sy	y molecula: l functiona stems fron
Course content						
<ul> <li>There will be an introduction to living molecular players (proteins, polymers, electurers. Typical topics include:</li> <li>Stochastic dynamics, diffusion, and sine Basics of non-equilibrium thermodyna</li> <li>Physical limits to sensing</li> <li>Discharmical networks and ariticality.</li> </ul>	enzyme ngle me	s). Further topics	may vary de	-		
<ul><li>Biochemical networks and criticality</li><li>Mechanochemical coupling, molecular</li></ul>	motor	s and force generat	ion			
• Mechanochennical coupling, molecular		0	1011			

- Collective behavior and phase behavior
- Self-organization and structure formation
- X-ray scattering and the structure of proteins
- Membranes and their theoretical description

## Literature

• William Bialek, Biophysics: Searching for Principles, Princeton University Press (2013).

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	irregular
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. Thomas Speck, Prof. Dr. Friederike Schmid
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 754		lule Topical pretical solid st	Courses: ate physics		ed 08.12	8.754
Compulsory or elective module	WP					
Credit points and workload	6 LF	6  LP = 180  h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Advanced theoretical solid state physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3  SWS		
Excercises (WP)	Ü			$1 \; \mathrm{SWS}$		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	successful completion of exercises or projects					
Module examination	Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation					
Qualification and program goals $/$	Comp	etences				
Students shall get acquainted with basic They will learn fundamentals concepts o		-				- •

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.

#### **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

- 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

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Each summer semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. J. Sinova
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 800		Module Topical Courses: "Theory of Soft Matter II"				08.128.800	
Compulsory or elective module	WP				·		
Credit points and workload	6 LF	6 LP = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- Designated Degree of Contact Self Cu					Credit	
Courses and teaching methods	pe	$\mathbf{term}$	obligation	$\operatorname{time}$	$\mathbf{study}$	points	
Lecture with excercises "Theory of Soft Matter II" (WP)		2	Р		138 h	6 LP	
Lecture (WP)	V			3 SWS			
Excercises (WP)	Ü			1 SWS			
To complete the module, the follow	ving ad	chievements mus	st be made:				
Presence							
Active participation	accor	ding to §5 subsect	ion 3				
Course achievements	succe	ssful completion of	f exercises or	projects			
Module examination	Writt	en exam (90-180 N	Min.) or oral	examination	(30 Min.)		
Qualification and program goals $/$	Comp	etences					
The students get acquainted with the sta of different soft matter systems. Special to classes.		- 0		0	/ 0	-	
Course content							
Topics are selected depending on the pre- interactions in colloids and polymers, m works and rubber elasticity, structure of systems, statistical physics of interfaces,	icro sw polyel	vimmers and active ectrolytes, viscoela	e particles, Zi	imm model, i	reptation 1	nodel, net-	

- 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

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. K. Kremer, Prof. Dr. F. Schmid
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

# 3.4.2 Quantum, Atomic and Neutron Physics

Modul 729	Module Topical Courses: "Quantum Op- 08.128.729					8.729		
	$\operatorname{tics}$	(Q-Ex-1)"						
Compulsory or elective module	WP							
Credit points and workload	6 LP	h = 180 h						
<b>Duration</b> according to the study plan	1							
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points		
Lecture with excercises "Quantum Op- tics" (WP), frequently joint theoretical- experimental course		1	Р		138 h	6 LP		
Lecture (WP)	V			3 SWS				
Excercises (WP)	Ü			1 SWS				
To complete the module, the follow	ving ac	chievements mus	st be made:					
Presence								
Active participation		ding to §5 subsecti						
Course achievements		ssful completion of		1 0				
Module examination		en exam (120-180 esentation	Min.), oral ex	xamination (5	30 Min.),	term paper		
Qualification and program goals / Competences								
methods shall be discussed along with fields.	selecte	d experiments whi	ich demonstr	ate effects of	quantize	d radiation		
Course content								
<ul> <li>Basic entry course to experimental quantu jointly by experimentalists and theorists. Contents:</li> <li>Quantization of electromagnetic fields.</li> <li>correlations in the radiation field and</li> </ul>	, quant	um states of radia	• -	-theory cours	e, frequen	tly lectured		
• quantized interaction of atoms with lig	-		amiltonian					
<ul> <li>"dressed states"</li> <li>Further possible topics:</li> <li>Photon detectors</li> </ul>	3,	,						
• single photon sources and entangled p	hotons							
• Bell equations, quantum mechanical co	orrelat	ions of entangled p	boton pairs					
• cavity quantum electrodynamics								
Literature								
<ul><li>Textbooks on quantum optics and light-a</li><li>Introductory quantum optics, Gerry &amp;</li></ul>		,						
• The Quantum theroy of light, Loudon								
• Quantum optics, Scully & Zubairy								
• Quantum optics, Walls & Milburn			• Atom photon interactions, Cohen-Tannoudji, Dupont-Roc & Grynberg					
• • •	noudii	Dupont-Roc & G	rvnberg					
• Atom photon interactions, Cohen-Tan	noudji	Dupont-Roc & G	rynberg					
• Atom photon interactions, Cohen-Tan Entry requirements	noudji	Dupont-Roc & G	rynberg					
• Atom photon interactions, Cohen-Tan	noudji	Dupont-Roc & G	Course lang	guage English m language F		German		

Modul 729	Module Topical Co tics (Q-Ex-1)"	08.128.729		
Module frequency		Annually in winter term		
Reasons for compulsory attendance				
Persons responsible for this module		Prof. Dr. J. Walz		
Applicable to the following programs		MSc. Physics		
Miscellaneous		Course language: English		

Modul 803	Module Topical Courses: "Photonics (Q- Ex-2)"08.128.803					
Compulsory or elective module	WP	WP				
Credit points and workload	6  LP = 180  h					
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	$\mathbf{term}$	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Photonics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation				
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.

#### 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

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.

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Annually in summer term
Reasons for compulsory attendance	

Modul 803	Module Topical Co Ex-2)"	08.128.803		
Persons responsible for this module		Prof. Dr. K. Wendt, Prof. Dr. J, Walz		
Applicable to the following programs		MSc. Physics		
Miscellaneous		Course language: English		

Modul 804	Module Topical Courses: "Quantum In- formation (Q-Ex-3)"08.128.804					8.804
Compulsory or elective module	WP				·	
Credit points and workload	6  LP = 180  h					
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- Designated Degree of Contact Self Credit					Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Quantum In- formation " (WP), frequently joint theoretical-experimental course		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	t be made:			•
Presence						
Active participation	accor	ding to §5 subsecti	ion 3			
Course achievements	successful completion of exercises or projects					
Module examination	Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation					
Qualification and program goals /	Comp	etences				
Based on their knowledge of atomic an	nd qua	ntum physics as v	vell as quant	um mechan	ics, the st	udents will

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.

#### **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.

#### 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

Entry requirements

#### Recommended prerequisites

Modul 804	Module Topical Co formation (Q-Ex-3)	08.128.804		
Language		Course language English Examination language Eng	lish or German	
Weighting of the achievement in th	e overall grade	6/120		
Module frequency		Annually in summer term		
Reasons for compulsory attendance	9			
Persons responsible for this module		Prof. Dr. F. Schmidt-Kaler		
Applicable to the following programs		MSc. Physics		
Miscellaneous	Course language: English			

Modul 805	Module Topical Courses: "Precision fun- damental physics (Q-Ex-4)"08.128.805					8.805
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Precision fun- damental physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		en exam (120-180 esentation	Min.), oral e	xamination (	30 Min.), t	erm paper
Qualification and program goals /	Comp	etences				

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.

#### **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

 $\bullet\,$  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

- Textbooks in atomics physics
- proceedings of summer-schools
- publications close to current research.

Entry requirements	
Recommended prerequisites	
Languaga	Course language English
Language	Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Annually in winter term
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. J. Walz
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

# 3.4.3 Nuclear and Particle Physics

Modul 730	Module Topical Courses: "Statistics, Da- ta Analysis and Simulation"08.128.730					
Compulsory or elective module	WP				I	
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Statistics, Da- ta Analysis and Simulation" (WP)		1	P		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ŭ Ü			1 SWS		
To complete the module, the follow	Ű	chiovomonts mu	t ho modo	15005	1	
Presence		linevenients mu	st be made.			
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements		essful completion o		projects		
Module examination		$\frac{120-180}{120-180}$			(30 Min )	term naner
	or pr	esentation	willi, ), orar c.		(50 1/111.),	term paper
Qualification and program goals $/$	$\operatorname{Comp}$	etences				
<b>Course content</b> The following areas shall be covered:						
<ul> <li>Probability distributions and the stati</li> </ul>	istical o	description of data	;			
• error propagations and the estimation	of par	ameters;				
• significance levels and decisions on hy	pothes	es;				
• Monte Carlo methods, as well as						
• Statistical analysis methods.						
Literature						
• R.J. Barlow, Statistics						
• Glen Cowan, Statistical data analysis						
• Olaf Behnke, Data analysis in high en	ergy p	hysics				
Entry requirements						
Recommended prerequisites						
Language				guage Englis on language		· German
Weighting of the achievement in th	Veighting of the achievement in the overall grade6/120					
Module frequency			Every sum	mer semester	r	
Reasons for compulsory attendance						
Persons responsible for this module			Prof. Dr. N			
Applicable to the following program	$\mathbf{ns}$		MSc. Physi			
Miscellaneous				guage: Englis	-	

Courses and teaching methods       pe       term       obligation       time       study       point         Lecture with excercises "Particle Detectors" (WP)       1       P       138 h       6 LP         Lecture (WP)       V       1       SWS       1       6         Excercises (WP)       Ú       1       NS       1       6       LP         To complete the module, the following achievements must be made:       1       SWS       1       1       NS       1       1       NS       1       1       NS       1       NS <th>Modul 731</th> <th colspan="5">Module Topical Courses: "Particle De- tectors" 08.128.7</th> <th>8.731</th>	Modul 731	Module Topical Courses: "Particle De- tectors" 08.128.7					8.731
Duration according to the study plan       1         Courses and teaching methods       Ty- pe       Designated term       Degree of obligation       Contact time       Self study       Credit point         Lecture with excercises "Particle Detec- tors" (WP)       1       P       138 h       6 LP         Lecture (WP)       V       3 SWS           Lecture (WP)       V       3 SWS           To complete the module, the following achievements must be made:            Presence        according to §5 subsection 3            Course achievements       successful completion of exercises or projects             Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation             Qualification and program goals / Competences               The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.	Compulsory or elective module	WP					
Courses and teaching methods       Ty- pe       Designated term       Degree of obligation       Contact time       Self study       Cred: point         Lecture with excercises "Particle Detec- tors" (WP)       1       P       138 h       6 LP         Lecture (WP)       V       3 SWS       1       1       Self       Self       Cred: point         Excercises (WP)       V       3 SWS       1       1       Self       6 LP         Lecture (WP)       V       3 SWS       1       1       Self       6 LP         Excercises (WP)       Ü       1 SWS       1       SWS       1         Active participation       according to §5 subsection 3       Course achievements       successful completion of exercises or projects         Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation       Gualification and program goals / Compretences         The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         Outract the following subjects shall be covered:       •       •       •<	Credit points and workload	6 LF	P = 180 h				
Courses and teaching methodspctermobligationtimestudypointLecture with excercises "Particle Detectors" (WP)1P138 h6 LPLecture (WP)V03 SWS00Excercises (WP)Ú1 SWS00To complete the module, the following achievements must be made:1 SWS00Presenceaccording to §5 subsection 355Course achievementssuccessful completion of exercises or projects5Module examinationwritten exam (120-180 Min.), oral examination (30 Min.), true pair presentation1 SWSOurse achievementssuccessful completion of exercises or projects5Module examinationWritten exam (120-180 Min.), oral examination (30 Min.), true pair presentation1 SWSOurse achievementssuccessful completion of exercises studies used in particle, hadron, nu or presentationanalysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and completer science) play import projects.Particle sources and accelerators;ImplementsImplementsDetection methods for charged and neutral radiation;ImplementsImplementsParticle detectors to measure time, energy, momentum and particle type;Applications in complex detector systems.ImplementsLiteratureK. Kleinknecht, Detectors for particle radiationImplementsImplementsCourse language Eurlistes </th <th><b>Duration</b> according to the study plan</th> <th>1</th> <th></th> <th></th> <th></th> <th></th> <th></th>	<b>Duration</b> according to the study plan	1					
tors" (WP)       I       P       I38 h       6 LP         Lecture (WP)       V       3 SWS       I       I         Excercises (WP)       Ú       1 SWS       I	Courses and teaching methods	-		-			Credit points
Excercises (WP)       Ú       1 SWS       1 SWS         To complete the module, the following achievements must be made:         Presence       according to §5 subsection 3         Active participation       according to §5 subsection 3         Course achievements       successful completion of exercises or projects         Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation         Qualification and program goals / Competences       The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         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.       Literature         K. Kleinknecht, Detectors for particle radiation       C. Grupen, B. Shwartz, Particle Detectors         Entry requirements       Course language English			1	Р		138 h	6 LP
To complete the module, the following achievements must be made:         Presence         Active participation       according to §5 subsection 3         Course achievements       successful completion of exercises or projects         Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation         Qualification and program goals / Competences	Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Presence       according to §5 subsection 3         Active participation       according to §5 subsection 3         Course achievements       successful completion of exercises or projects         Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation         Qualification and program goals / Competences       The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         Course content       The following subjects shall be covered:         Particle sources and accelerators;       0         Detection methods for charged and neutral radiation;       0         Data acquisition;       0         Particle detectors to measure time, energy, momentum and particle type;       0         Applications in complex detector systems.       1         Literature       K. Kleinknecht, Detectors for particle radiation         C. Grupen, B. Shwartz, Particle Detectors       Entry requirements         Recommended prerequisites       Course language English	Excercises (WP)	Ü			1 SWS		
Active participation       according to §5 subsection 3         Course achievements       successful completion of exercises or projects         Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation         Qualification and program goals / Competences       The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         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.       Literature         • K. Kleinknecht, Detectors for particle radiation       • C. Grupen, B. Shwartz, Particle Detectors         Entry requirements       Course language English	To complete the module, the follow	ving a	chievements mus	t be made:			
Course achievements       successful completion of exercises or projects         Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation         Qualification and program goals / Competences       The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         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.       Literature         • K. Kleinknecht, Detectors for particle radiation       • C. Grupen, B. Shwartz, Particle Detectors         Entry requirements       Course language English	Presence						
Module examination       Written exam (120-180 Min.), oral examination (30 Min.), term pa or presentation         Qualification and program goals / Competences         The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         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.         Literature         • K. Kleinknecht, Detectors for particle radiation         • C. Grupen, B. Shwartz, Particle Detectors         Entry requirements         Recommended prerequisites	Active participation	accor	ding to §5 subsecti	on 3			
or presentation         Qualification and program goals / Competences         The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.         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.         Literature         • K. Kleinknecht, Detectors for particle radiation         • C. Grupen, B. Shwartz, Particle Detectors         Entry requirements         Recommended prerequisites	Course achievements	succe	essful completion of	exercises or	projects		
The course provides an overview of the detection, read-out and analysis techniques used in particle, hadron, nu ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics. 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. Literature • K. Kleinknecht, Detectors for particle radiation • C. Grupen, B. Shwartz, Particle Detectors Entry requirements Recommended prerequisites Course language English	Module examination			Min.), oral e	xamination (	(30 Min.), 1	term paper
ar, and astroparticle physics. The goal is to provide a solid basis for the successful completion of a master's the Cross disciplinary aspects (solid state physics, electronics, mathematics, and computer science) play import roles. Therefore the course is also suitable to students that focus on other areas of physics.          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.         Literature         • K. Kleinknecht, Detectors for particle radiation         • C. Grupen, B. Shwartz, Particle Detectors         Entry requirements         Recommended prerequisites	Qualification and program goals /	Comp	etences				
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.  Literature  K. Kleinknecht, Detectors for particle radiation  C. Grupen, B. Shwartz, Particle Detectors  Entry requirements Recommended prerequisites  Course language English	ar, and astroparticle physics. The goal is Cross disciplinary aspects (solid state p	to pro hysics,	vide a solid basis fo electronics, mathe	r the success matics, and	ful completio computer sci	on of a masi ience) play	ter's thesis.
<ul> <li>Particle sources and accelerators;</li> <li>Detection methods for charged and neutral radiation;</li> <li>Data acquisition;</li> <li>Particle detectors to measure time, energy, momentum and particle type;</li> <li>Applications in complex detector systems.</li> <li>Literature         <ul> <li>K. Kleinknecht, Detectors for particle radiation</li> <li>C. Grupen, B. Shwartz, Particle Detectors</li> </ul> </li> <li>Entry requirements         <ul> <li>Recommended prerequisites</li> <li>Course language English</li> </ul> </li> </ul>	Course content						
<ul> <li>Data acquisition;</li> <li>Particle detectors to measure time, energy, momentum and particle type;</li> <li>Applications in complex detector systems.</li> <li>Literature         <ul> <li>K. Kleinknecht, Detectors for particle radiation</li> <li>C. Grupen, B. Shwartz, Particle Detectors</li> </ul> </li> <li>Entry requirements         <ul> <li>Recommended prerequisites</li> <li>Course language English</li> </ul> </li> </ul>							
<ul> <li>Data acquisition;</li> <li>Particle detectors to measure time, energy, momentum and particle type;</li> <li>Applications in complex detector systems.</li> <li>Literature         <ul> <li>K. Kleinknecht, Detectors for particle radiation</li> <li>C. Grupen, B. Shwartz, Particle Detectors</li> </ul> </li> <li>Entry requirements         <ul> <li>Recommended prerequisites</li> <li>Course language English</li> </ul> </li> </ul>	• Detection methods for charged and ne	eutral r	adiation;				
<ul> <li>Particle detectors to measure time, energy, momentum and particle type;</li> <li>Applications in complex detector systems.</li> <li>Literature         <ul> <li>K. Kleinknecht, Detectors for particle radiation</li> <li>C. Grupen, B. Shwartz, Particle Detectors</li> </ul> </li> <li>Entry requirements         <ul> <li>Recommended prerequisites</li> <li>Course language English</li> </ul> </li> </ul>	-						
<ul> <li>Applications in complex detector systems.</li> <li>Literature         <ul> <li>K. Kleinknecht, Detectors for particle radiation</li> <li>C. Grupen, B. Shwartz, Particle Detectors</li> </ul> </li> <li>Entry requirements         <ul> <li>Recommended prerequisites</li> <li>Course language English</li> </ul> </li> </ul>		ergy, n	nomentum and par	ticle type;			
Literature         • K. Kleinknecht, Detectors for particle radiation         • C. Grupen, B. Shwartz, Particle Detectors         Entry requirements         Recommended prerequisites         Course language English			Ĩ	v <b>i</b> /			
<ul> <li>K. Kleinknecht, Detectors for particle radiation</li> <li>C. Grupen, B. Shwartz, Particle Detectors</li> <li>Entry requirements</li> <li>Recommended prerequisites</li> </ul>							
C. Grupen, B. Shwartz, Particle Detectors  Entry requirements Recommended prerequisites  Course language English		radiat	ion				
Recommended prerequisites Course language English							
Recommended prerequisites Course language English	Entry requirements						
Course language English							
Language Examination language English or German	Language						German

Language	Course language English
Language	Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every winter semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. M. Schott
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 732	Module Topical Courses: "Cosmology 08.12 and General Relativity"					28.732
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	$\mathbf{study}$	points
Lecture with excercises "Cosmology and General Relativity" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3  SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		ten exam (120-180 esentation	Min.), oral ex	xamination (	(30 Min.),	term paper
Qualification and program goals /	Comp	etences				
Qualification and program goals / The lectures' program goal is to provide the current concepts and phenomena of Course content	e a bas	ic understanding o	f the theory of	of General R	telativity a	as well as of
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma	e a basi cosmol ferentia v, big-b	ic understanding o ogy. l geometry, Einste ang nucleosynthesi	in equation,	Schwarzschil	d metric,	black holes,
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark mathematical Literature	e a bas cosmol ferentia 7, big-b atter a	ic understanding o ogy. l geometry, Einste ang nucleosynthesi	in equation,	Schwarzschil	d metric,	black holes,
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode	e a bas cosmol ferentia 7, big-b atter a	ic understanding o ogy. l geometry, Einste ang nucleosynthesi	in equation,	Schwarzschil	d metric,	black holes,
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode <b>Entry requirements</b>	e a bas cosmol ferentia 7, big-b atter a	ic understanding o ogy. l geometry, Einste ang nucleosynthesi	in equation,	Schwarzschil	d metric,	black holes,
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode	e a bas cosmol ferentia 7, big-b atter a	ic understanding o ogy. l geometry, Einste ang nucleosynthesi	in equation, s, cosmic mic	Schwarzschil rrowave back guage Englis	d metric, <sup>†</sup> ground, st	black holes, cructure de-
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b>	e a bas cosmol ferentia , big-b atter a elson	ic understanding o ogy. l geometry, Einste ang nucleosynthesi nd dark energy.	in equation, s, cosmic mic s, cosmic mic Course lang Examinatic	Schwarzschil crowave back	d metric, <sup>†</sup> ground, st	black holes, cructure de-
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b> Weighting of the achievement in the	e a bas cosmol ferentia , big-b atter a elson	ic understanding o ogy. l geometry, Einste ang nucleosynthesi nd dark energy.	in equation, s, cosmic mic	Schwarzschil rrowave back guage Englis	d metric, <sup>†</sup> ground, st	black holes, cructure de-
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b> Weighting of the achievement in the Module frequency	e a bas: cosmol ferentia 7, big-b atter a elson	ic understanding o ogy. l geometry, Einste ang nucleosynthesi nd dark energy.	in equation, s, cosmic mic s, cosmic mic Course lang Examinatic	Schwarzschil rrowave back guage Englis	d metric, <sup>†</sup> ground, st	black holes, cructure de-
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b> Weighting of the achievement in the Module frequency Reasons for compulsory attendance	e a bas cosmol ferentia 7, big-b atter a elson he over	ic understanding o ogy. l geometry, Einste ang nucleosynthesi nd dark energy.	in equation, s, cosmic mice s, cosmic mice Course lang Examinatio 6/120	Schwarzschil crowave back guage Englis on language	d metric, <sup>†</sup> ground, st	black holes, cructure de-
The lectures' program goal is to provide the current concepts and phenomena of <b>Course content</b> General coordinate transformations, diff Friedmann-Robertson-Walker cosmology velopment in the early universe, dark ma <b>Literature</b> e.g. Carroll, Wald, Kolb & Turner, Dode <b>Entry requirements</b> <b>Recommended prerequisites</b> <b>Language</b> Weighting of the achievement in the Module frequency	e a basi cosmol ferentia , big-b atter a elson ne over	ic understanding o ogy. l geometry, Einste ang nucleosynthesi nd dark energy.	in equation, s, cosmic mic s, cosmic mic Course lang Examinatic	Schwarzschil rowave back guage Englis on language I I. Neubert	d metric, <sup>†</sup> ground, st	black holes, cructure de-

Modul 733	Module Topical Courses: "Symmetries in Physics"				n 08.12	08.128.733	
Compulsory or elective module	WP						
Credit points and workload	6 LF	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} {f study}$	Credit points	
Lecture with excercises "Symmetries in Physics" (WP)		1	Р		138 h	6 LP	
Lecture (WP)	V			3 SWS			
Excercises (WP)	Ü			1 SWS			
To complete the module, the follow	ving a	chievements mus	st be made:			-	
Presence							
Active participation	accor	ding to §5 subsecti	ion 3				
Course achievements	succe	essful completion of	f exercises or	projects			
Module examination		ten exam (120-180 esentation	Min.), oral e	xamination (	30 Min.),	term paper	
The lectures' program goal is to provide <b>Course content</b> Group theory, representations, unitary sy							
physics.		files, file groups, ap					
Literature							
e.g. Georgi, Tung							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English or German				
Weighting of the achievement in th	e over	rall grade	6/120				
Module frequency							
Reasons for compulsory attendance							
Persons responsible for this module			Prof. Dr. M. Neubert				
Applicable to the following programs			MSc. Physics				
Applicable to the following program Miscellaneous	ns		, v	cs guage: Englis			

Modul 734	Module Topical Courses: "Modern Me- 08.128.734						
	thods in Theoretical High Energy, Par-						
		ticle and Nuclear Physics"					
			U				
Compulsory or elective module	WP						
Credit points and workload	6 LH	P = 180 h					
<b>Duration</b> according to the study plan	1						
	Ty-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points	
Lecture with excercises "Modern Me-					Ī		
thods in Theoretical High Energy, Par-		1	Р		138 h	6 LP	
ticle and Nuclear Physics" (WP)							
Lecture (WP)	V			3 SWS			
Excercises (WP)	Ü			1 SWS			
To complete the module, the follow	ving a	chievements mus	t be made:				
Presence							
Active participation	accor	ding to §5 subsection	ion 3				
Course achievements	succe	essful completion of	exercises or	projects			
Module examination	Writ	ten exam (120-180	Min.), oral e	xamination	(30 Min.),	term paper	
	or pr	esentation					
Qualification and program goals /	Comp	etences					
The lectures' program goal is to provide	e a basi	ic understanding of	a topic relat	ted to current	nt research	in the field	
of high energy, particle and nuclear phy	vsics. A	n additional goal i	s to teach th	e methods	which are	required for	
the masters's thesis.							
Course content							
Concerning to the lecturer the focus is p	utona	current scientifical	topic from th	o following	rosoarch ar	one: oloctro	
weak and strong interactions, lattice ga			-	-			
theory, functional integration in quantum							
the standard model (e.g. supersymmetr	y, strin	ng theory) and othe	ers. Lectures	of this mod	ule are off	ered by dif-	
ferent lecturers and topics can change e			e a student o	an subscrib	e to this m	nodule more	
than once and the module will not be co	ounted	as identical.					
Literature							
various textbooks, publications close to	scionec						
	science	;	1				
Entry requirements							
Recommended prerequisites			Course 1:		-h		
Language			Course language English				
Weighting of the achievement in th		rall grade	Examination language English or German 6/120				
Module frequency			0/120				
Reasons for compulsory attendance	ρ						
reasons for computery attenuance							
			Prof Dr N	I Neubort	Prof Dr I	H Wittig	
Persons responsible for this modul	e			I. Neubert,	Prof. Dr. H	I. Wittig	
	e		MSc. Physi			I. Wittig	

Modul 735	Module Topical Courses: "Accelerator Physics"08.128.735						
Compulsory or elective module	WP				·		
Credit points and workload	6 LP	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points	
Lecture with excercises "Accelerator Physics" (WP)		1	Р		138 h	6 LP	
Lecture (WP)	V			3  SWS			
Excercises (WP)	Ü			1 SWS			
To complete the module, the follow	ving ad	chievements mus	st be made:				
Presence							
Active participation	accor	ding to §5 subsect	ion 3				
Course achievements	succe	ssful completion of	f exercises or	projects			
Module examination		Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation					
Qualification and program goals /	Comp	etences					

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

#### **Course content**

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

#### Literature

• H. Wiedemann, Particle Accelerator Physics Bd. 1&2

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every winter semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. K. Aulenbacher
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 737	Module Topical Courses: "Astroparticle08.128.737Physics"					8.737
Compulsory or elective module	WP					
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	$\mathbf{term}$	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Astroparticle Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving ad	chievements mus	t be made:			
Presence						
Active participation	accor	ding to §5 subsecti	ion 3			
Course achievements	succe	ssful completion of	exercises or	projects		
Module examination		Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation				
Qualification and program goals /	Comp	etences				

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.

#### **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.

- A. Liddle, An introduction to modern cosmology
- P. Schneider, Extragalaktische Astronomie und Kosmologie
- C. Grupen, Astroteilchenphysik
- D. Perkins, Particle Astrophysics

	1
Entry requirements	
Recommended prerequisites	
Language	Course language English
Language	Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every summer semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. U. Oberlack
Applicable to the following programs	MSc. Physics

Modul 737	Module Topical Courses: "Astroparticle Physics"	08.128.737
Miscellaneous	Course language: English	

Modul 738	Mod sics'	lule Topical Co ,	ourses: "Pa	article Phy	y- 08.12	8.738
Compulsory or elective module	WP					
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and tenshing methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Particle Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving ad	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		en exam (120-180 esentation	Min.), oral e	xamination (	(30 Min.), t	term paper
Qualification and program goals /	Comp	etences				

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.

## **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.

- 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

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. M. Schott
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

		lule Topical C ticle Physics"	Courses: "	Theoretica	d 08.12	8.809
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} {f study}$	Credit points
Lecture with excercises "Theoretical Particle Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsecti	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		ten exam (120-180 esentation	Min.), oral e	xamination (3	30 Min.),	term paper
Qualification and program goals /	Comp	etences				
The lecture course "Theoretical Particl Quantum Field Theory". The lectures' pr of quantum field theory which are require	rogram	goal is to provide	a basic under	standing of c		
Course content Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics			QED, renorma	alization grou		
Path integral formalism, quantum correct			QED, renorma	alization grou		
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics.	D), sp		QED, renorma	alization grou		
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature	D), sp		QED, renorma	alization grou		
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z	D), sp		QED, renorma	alization grou		
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z Entry requirements	D), sp		2ED, renorma ry breaking, 2	alization grou	iism, stan	dard model
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z Entry requirements Recommended prerequisites	CD), sp ee	ontaneous symmet.	2ED, renorma ry breaking, 2 Course lan	lization grou Higgs mechar guage English	iism, stan	dard model
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z Entry requirements Recommended prerequisites Language	CD), sp ee	ontaneous symmet.	2ED, renorma ry breaking, 2 Course lang Examinatio 6/120	lization grou Higgs mechar guage English	iism, stan	dard model
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z Entry requirements Recommended prerequisites Language Weighting of the achievement in the	CD), sp ee ee	ontaneous symmet.	2ED, renorma ry breaking, 2 Course lang Examinatio 6/120	alization grou Higgs mechar guage English on language E	iism, stan	dard model
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency	2D), sp ee ne over	ontaneous symmet.	2ED, renorma ry breaking, 2 Course lang Examinatio 6/120	alization grou Higgs mechar guage English on language E	iism, stan	dard model
Path integral formalism, quantum correct theories, quantum chromodynamics (QC of particle physics. Literature Peskin & Schroeder, Ryder, Schwartz, Z Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency Reasons for compulsory attendance	2D), sp ee ee ee ee ee	ontaneous symmet.	2ED, renorma ry breaking, 2 Course lang Examinatio 6/120 Usually eve	alization grou Higgs mechar guage English on language F ery semester . Weinzierl	iism, stan	dard model

Modul 751		lule Topical ( lear Physics"	Courses: "	Theoretic	al 08.12	28.751
Compulsory or elective module	WP				I	
Credit points and workload	6 LP	= 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Theoretical Nuclear Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving ac	hievements mu	st be made:			
Presence						
Active participation	accore	ding to §5 subsect	ion 3			
Course achievements	succes	ssful completion o	f exercises or	projects		
Module examination	1	en exam (120-180 esentation	Min.), oral ex	xamination	(30 Min.),	term paper
	01 p10					
Qualification and program goals / The aim of this course is to provide stud introduction to modern nuclear theories when possible, the subject will be linked Course content	<b>Compe</b> lents wi and top	e <b>tences</b> ith a survey of nu pics. While the fo	cus is on the	oretical aspe	cts of nucl	ear physics
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked	<b>Compe</b> lents wi and top to rece s, Theo s for nu	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics crophysics. lear spectra
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods	<b>Compe</b> lents wi and top to rece s, Theo s for nu	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics crophysics. lear spectra
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element	Compe lents wi and top to rece s, Theo s for nu nts.	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta uclei, Many-body	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics prophysics. lear spectra
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g.	Compe lents wi and top to rece s, Theo s for nu nts.	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta iclei, Many-body ysics.	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics prophysics. lear spectra
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nuclear	Compe lents wi and top to rece s, Theo s for nu nts. lear Ph in a Nu	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta uclei, Many-body ysics. tshell.	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics crophysics.
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nuc • Carlos A. Bertulani, Nuclear Physics in	Compe lents wi and top to rece s, Theo s for nu nts. lear Ph in a Nu	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta uclei, Many-body ysics. tshell.	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics crophysics.
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nucleies Carlos A. Bertulani, Nuclear Physics is • Kenneth S. Krane, Introductory Nucleies Entry requirements	Compe lents wi and top to rece s, Theo s for nu nts. lear Ph in a Nu	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta uclei, Many-body ysics. tshell.	cus is on theo progress and a a and gamma	pretical aspe applications, decays, Ty	cts of nucl e.g. to ast pes of nuc	ear physics crophysics.
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nuclear Physics is • Kenneth S. Krane, Introductory Nuclear Physics is	Compe lents wi and top to rece s, Theo s for nu nts. lear Ph in a Nu	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta uclei, Many-body ysics. tshell.	cus is on theo progress and a a and gamma methods for r	decays, Typ decays, Typ nuclei, Nucle	cts of nucl e.g. to ast pes of nuc ear reactio	ear physics crophysics. lear spectra ons, Nuclea
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nucleies • Carlos A. Bertulani, Nuclear Physics is • Kenneth S. Krane, Introductory Nucleies Entry requirements Recommended prerequisites Language	Compe lents wi and top to rece s, Theo s for nu nts. lear Phy ear Phy	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta cclei, Many-body ysics. tshell. rsics.	cus is on theo orogress and a a and gamma methods for r Course lang Examinatio	decays, Typuclei, Nucle	cts of nucl e.g. to ast pes of nuc ear reactio	ear physics. crophysics. lear spectra ons, Nuclea
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nucleies Carlos A. Bertulani, Nuclear Physics if • Kenneth S. Krane, Introductory Nucleies Entry requirements Recommended prerequisites Language Weighting of the achievement in the	Compe lents wi and top to rece s, Theo s for nu nts. lear Phy ear Phy	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta cclei, Many-body ysics. tshell. rsics.	cus is on theo progress and a a and gamma methods for r	guage Englis on language	cts of nucl e.g. to ast pes of nuc ear reactions sh	ear physics crophysics. lear spectra ons, Nuclea
The aim of this course is to provide studies introduction to modern nuclear theories when possible, the subject will be linked <b>Course content</b> Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element <b>Literature</b> Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nucleies Carlos A. Bertulani, Nuclear Physics if • Kenneth S. Krane, Introductory Nucleies Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency	Compe lents wi and top to rece s, Theo s for nu nts. lear Phy in a Nu ear Phy	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta cclei, Many-body ysics. tshell. rsics.	cus is on theo progress and a a and gamma methods for r Course lang Examinatio 6/120	guage Englis on language	cts of nucl e.g. to ast pes of nuc ear reactions sh	ear physics crophysics. lear spectrons, Nuclea
The aim of this course is to provide study introduction to modern nuclear theories when possible, the subject will be linked Course content Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element Literature Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nuclear • Carlos A. Bertulani, Nuclear Physics if • Kenneth S. Krane, Introductory Nuclea Entry requirements Recommended prerequisites Language Weighting of the achievement in the	Compe lents wi and top to rece s, Theo s for nu nts. lear Phy he over	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta cclei, Many-body ysics. tshell. rsics.	cus is on theo progress and a a and gamma methods for r Course lang Examinatio 6/120	guage Englis manuales	cts of nucl e.g. to ast pes of nuc ear reactions sh	ear physics. crophysics. lear spectra ons, Nuclea
The aim of this course is to provide study introduction to modern nuclear theories when possible, the subject will be linked Course content Introduction to nuclei and nuclear force and EM transitions, Few-body methods astrophysics and formation of the element Literature Text books on nuclear physics, e.g. • Samuel S.M. Wong, Introductory Nucle • Carlos A. Bertulani, Nuclear Physics i • Kenneth S. Krane, Introductory Nucle Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency Reasons for compulsory attendance	Compe lents wi and top to rece s, Theo s for nu nts. lear Phy in a Nu ear Phy e	etences ith a survey of nu pics. While the fo ent experimental p ory for alpha, beta cclei, Many-body ysics. tshell. rsics.	cus is on theo orogress and a a and gamma methods for m Course lang Examinatio 6/120 Winter sem	pretical aspe applications, decays, Typ nuclei, Nucle guage Englis on language nester . Bacca	cts of nucl e.g. to ast pes of nuc ear reactions sh	ear physics. crophysics. lear spectra ons, Nuclea

Modul 746	Module Topical Courses: "Introduction to Lattice Gauge Theory"				on 08.12	08.128.746	
Compulsory or elective module	WP						
Credit points and workload	6 LF	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Introduction to Lattice Gauge Theory" (WP)		1	Р		138 h	6 LP	
Lecture (WP)	V			3 SWS			
Excercises (WP)	Ü			1 SWS			
To complete the module, the follow	ving a	chievements mus	st be made:				
Presence							
Active participation	accor	ding to §5 subsect	ion 3				
Course achievements	succe	ssful completion of	f exercises or	projects			
Module examination		en exam (120-180 esentation	Min.), oral e	xamination (	(30  Min.), 1	term paper	
Qualification and program goals /	Comp	etences					
The lectures' program goal is to provide applications to problems in particle and required for pursuing a master's thesis in	ł nucle	ar physics. A part			0 0	v	
Course content							
Discretization of PDEs by finite difference	es nati	n integral in quantu	m mechanics	· Euclidean c	orrelation f	functions in	

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.

- 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.

Entry requirements	
Recommended prerequisites	
Language	Course language English
Language	Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Irregular
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. H. Wittig
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

		lule Topical C tring Theory"	Courses: "I	ntroductio	on 08.12	28.760
Compulsory or elective module	WP				<b>I</b>	
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Introduction to String Theory" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \ \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ing a	chievements mu	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	tion 3			
Course achievements	succe	essful completion o	f exercises or	projects		
Module examination		ten exam (120-180 esentation	Min.), oral e	xamination	(30 Min.),	term pape
Common combount			-	the maters's		
Course content Classical bosonic string, quantisation (l strings, introduction to conformal field t Literature various textbooks, publications close to s • Zwiebach: A First Course in String Th • Blumenhagen, Lüst, Theisen: Basic Co • Polchinski: String Theory, Vol. 1 & 2, • Green, Schwarz, Witten: String Theor • Becker, Becker, Schwarz: String Theor	heory, science neory, oncept Camb y, Vol.	string amplitudes. c, e.g.: Cambridge Univer s of String Theory ridge University P 1 & 2, Cambridge	n integral, BF sity Press 200 , Springer 201 ress 1998; e University F	RST formalis 04; .2; Press 1987;	sm), D-br:	
<ul> <li>Classical bosonic string, quantisation (1 strings, introduction to conformal field t</li> <li>Literature</li> <li>various textbooks, publications close to s</li> <li>Zwiebach: A First Course in String TI</li> <li>Blumenhagen, Lüst, Theisen: Basic Co</li> <li>Polchinski: String Theory, Vol. 1 &amp; 2,</li> <li>Green, Schwarz, Witten: String Theor</li> <li>Becker, Becker, Schwarz: String Theor 2007</li> </ul>	heory, science neory, oncept Camb y, Vol.	string amplitudes. c, e.g.: Cambridge Univer s of String Theory ridge University P 1 & 2, Cambridge	n integral, BF sity Press 200 , Springer 201 ress 1998; e University F	RST formalis 04; .2; Press 1987;	sm), D-br:	
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Modul 766	Module Topical Courses: "Effective Field       08.128.766         Theories"					8.766
Compulsory or elective module	WP					
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and topshing methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Effective Field Theories" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving ad	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	ssful completion of	f exercises or	projects		
Module examination		en exam (120-180 esentation	Min.), oral e	xamination (	30 Min.), t	erm paper
Qualification and program goals /	Comp	etences				

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.

#### 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.

- 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

Entry requirements	
Recommended prerequisites	
Language	Course language English
Language	Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Irregular
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. M. Neubert
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

		lule Topical roparticle Phy		Theoretic	al 08.12	28.762
Compulsory or elective module	WP				•	
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Theoretical Astroparticle Physics" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mu	ist be made:		•	
Presence						
Active participation	accor	ding to §5 subsec	tion 3			
Course achievements	succe	essful completion of	of exercises or	projects		
Module examination		ten exam $(120-180)$ esentation	) Min.), oral e	xamination	(30 Min.),	term paper
Qualification and program goals /	Comp	etences				
astroparticle physics. Its goal is to prepa dark matter, neutrinos and related topic experimental or theoretical astroparticle	re stud s and t	lents to understand o prepare them for		scientific lit	terature on	cosmology.
astroparticle physics. Its goal is to prepa dark matter, neutrinos and related topic experimental or theoretical astroparticle <b>Course content</b>	re stud s and t physic	lents to understan to prepare them for es.	nd the current or their own re	scientific lit search proje	terature on ects (Maste	a cosmology er / PhD) in
astroparticle physics. Its goal is to prepa dark matter, neutrinos and related topic experimental or theoretical astroparticle	n, expa he Uni rophysic	lents to understan o prepare them for es. nsion of the Uniververse; dark matter ical experiments) cplain the smallne	erse); big bang er (production ; the cosmic m ss of neutrino r	scientific lit search proje nucleosynth in the early atter-antim nasses; theo	esis; cosmi y Universe atter asym	c microwave by therma metry; high
astroparticle physics. Its goal is to prepa dark matter, neutrinos and related topic experimental or theoretical astroparticle <b>Course content</b> The big bang theory (Friedmann equation background; formation of structure in the freeze-out, searches in terrestrial and ast energy cosmic rays; neutrinos (mechanism	n, expa he Uni rophysic	lents to understan o prepare them for es. nsion of the Uniververse; dark matter ical experiments) cplain the smallne	erse); big bang er (production ; the cosmic m ss of neutrino r	scientific lit search proje nucleosynth in the early atter-antim nasses; theo	esis; cosmi y Universe atter asym	c microwave by thermal metry; high
astroparticle physics. Its goal is to prepa dark matter, neutrinos and related topic experimental or theoretical astroparticle <b>Course content</b> The big bang theory (Friedmann equation background; formation of structure in the freeze-out, searches in terrestrial and ast energy cosmic rays; neutrinos (mechanism of neutrino oscillations; impact of neutrino	are stud s and t physic n, expa he Uni rophys as to ex- nos on	lents to understan o prepare them for es. nsion of the Uniververse; dark matter ical experiments) cplain the smallne cosmology; super	erse); big bang er (production ; the cosmic m ss of neutrino r	scientific lit search proje nucleosynth in the early atter-antim nasses; theo	esis; cosmi y Universe atter asym	c microwave by thermal metry; high
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astroparticle physics. Its goal is to prepa dark matter, neutrinos and related topic experimental or theoretical astroparticle Course content The big bang theory (Friedmann equation background; formation of structure in the freeze-out, searches in terrestrial and ast energy cosmic rays; neutrinos (mechanism of neutrino oscillations; impact of neutrino Literature various textbooks, publications close to a Entry requirements Recommended prerequisites Language Weighting of the achievement in the Module frequency Reasons for compulsory attendance	re stud s and t physic n, expa he Uni rophys ns to ex nos on science	lents to understan o prepare them for cs. nsion of the Uniververse; dark matter ical experiments) cplain the smallne cosmology; super	nd the current or their own re erse); big bang er (production ; the cosmic m ss of neutrino mova neutrino Course lang Examinatic 6/120 Irregular	scientific lit search proje nucleosynth in the early atter-antim nasses; theo s); axions guage Englis on language . Kopp	esis; cosmi- y Universe atter asym ry and phe	a cosmology er / PhD) in c microwave by therma metry; high nomenology

Modul 764	Module Topical Courses: "Amplitudes08.128.764and Precision Physics at the LHC"					
Compulsory or elective module	WP					
Credit points and workload	6 LP = 180 h					
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
	pe	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Amplitudes and Precision Physics at the LHC" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the following achievements must be made:						
Presence						
Active participation	according to §5 subsection 3					
Course achievements	successful completion of exercises or projects					
Module examination	Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation					
Qualification and program goals /	Comp	etences				
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						

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.

#### **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).

- 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

Entry requirements			
Recommended prerequisites			
Language	Course language English		
Language	Examination language English or German		
Weighting of the achievement in the overall grade	6/120		
Module frequency	Irregular		
Reasons for compulsory attendance			
Persons responsible for this module	Prof. Dr. J. Henn, Prof. Dr. S. Weinzierl		
Applicable to the following programs	MSc. Physics		
Miscellaneous	Course language: English		

Modul 747	Module Topical Courses: "Functional Methods and Exact Renormalization Group"08.128.747					
Compulsory or elective module	WP					
Credit points and workload	6 LP = 180 h					
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
	pe	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Functional Methods and Exact Renormalization Group" (WP)		1	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the following achievements must be made:						
Presence						

Presence	
Active participation	according to §5 subsection 3
Course achievements	successful completion of exercises or projects
Module examination	Written exam (120-180 Min.), oral examination (30 Min.), term paper or presentation

### 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.

#### **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 Thetavacua).
- (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.

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Irregular
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. M. Reuter
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

	Modu Parti	ıle Topical cle Physics"	Courses:	"Advance	ed 08.1	28.806
Compulsory or elective module	WP					
Credit points and workload	6 LP	= 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту- ре	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Advanced Par- ticle Physics" (WP)		2	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving acl	nievements mu	st be made:		•	
Presence						
Active participation	accord	ing to §5 subsect	tion 3			
Course achievements	success	sful completion of	of exercises or	projects		
Module examination	Writte	n exam (90-180	Min.) or oral	examination	(30 Min.)	)
Qualification and program goals /	Compe	tences				
course provides the students with advant thesis in a related research area.	nced kn	owledge that wi	ll help in com	pleting an	experimen	tal master's
thesis in a related research area. Course content The content of the course is variable and						tal master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> </ul>						ital master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> <li>Strong interaction,</li> </ul>						tal master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> <li>Strong interaction,</li> <li>Electro-weak interaction, as well as</li> </ul>	l will ty	pically include of	ne of the follo			tal master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> <li>Strong interaction,</li> <li>Electro-weak interaction, as well as</li> <li>Models for the unification and extrems</li> </ul>	l will ty	pically include of	ne of the follo			tal master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> <li>Strong interaction,</li> <li>Electro-weak interaction, as well as</li> <li>Models for the unification and extrems</li> <li>Literature</li> </ul>	l will ty	pically include of	ne of the follo			tal master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> <li>Strong interaction,</li> <li>Electro-weak interaction, as well as</li> <li>Models for the unification and extrems</li> <li>Literature</li> <li>C. Berger, Elementarteilchenphysik</li> </ul>	l will ty sion of th	pically include of ne Standard Mod	ne of the follo			tal master's
<ul> <li>thesis in a related research area.</li> <li>Course content</li> <li>The content of the course is variable and</li> <li>Lepton scattering at high energies,</li> <li>Strong interaction,</li> <li>Electro-weak interaction, as well as</li> <li>Models for the unification and extrems</li> <li>Literature</li> <li>C. Berger, Elementarteilchenphysik</li> <li>D. Griffiths, Introduction to Elementarteilchenphysik</li> </ul>	l will ty sion of the ty Parti	pically include of ne Standard Mod cles	ne of the follo	wing subject	ts:	tal master's
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Modul 807	Modu Chapt	le Topical ters on Suba	Courses: tomic Phys		ed   08.12	28.807
	Chapt		tonne i nys	103		
Compulsory or elective module	WP					
Credit points and workload	6 LP =	= 180 h				
<b>Duration</b> according to the study plan	1					
	Ty- I	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe t	erm	obligation	$\mathbf{time}$	study	points
Lecture with excercises "Advanced Chapters on Subatomic Physics" (WP)	د 2	2	Р		138 h	6 LP
Lecture (WP)	V			$3 \; \mathrm{SWS}$		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ing ach	ievements mu	st be made:			-
Presence						
Active participation	accordi	ng to §5 subsec	tion 3			
Course achievements	success	ful completion of	of exercises or	projects		
Module examination	Written	exam (90-180	Min.) or oral	examination	(30 Min.)	
Qualification and program goals /	Compet	ences			, ,	
Course content	aster's th	nesis in related	ill provide the fields.	e essential kr	nowledge 1	necessary t
successfully complete an experimental m	aster's th agnetic a ns of had	The lecture we nesis in related and hadronic pr rons; effective t	ill provide the fields.	e essential kn ation experim roscopy, sym	nowledge n nents; reso umetry an	necessary t onances, de d structure
successfully complete an experimental m <b>Course content</b> Current experimental methods, electrom cays, form factors and structure function of hadrons, the impact of hadron physis discussed for all topics.	aster's th agnetic a ns of had	The lecture we nesis in related and hadronic pr rons; effective t	ill provide the fields.	e essential kn ation experim roscopy, sym	nowledge n nents; reso umetry an	necessary t onances, de d structure
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successfully complete an experimental m <b>Course content</b> Current experimental methods, electrom cays, form factors and structure function of hadrons, the impact of hadron physic discussed for all topics. <b>Literature</b> Several text books, e.g.	aster's th agnetic a ns of had	The lecture we nesis in related and hadronic pr rons; effective t	ill provide the fields.	e essential kn ation experim roscopy, sym	nowledge n nents; reso umetry an	necessary t onances, de d structure
<ul> <li>successfully complete an experimental m</li> <li>Course content</li> <li>Current experimental methods, electrom cays, form factors and structure function of hadrons, the impact of hadron physic discussed for all topics.</li> <li>Literature</li> <li>Several text books, e.g.</li> <li>B. Povh et al., Teilchen und Kerne</li> <li>D. H. Perkins, High Energy Physics</li> </ul>	aster's th nagnetic a ns of had cs on pro	. The lecture we nesis in related is and hadronic prons; effective t ecision tests of	ill provide the fields.	e essential kn ation experim roscopy, sym	nowledge n nents; reso umetry an	necessary t onances, de d structure
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Modul 808	Mod Astro	ule Topical oparticle- and		"Advance sics"	d 08.12	28.808
Compulsory or elective module	WP					
Credit points and workload	6 LP	= 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} {f study}$	Credit points
Lecture with excercises "Advanced Astroparticle- and Astrophysics" (WP)		2	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving ac	hievements mus	st be made:			
Presence						
Active participation	accord	ling to §5 subsect	ion 3			
Course achievements	succes	sful completion of	f exercises or	projects		
Module examination	Writte	en exam (90-180 N	Min.) or oral	examination	(30 Min.)	
Qualification and program goals /	Compe	tences				
This course covers special aspects of as perimental methods and results. The co- completing an experimental master's the	troparti ourse pr	cle physics and a covides the studer	nts with adva			
perimental methods and results. The co	troparti purse pr esis in a e emphas	cle physics and a covides the studer related research a sis will be put on r	nts with adva area.	nced knowle	dge that	will help in
perimental methods and results. The co- completing an experimental master's the <b>Course content</b> Depending on interest of the lecturer, the subjects:	troparti purse pr esis in a e emphas chesis, d	cle physics and a covides the studer related research a sis will be put on r ark components),	nts with adva area. nuclear- or ast	nced knowle	dge that	will help in he following
<ul> <li>perimental methods and results. The concompleting an experimental master's the completing an experimental master's the completing on interest of the lecturer, the subjects:</li> <li>Cosmology (early universe, nucleosynt)</li> <li>Stars (formation, energy production as a concompletion of the lecture of the lecture of the lecture of the lecture)</li> </ul>	troparti purse pr esis in a e emphas chesis, d	cle physics and a covides the studer related research a sis will be put on r ark components),	nts with adva area. nuclear- or ast	nced knowle	dge that	will help in he following
<ul> <li>perimental methods and results. The concompleting an experimental master's the completing on interest of the lecturer, the subjects:</li> <li>Cosmology (early universe, nucleosynt)</li> <li>Stars (formation, energy production at nisms, etc.).</li> </ul>	troparti purse pr esis in a e emphas chesis, d	cle physics and a covides the studer related research a sis will be put on r ark components),	nts with adva area. nuclear- or ast	nced knowle	dge that	will help in he following
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Modul 816	Module Topical Courses: "Advanced Ac-       08.128.816         celerator Physics"       0.00000000000000000000000000000000000					8.816
Compulsory or elective module	WP					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	time	study	points
Lecture with excercises "Advanced Accelerator Physics" (WP)		2	Р		138 h	6 LP
Lecture (WP)	V			3 SWS		
Excercises (WP)	Ü			1 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	accor	ding to §5 subsect	ion 3			
Course achievements	succe	essful completion of	f exercises or	projects		
Module examination	Writt	ten exam (90-180 N	Min.) or oral	examination	(30 Min.)	
Qualification and program goals /	Comp	otoncos				

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.

#### 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.

#### 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

Entry requirements	
Recommended prerequisites	
Language	Course language English Examination language English or German
Weighting of the achievement in the overall grade	6/120
Module frequency	Every summer semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. K. Aulenbacher
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

# 3.5 Focus Courses

The list of Focus courses changes from semester to semester and is only available in Jogustine. For the general description of the module see below:

Modul 650	Mo	Module "Focus Courses"				3.128.650
Compulsory or elective module	W					
Credit points and workload	3-9	LP = 90-270 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Topical Course"		1/2	W		69 h	3 LP
Lecture	V			$1.5 \ \mathrm{SWS}$		
Excercises (WP)	Ü			$0.5 \ \mathrm{SWS}$		
Advanced Seminar	OS	1/2	W	2  SWS	69 h	3 LP
Industrial Internship	Р	1/2	W	2  SWS	69 h	3 LP
To complete the module, the follow	-		st be made:			
Presence	OS, I	Р				
Active participation	accor	ding to §5 subsect	tion 3			
Course achievements	succe	essful completion of	of exercises or	projects		
Module examination	This	module will not b	e graded			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language				guage Englis on language		German
Weighting of the achievement in th	e ove	rall grade	3-9/120			
Module frequency			Every seme	ester		
Reasons for compulsory attendance	Э					
Persons responsible for this module	е		Prof. Dr. M	I. Ostrick		
Applicable to the following program	$\mathbf{ns}$		MSc. Physi	cs		
Miscellaneous						

## 3.6 Research Phase

Modul 660	Specialization				M.08	.128.660
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	1					
Courses and too shing methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
Specialization (P)		3	Р	60 h	390 h	15 LP
To complete the module, the follow	ving ad	chievements mus	st be made:			
Presence						
Active participation		ing on the researc ssion.	h project wit	h at least or	ne weekly	supervising
Course achievements						
Module examination	A con	ncluding presentati	on to the wo	rking group.		
Qualification and program goals /	Comp	etences				
Within a working group the course inter	-			1.1		

• 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.

#### **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.

Entry requirements	All teaching units of the master's courses from the 1st and 2nd semester, with the pos- sible exception of the Topical Course II, the Advanced Course and Seminar II.
Recommended prerequisites	All teaching units of the master's courses from the 1st and 2nd semester, with the pos- sible exception of the Topical Course II, the Advanced Course and Seminar II.
Language	Course language German/English Examination language German/English
Weighting of the achievement in the overall grade	0/120 (the module does not enter in the over- all grade)
Module frequency	Every semester
Reasons for compulsory attendance	
Persons responsible for this module	Prof. Dr. M. Ostrick
Applicable to the following programs	MSc. Physics
Miscellaneous	Course language: English

Modul 670	Methodological Knowledge M					128.670
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Methodological Knowledge (P)		3	Р	60 h	390 h	15 LP
To complete the module, the follow	ving ac	chievements mus	t be made:		1	1
Presence						
Active participation	Learr discu	ing the methods i ssion	in addition to	o at least or	ne weekly s	supervising
Course achievements						
Module examination	Basec portfe	l on a concluding p olio	presentation t	to the working	ig group or	creating a
Qualification and program goals /	Comp	etences				
<ul> <li>the special knowledge necessary to successfully composition.</li> </ul>		· ·			on a specif	ic scientific
Course content						
For the topic of the master's thesis from the student will become familiar with th		- 0	-		etical worl	
			1	naster's thes	sis.	king group,
Entry requirements			-	pecialization		king group,
Entry requirements Recommended prerequisites			Module "S		"	king group,
			Module "Sp Module "Sp Course lang	pecialization	" " n/English	
Recommended prerequisites	e over	all grade	Module "Sp Module "Sp Course lang	pecialization pecialization guage Germa	" " n/English	
Recommended prerequisites Language	e over	all grade	Module "Sp Module "Sp Course lang Examinatio	pecialization pecialization guage Germa on language (	" " n/English	
Recommended prerequisites Language Weighting of the achievement in th		all grade	Module "Sp Module "Sp Course lang Examinatio 15/120	pecialization pecialization guage Germa on language (	" " n/English	
Recommended prerequisites Language Weighting of the achievement in the Module frequency	;	all grade	Module "Sp Module "Sp Course lang Examinatio 15/120	pecialization pecialization guage Germa on language ester	" " n/English	
Recommended prerequisites Language Weighting of the achievement in th Module frequency Reasons for compulsory attendance	9 9	all grade	Module "Sp Module "Sp Course lang Examination 15/120 Every seme	pecialization pecialization guage Germa on language ester I. Ostrick	" " n/English	

Modul 969	Mas	ster Thesis			A.08	.128.969
Compulsory or elective module	Р				<b>I</b>	
Credit points and workload	30 L	P = 900 h				
<b>Duration</b> according to the study plan	1					
	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	$\mathbf{study}$	points
Master thesis (P)		4	Р	110 h	760 h	29 LP
Final Colloquium (P)		4	Р	2 h	28 h	1 LP
To complete the module, the follow	ing a	chievements mus	st be made:			
Presence						
Active participation	1	loping the new res veekly supervising		ontiers of kn	owledge w	ith at leas
Course achievements	Write	ten master thesis				
Module examination	Final	colloquium in from	nt of the work	ing group o	r a wider a	audience
Course content						
Course content For the topic of the master thesis from t student will develop new results at the f			experimental	or theoretic	al working	group, th
For the topic of the master thesis from t			Module "S	or theoretic pecialization dge" of the 1	" and "M	ethodologi
For the topic of the master thesis from t student will develop new results at the f			Module "Sp cal Knowled Module "Sp	pecialization	" and "Me research ph	ethodologi nase ethodologi
For the topic of the master thesis from t student will develop new results at the f Entry requirements			Module "Sj cal Knowle Module "Sj cal Knowle Course lang	pecialization dge" of the 1 pecialization	" and "Me research ph " and "Me research ph an/English	ethodologi nase ethodologi nase
For the topic of the master thesis from t student will develop new results at the f Entry requirements Recommended prerequisites	rontier	s of knowledge.	Module "Sj cal Knowle Module "Sj cal Knowle Course lang Examinatio	pecialization dge" of the r pecialization dge" of the r guage Germa	" and "Me research ph " and "Me research ph an/English German/E	ethodologi nase ethodologi nase
For the topic of the master thesis from t student will develop new results at the f Entry requirements Recommended prerequisites Language Weighting of the achievement in th	rontier	s of knowledge.	Module "Sj cal Knowle Module "Sj cal Knowle Course lang Examinatio	pecialization dge" of the r pecialization dge" of the r guage Germa in language ( § 16 of the	" and "Me research ph " and "Me research ph an/English German/E	ethodologi nase ethodologi nase
For the topic of the master thesis from t student will develop new results at the f Entry requirements Recommended prerequisites Language	rontier e over	s of knowledge.	Module "Sp cal Knowled Module "Sp cal Knowled Course lang Examinatic 30/120 (see Every seme	pecialization dge" of the r pecialization dge" of the r guage Germa n language \$ 16 of the ster	" and "Me research ph " and "Me research ph an/English German/E	ethodologi nase ethodologi nase
For the topic of the master thesis from t student will develop new results at the f Entry requirements Recommended prerequisites Language Weighting of the achievement in th Module frequency Reasons for compulsory attendance Persons responsible for this module	e over	s of knowledge.	Module "Sj cal Knowlee Module "Sj cal Knowlee Course lang Examinatic 30/120 (see	pecialization dge" of the r pecialization dge" of the r guage Germa n language \$ 16 of the ster	" and "Me research ph " and "Me research ph an/English German/E	ethodologi nase ethodologi nase
For the topic of the master thesis from t student will develop new results at the f Entry requirements Recommended prerequisites Language Weighting of the achievement in th Module frequency Reasons for compulsory attendance	e over	s of knowledge.	Module "Sj cal Knowled Module "Sj cal Knowled Course lang Examinatic 30/120 (see Every seme Prof. Dr. M MSc. Physi	pecialization dge" of the r pecialization dge" of the r guage Germa m language \$ 16 of the ster I. Ostrick	" and "Me research ph " and "Me research ph an/English German/E PO)	ethodologi nase ethodologi nase

# 3.7 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.

## 3.7.1 Chemistry

Modul 1005	Nuc	Nuclear Chemistry				.032.1005
Compulsory or elective module	Р					
Credit points and workload	9 LF	P = 270 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} {f study}$	Credit points
Lecture "Einführung in die Kernche- mie" (WP)	V	1	Р	2 SWS	39 h	2 LP
Excercises "Einführung in die Kernche- mie" (WP)	Ü	1	Р	1 SWS	49.5 h	2 LP
Kernchemisches Praktikum I (WP)	Pr	1	Р	$5 \ \mathrm{SWS}$	97.5 h	5 LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	succe	essful completion of	f the exercises	5		
Course achievements						
Module examination	Oral	examination (30-4	5 Min.)			
Qualification and program goals / Course content	Comp	etences				
Entry requirements						
Recommended prerequisites						
Language				guage Englis on language l		
Weighting of the achievement in th	e ove	rall grade	9/120			
Module frequency						
Reasons for compulsory attendance	e					
Persons responsible for this module	е		Prof. Dr. F	. Rösch		
Applicable to the following program	ns		MSc Physil	X		
Miscellaneous			Further de	guage: Germ tails can be of the Chem	found in t	

Modul 1006	Nuclear Chemistry (with one additional advanced course)M.09.032.1006				032.1006	
Compulsory or elective module	Р					
Credit points and workload	12 L	P = 270 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	time	study	points
Lecture "Einführung in die Kernche- mie" (WP)	V	1	Р	2 SWS	39 h	2 LP

Modul 1006		elear Chemistry anced course)	(with one	e addition	al M.09	.032.1006
Excercises "Einführung in die Kernche- mie" (WP)	Ü	1	Р	1 SWS	49.5 h	2 LP
Kernchemisches Praktikum I (WP)	Pr	1	Р	5 SWS	97.5 h	5 LP
Spezialvorlesung I (WP)		1	Р	2 SWS	69 h	3 LP
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation	succe	essful completion of	the exercise	s		
Course achievements						
Module examination	Oral	examination (30-45	5 Min.)			
Qualification and program goals /	Comp	etences				
Course content Entry requirements			[			
Recommended prerequisites						
Language			Course language English Examination language English			
Weighting of the achievement in th	e over	rall grade	12/120			
Module frequency						
Reasons for compulsory attendance	e					
Persons responsible for this module			Prof. Dr. F. Rösch			
Applicable to the following program	ns					
Miscellaneous			Course language: German Further details can be found in the module handbooks of the Chemistry programs.			

Modul 1007		lear Chemistry anced courses)	r (with two	o additiona	al M.09.	.032.1007
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 270 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	study	points
Lecture "Einführung in die Kernche- mie" (WP)	V	1	Р	2 SWS	39 h	2 LP
Excercises "Einführung in die Kernche- mie" (WP)	Ü	1	Р	1 SWS	49.5 h	2 LP
Kernchemisches Praktikum I (WP)	Pr	1	Р	5  SWS	97.5 h	5  LP
Spezialvorlesung I (WP)		1	Р	2  SWS	69 h	3 LP
Spezialvorlesung II (WP)		1	Р	2  SWS	69 h	3 LP
To complete the module, the follow	ving ad	chievements mus	t be made:		•	
Presence						
Active participation	succe	ssful completion of	the exercises	3		
Course achievements						
Module examination	Oral examination (30-45 Min.)					
Qualification and program goals / Competences						

Modul 1007	Nuclear Chemistry advanced courses)	(with two additional	M.09.032.1007	
Course content				
Entry requirements				
Recommended prerequisites				
Language	Course language English Examination language English			
Weighting of the achievement in th	ne overall grade	15/120		
Module frequency				
Reasons for compulsory attendance	e			
Persons responsible for this module	е	Prof. Dr. F. Rösch		
Applicable to the following program	ns			
Miscellaneous	Course language: German Further details can be found in the module handbooks of the Chemistry programs.			

Modul 1010	Introduction to Theoretical Chemistry					0.032.1010	
Compulsory or elective module	Р						
Credit points and workload	9 LF	P = 270  h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	time	study	points	
Lecture/Excercises "Einführung in die Theoretische Chemie" (WP)	V	1	Р	$5 \mathrm{SWS}$	127 h	6 LP	
Lab course "Computerchemie" (WP)	Pr	1	Р	$5 \ \mathrm{SWS}$	37 h	3 LP	
To complete the module, the follow	ving a	chievements mus	t be made:		•	1	
Presence							
Active participation	successful completion of the exercises						
Course achievements							
Module examination	Written exam (120 min) or oral examination (30 min)						
Qualification and program goals /	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English				
			Examination language English				
Weighting of the achievement in th	le over	rall grade	9/120				
Module frequency							
Reasons for compulsory attendance							
Persons responsible for this module			Prof. Dr. J	ürgen Gauß			
Applicable to the following program	ns			~			
Miscellaneous			Course language: German Further details can be found in the german version of the module handbook				

Modul 1011	Theoretical Chemistry				M.09	M.09.032.1011	
Compulsory or elective module	Р						
Credit points and workload	12 I	AP = 360 h					
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture/Excercises "Theoretische Che- mie 1" (WP)	V	1	Р	3 SWS	88 h	4 LP	
Lab course "Theoretische Chemie 1" (WP)	Pr	1	Р	$5 \mathrm{SWS}$	7 h	2 LP	
Lecture/Excercises "Theoretische Che- mie 2" (WP)	V	1	Р	3 SWS	88 h	4 LP	
Lab course "Computerchemie" (WP)	Pr	1	Р	$5 \ \mathrm{SWS}$	7 h	2 LP	
To complete the module, the follow	ving a	chievements mu	st be made:		•	-	
Presence							
Active participation	successful completion of the exercises						
Course achievements	Kolloquium zum Praktikum Computerchemie						
Module examination	Writ	ten exam (120 min	) or oral exar	mination (30	min)		
Qualification and program goals / $\ $	$\operatorname{Comp}$	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	e ove	rall grade	12/120				
Module frequency							
Reasons for compulsory attendance	е						
Persons responsible for this module	е		Prof. Dr. Jürgen Gauß				
Applicable to the following program	ns		MSc Physil				
Miscellaneous			Course language: German Further details can be found in the german version of the module handbook				

#### 3.7.2 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.

Modul xx1	Con	Computer Science I			M.08	.079.xx1
Compulsory or elective module	P					
Credit points and workload	9 LF	P = 270 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- Designated Degree of Contact Self					
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
Course A (WP)	V	1	Р	2 SWS	69 h	3 LP
Excercises to Course A (WP)	V	1	Р	1 SWS	79.5 h	3 LP
Lab course A (WP)	V	1	Р	2 SWS	69 h	3 LP
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation	succe	ssful completion of	the exercises	3		
Course achievements	succesfull completion of the lab course					
Module examination	Writt	en exam (120 min)	) or oral exar	nination (30	min)	
Qualification and program goals $/$	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
			Examination language English			
Weighting of the achievement in th	ne over	all grade	9/120			
Module frequency						
Reasons for compulsory attendance						
Persons responsible for this module						
Applicable to the following program	ns					
Miscellaneous			Course language: German Further details can be found in the modu- le handbooks of the Computer Science pro- grams.			

Modul xx2	Computer Science II	M.08.079.xx2
Compulsory or elective module	Р	
Credit points and workload	12  LP = 360  h	
<b>Duration</b> according to the study plan	1	

Modul xx2	Con	nputer Science	II		M.08	.079.xx2
	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	time	study	points
Course A (WP)	V	1	Р	2 SWS	69 h	3 LP
Excercises to Course A (WP)	V	1	Р	1 SWS	$79.5 \ h$	3 LP
Course B (WP)	V	1	Р	2 SWS	69 h	3 LP
Excercises to Course B (WP)	V	1	Р	1 SWS	$79.5~\mathrm{h}$	3 LP
To complete the module, the follow	ving a	chievements mu	st be made:			
Presence						
Active participation	succe	essful completion o	f the exercises	8		
Course achievements	Written exam (120 min) or oral examination (30 min) for each of the two courses					each of the
Module examination	Avera	age of the two cour	rse achieveme	nts		
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
			Examination language English			
Weighting of the achievement in th	ne over	rall grade	12/120			
Module frequency						
Reasons for compulsory attendanc						
Persons responsible for this modul						
Applicable to the following program	ms			0		
Miscellaneous			Further de	guage: Germa tails can be ks of the Co	found in	

Modul xx3	Con	Computer Science III				.079.xx3
Compulsory or elective module	P					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	time	study	points
Course A (WP)	V	1	Р	2 SWS	69 h	3 LP
Excercises to Course A (WP)	V	1	Р	1 SWS	$79.5 \ h$	3 LP
Course B (WP)	V	1	Р	2 SWS	69 h	3 LP
Excercises to Course B (WP)	V	1	Р	1 SWS	$79.5~\mathrm{h}$	3 LP
Lab course A or B (WP)	V	1	Р	2 SWS	69 h	3 LP
To complete the module, the follow	ving a	chievements mus	t be made:	·		
Presence						
Active participation	succe	ssful completion of	the exercises	8		
Course achievements	Written exam (120 min) or oral examination (30 min) for each of the two courses					
	Succe	esfull completion of	t the lab cour	se		
Module examination	Avera	age of the course ac	chievements			

Modul xx3	Computer Science III	M.08.079.xx3							
Qualification and program goals / Competences									
Course content									
Entry requirements									
Recommended prerequisites									
Language		Course language English Examination language English							
Weighting of the achievement in th	e overall grade 15/120								
Module frequency									
Reasons for compulsory attendance									
Persons responsible for this module	2								
Applicable to the following program	ns								
Miscellaneous		e: German can be found in the modu- f the Computer Science pro-							

Modul xx4	Con	Computer Science IV				.079.xx4	
Compulsory or elective module	Р	Р					
Credit points and workload	16 L	P = 480 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	$\begin{array}{c} \mathbf{Self} \\ \mathbf{study} \end{array}$	Credit points	
Course A (WP)	V	1	Р	2 SWS	69 h	3 LP	
Excercises to Course A (WP)	V	1	Р	1 SWS	79.5 h	3 LP	
Course B (WP)	V	1	Р	2  SWS	69 h	3 LP	
Excercises to Course B (WP)	V	1	Р	1 SWS	79.5 h	3 LP	
Lab course A or B (WP)	V	1	Р	2  SWS	99 h	4 LP	
To complete the module, the follow	ving a	chievements mus	st be made:			1	
Presence							
Active participation	succe	ssful completion of	f the exercises	3			
Course achievements	Written exam (120 min) or oral examination (30 min) for each of the two courses Seminar presentation					each of the	
Module examination	Avera	age of the course a	chievements				
Qualification and program goals / Course content	Comp	etences					
Entry requirements							
Recommended prerequisites							
Language				Course language English Examination language English			
Weighting of the achievement in th	e over	rall grade	15/120		_		
Module frequency							
Reasons for compulsory attendance	Э						
Persons responsible for this module							

Modul xx4	Computer Science IV		M.08.079.xx4
Applicable to the following program			
Miscellaneous		Course language: German Further details can be fou le handbooks of the Comp grams.	

## 3.7.3 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 successfully 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

Modul 4140	Inte	International Trade			M.03	3.184.4140	
Compulsory or elective module	Р						
Credit points and workload	6 LF	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
a) Lecture: International Trade: Theory and Policy	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: International Trade: Theory and Policy	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the follow	ving a	chievements mus	st be made:		-		
Presence							
Active participation							
Course achievements							
Module examination	Writt	en exam (120 min	)				
Qualification and program goals /	Comp	etences					
Course content							
<b>T</b>							
Entry requirements							
Recommended prerequisites					1		
Language			Course language English Examination language English				
Weighting of the achievement in th		all grade	6/120	Jii language	Eligiisii		
Module frequency	le over	an graue	Winter terr	m			
Reasons for compulsory attendance	<u>`</u>		WILLOCI UCI				
Persons responsible for this module				hilipp Harm	s		
Applicable to the following program				Prof. Dr. Philipp Harms M.Sc. Physik			
reprictable to the following program			Language:				
Miscellaneous			Further de	tails can be the module h		the german	

Modul 4105	Mik	roökonomie II			M.03	.184.4105
Compulsory or elective module	P					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and too shing matheda	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	$\mathbf{term}$	obligation	time	$\mathbf{study}$	points
a) Lecture: Mikroökonomie II	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Mikroökonomie II	Ü	1	Р	1 SWS	$49,5~{\rm h}$	2 LP
To complete the module, the follow	ving ad	chievements mus	t be made:			
Presence						
Active participation						
Course achievements						
Module examination	Writt	en exam (120 min	)			
Qualification and program goals /	Comp	etences				
Course content						

Modul 4105	Mikroökonomie II		M.03.184.4105	
Entry requirements				
Recommended prerequisites				
T		Course language English		
Language		Examination language Eng	lish	
Weighting of the achievement in th	e overall grade	6/120		
Module frequency		Winter term		
Reasons for compulsory attendance	e			
Persons responsible for this module	e	JProf. Dr. Wondratschek		
Applicable to the following program	ns	M.Sc. Physik		
		Language: German		
Miscellaneous		Further details can be fou	nd in the german	
		version of the module hand	lbook	

Modul 4115	Öffe	ntliche Finanzo	en		M.03	.184.4115
Compulsory or elective module	Р					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	$\mathbf{study}$	points
a) Lecture: Öffentliche FInanzen	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Öffentliche FInanzen	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation						
Course achievements						
Module examination	Write	en exam (120 min	)			
Qualification and program goals $/$	Comp	etences				
Course content						
			_			
Entry requirements						
Recommended prerequisites						
Language			Course language English			
				on language	English	
Weighting of the achievement in th	ne over	rall grade	6/120			
Module frequency			Winter terr	n		
Reasons for compulsory attendance						
Persons responsible for this module				aniel Schun	k	
Applicable to the following program	$\mathbf{ns}$		M.Sc. Phys	sik		
			Language:			
Miscellaneous				tails can be		he german
			version of t	he module h	nandbook	

Modul 4120	Wir	tschaftspolitik			M.03	.184.4120
Compulsory or elective module	P					
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	$\mathbf{term}$	obligation	$\mathbf{time}$	study	points
a) Lecture: Wirtschaftspolitik	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Wirtschaftspolitik	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving ad	chievements mus	st be made:			1
Presence						
Active participation						
Course achievements						
Module examination	Writt	en exam (120 min	)			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						

Modul 4120	Wirtschaftspolitik		M.03.184.4120	
Language		Course language English		
Language		Examination language Eng	glish	
Weighting of the achievement in th	ne overall grade	6/120		
Module frequency		Winter term		
Reasons for compulsory attendance	е			
Persons responsible for this module	e	JunProf. Dr. Iryna Stewe	n	
Applicable to the following program	ms	M.Sc. Physik		
		Language: German		
Miscellaneous		Further details can be fou	nd in the german	
		version of the module hand	lbook	

Modul 4145	Intertemporale Optimierung			M.03	3.184.4145		
Compulsory or elective module	Р						
Credit points and workload	6 LF	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
a) Lecture: Intertemporale Optimie- rung	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: Intertemporale Optimie- rung	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the follow	ving a	chievements mus	st be made:			-	
Presence							
Active participation							
Course achievements							
Module examination	Writt	ten exam (120 min	)				
Qualification and program goals $/$	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English				
			Examination language English				
Weighting of the achievement in th	le over	rall grade	6/120				
Module frequency			Winter terr	n			
Reasons for compulsory attendance							
Persons responsible for this module				Prof. Dr. Klaus Wälde			
Applicable to the following program	ns		M.Sc. Phys				
Miscellaneous				German tails can be he module h		the german	

Modul 4405	Micro Econometrics			M.03	.184.4405	
~						
Compulsory or elective module	P					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and too shing mathada	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	$\mathbf{term}$	obligation	$\mathbf{time}$	$\mathbf{study}$	points
a) Lecture: Micro Econometrics	V	1	Р	2  SWS	99 h	4 LP
b) Exercises: Micro Econometrics	Ü	1	Р	1 SWS	$49,5~{\rm h}$	2 LP
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation						
Course achievements						
Module examination	Writt	en exam (120 min	)			
Qualification and program goals / Competences						
Course content						

Modul 4405	Micro Econometrics	3	M.03.184.4405	
Entry requirements				
Recommended prerequisites				
T		Course language English		
Language		Examination language Eng	çlish	
Weighting of the achievement in the	overall grade	6/120		
Module frequency		Winter term		
Reasons for compulsory attendance				
Persons responsible for this module		Prof. Dr. Reyn van Ewijk		
Applicable to the following program	s	M.Sc. Physik		
		Language: English		
Miscellaneous		Further details can be four	nd in the german	
		version of the module hand	lbook	

Modul 4125	Exchange Rates and International Capi- tal Markets M.03.184.4125					.184.4125
Compulsory or elective module	P					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
a) Lecture: Exchange Rates and Inter- national Capital Markets	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Exchange Rates and In- ternational Capital Markets	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving a	chievements mu	st be made:		•	
Presence						
Active participation						
Course achievements						
Module examination	Writt	ten exam $(120 \text{ min})$	L)			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English Examination language English			
Weighting of the achievement in th	le over	all grade	6/120			
Module frequency			Summer te	rm		
Reasons for compulsory attendance	e					
Persons responsible for this module	odule Prof. Dr. Philipp Harms					
Applicable to the following program	ns		M.Sc. Phys			
Miscellaneous			Language: English Further details can be found in the german version of the module handbook			

Modul 4110	Mak	kroökonomie II			M.03	M.03.184.4110	
Compulsory or elective module	P						
Credit points and workload	6 LF	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	time	study	points	
a) Lecture: Makroökonomie II	V	1	Р	2  SWS	99 h	4 LP	
b) Exercises: Makroökonomie II	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the follow	ving a	chievements mus	st be made:				
Presence							
Active participation							
Course achievements							
Module examination	Written exam (120 min)						
Qualification and program goals / Competences							

Modul 4110	Makroökonomie II		M.03.184.4110	
Course content				
Entry requirements				
Recommended prerequisites				
Language		Course language English Examination language English		
Weighting of the achievement in th	ne overall grade	6/120		
Module frequency		Summer term		
Reasons for compulsory attendance	e			
Persons responsible for this module	e	Prof. Dr. Klaus Wälde		
Applicable to the following program	ms	M.Sc. Physik		
Miscellaneous		Language: English Further details can be fou version of the module hand	0	

Modul 4410	Zeit	reihenanalyse			M.03	.184.4410
Compulsory or elective module	Р					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
a) Lecture: Zeitreihenanalyse	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Zeitreihenanalyse	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving a	chievements mus	st be made:		•	
Presence						
Active participation						
Course achievements						
Module examination	Write	en exam (120 min	)			
Qualification and program goals $/$	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
				on language	English	
Weighting of the achievement in th	le over	all grade	6/120			
Module frequency			Summer te	rm		
Reasons for compulsory attendance						
Persons responsible for this module			N.N.			
Applicable to the following program	ns		M.Sc. Phys			
			Language: German			
Miscellaneous				tails can be		he german
			version of t	he module h	andbook	

Modul 4205	Rec	Rechnungslegung nach HGB				M.03.184.4205	
Compulsory or elective module	Р	P					
Credit points and workload	6 LP	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	${f Self} \ {f study}$	Credit points	
a) Lecture: Rechnungslegung nach HGB	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: Rechnungslegung nach HGB	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the follow	ing ad	chievements mus	st be made:				
Presence							
Active participation							
Course achievements							
Module examination	Writt	ten exam $(120 \text{ min})$	)				
Qualification and program goals /	Comp	etences					
Course content							

Modul 4205	Rechnungslegung nach HGB		M.03.184.4205	
Entry requirements				
Recommended prerequisites				
T		Course language English		
Language		Examination language English		
Weighting of the achievement in the	6/120			
Module frequency		Winter term		
Reasons for compulsory attendance				
Persons responsible for this module		Prof. Dr. Stefan Rammert		
Applicable to the following programs	5	M.Sc. Physik		
		Language: German		
Miscellaneous		Further details can be fou	nd in the german	
		version of the module hand	lbook	

Modul 4210	Stei	iern			M.03	.184.4210
Compulsory or elective module	Р					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	study	points
a) Lecture: Steuern	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Steuern	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation						
Course achievements						
Module examination	Write	en exam (120 min	)			
Qualification and program goals $/$	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
				on language l	English	
Weighting of the achievement in th	ne over	all grade	6/120			
Module frequency			Winter terr	n		
Reasons for compulsory attendance	e					
Persons responsible for this module	e		Prof. Dr. R	oland Euler		
Applicable to the following program	ns		M.Sc. Phys	ik		
Miscellaneous				German tails can be he module h		he german

Modul 4220	Fina	Finanzierung				M.03.184.4220	
Compulsory or elective module	P						
Credit points and workload	6 LP	P = 180 h					
<b>Duration</b> according to the study plan	1						
Courses and too shing methods	Ту-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	ре	$\mathbf{term}$	obligation	$\mathbf{time}$	$\mathbf{study}$	points	
a) Lecture: Finanzierung	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: Finanzierung	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the follow	ving ad	chievements mus	st be made:				
Presence							
Active participation							
Course achievements							
Module examination	Writt	ten exam (120 min	)				
Qualification and program goals /	Comp	etences					
Course content							
			-				
Entry requirements							
Recommended prerequisites							

Modul 4220	Finanzierung		M.03.184.4220	
Language		Course language English Examination language Eng	rlish	
Weighting of the achievement in th	e overall grade	6/120	511011	
Module frequency		Winter term		
Reasons for compulsory attendance	9			
Persons responsible for this module	е	Prof. Dr. Siegfried Trautmann		
Applicable to the following program	ns	M.Sc. Physik		
Miscellaneous		Language: German Further details can be fou version of the module hand	Ŭ	

Modul 4215	Con	trolling			M.03	.184.4215
Compulsory or elective module	Р					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	study	points
a) Lecture: Controlling	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Controlling	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving a	chievements mus	st be made:			1
Presence						
Active participation						
Course achievements						
Module examination	Writt	ten exam (120 min	.)			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
				on language	English	
Weighting of the achievement in th	ie over	rall grade	6/120			
Module frequency			Summer te	rm		
Reasons for compulsory attendance						
Persons responsible for this module			Prof. Dr. L	ouis Velthui	s	
Applicable to the following program	$\mathbf{ms}$		M.Sc. Phys	sik		
Miscellaneous			Language: German Further details can be found in the german			
				he module h		ne Serman

Modul 4225	Ban	Banken				M.03.184.4225	
Compulsory or elective module	P	P					
Credit points and workload	6 LP	P = 180 h					
<b>Duration</b> according to the study plan	1						
	Ty-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	study	points	
a) Lecture: Banken	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: Banken	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the follow	ving ad	chievements mus	st be made:				
Presence							
Active participation							
Course achievements							
Module examination	Writt	en exam (120 min	)				
Qualification and program goals /	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							

Modul 4225	Banken		M.03.184.4225	
Language	<u> </u>	Course language English Examination language Eng	glish	
Weighting of the achievement in th	e overall grade	6/120		
Module frequency		Summer term		
Reasons for compulsory attendance	e			
Persons responsible for this module	e	Prof. Dr. Dietmar Leisen		
Applicable to the following program	ns	M.Sc. Physik		
Miscellaneous		Language: German Further details can be fou version of the module hand	Ŭ	

Modul 4310	Ban	ken			M.03	.184.4310
Compulsory or elective module	Р					
Credit points and workload	6 LF	P = 180 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	study	points
a) Lecture: Organisation	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Organisation	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ing a	chievements mus	st be made:			1
Presence						
Active participation						
Course achievements						
Module examination	Writt	ten exam (120 min	.)			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
				on language l	English	
Weighting of the achievement in th	le over	rall grade	6/120			
Module frequency			Winter terr	n		
Reasons for compulsory attendance	e					
Persons responsible for this module	e		Prof. Dr. E	rk Piening		
Applicable to the following program	ns		M.Sc. Phys	ik		
Miscellaneous				German tails can be he module h		he german

Modul 4320	Wirtschaftsinformatik			M.03	M.03.184.4320	
Compulsory or elective module	P					
Credit points and workload	6 LP	P = 180 h				
<b>Duration</b> according to the study plan	1					
	Ту-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	ре	term	obligation	$\mathbf{time}$	study	points
a) Lecture: Wirtschaftsinformatik	V	1	Р	2 SWS	99 h	4 LP
b) Exercises: Wirtschaftsinformatik	Ü	1	Р	1 SWS	49,5 h	2 LP
To complete the module, the follow	ving ad	chievements mus	st be made:			
Presence						
Active participation						
Course achievements						
Module examination	Writt	en exam (120 min	)			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						

Modul 4320	Wirtschaftsinformatik		M.03.184.4320	
I an mua ma		Course language English		
Language		Examination language Eng	glish	
Weighting of the achievement in th	ne overall grade	6/120		
Module frequency		Winter term		
Reasons for compulsory attendance	Э			
Persons responsible for this module	е	Prof. Dr. Stefan Irnich		
Applicable to the following program	ns	M.Sc. Physik		
		Language: German		
Miscellaneous		Further details can be four	nd in the german	
		version of the module hand	lbook	

Modul 4305	Marketing				M.03	M.03.184.4305	
Compulsory or elective module	Р						
Credit points and workload	6 LP = 180 h						
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit	
	ре	term	obligation	$\mathbf{time}$	$\mathbf{study}$	points	
a) Lecture: Marketing	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: Marketing	Ü	1	Р	$1 \ \mathrm{SWS}$	49,5 h	2 LP	
To complete the module, the follow	ving a	chievements mus	st be made:				
Presence							
Active participation							
Course achievements							
Module examination	Written exam (120 min)						
Qualification and program goals /	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
			Course language English				
Language			Examination language English				
Weighting of the achievement in the overall grade			6/120				
Module frequency			Summer term				
Reasons for compulsory attendance	Э						
Persons responsible for this module			Prof. Dr. Oliver Heil				
Applicable to the following programs			M.Sc. Physik				
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 4315	Logistikmanagement				M.03	M.03.184.4315	
Compulsory or elective module	P						
Credit points and workload	6 LP = 180 h						
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
	ре	term	obligation	$\mathbf{time}$	study	points	
a) Lecture: Logistikmanagement	V	1	Р	2 SWS	99 h	4 LP	
b) Exercises: Logistikmanagement	Ü	1	Р	1 SWS	49,5 h	2 LP	
To complete the module, the following achievements must be made:							
Presence							
Active participation							
Course achievements							
Module examination	Written exam (120 min)						
Qualification and program goals / Competences							
Course content							
Entry requirements							
Recommended prerequisites							

Modul 4315	Logistikmanagement		M.03.184.4315		
Language		Course language English			
Language		Examination language English			
Weighting of the achievement in th	6/120				
Module frequency	Summer term				
Reasons for compulsory attendance	е				
Persons responsible for this module		Prof. Dr. Stefan Irnich			
Applicable to the following programs		M.Sc. Physik			
		Language: German			
Miscellaneous		Further details can be fou	nd in the german		
		version of the module hand	lbook		

# 3.7.4 History of Natural Sciences

Modul 060	History of Natural Science I			M.08	M.08.275.060		
Compulsory or elective module	P						
Credit points and workload	15  LP = 450  h						
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
a) Vorlesung: Geschichte der Naturwissenschaft I (P)	V	1	Р	2 SWS	69 h	3 LP	
b) Seminar: Einführung in das wissen- schaftshistorische Arbeiten (P)	S	1	Р	2 SWS	69 h	3 LP	
c) Vorlesung: Geschichte der Naturwissenschaft II (P)	V	1	Р	2 SWS	69 h	3 LP	
d) Lektürekurs (P)		1	Р	2 SWS	69 h	3 LP	
e) Übungen (P)	Ü	1	Р	2 SWS	69 h	3 LP	
To complete the module, the follow	ving a	chievements m	ust be made:				
Presence							
Active participation	Participation in all seminars						
Course achievements	<ul><li>d) Presentation</li><li>e) Essays and/or Exercises</li></ul>						
Module examination	Oral examination (20-30 Min)						
Qualification and program goals /	Comp	oetences					
,							
Course content							
Entry requirements							
Recommended prerequisites							
Language			· · · · · · · · · · · · · · · · · · ·	Course language English Examination language English			
Weighting of the achievement in the overall grade			15/180 (BS	15/180 (BSc) or 15/120 (MSc)			
Module frequency			Every semester				
Reasons for compulsory attendance	э						
Persons responsible for this module			Prof. Dr. S	Prof. Dr. Sauer			
Applicable to the following programs			BSc. Physik, MSc Physik				
Miscellaneous			Further de	Course language: German (maybe English) Further details can be found in the german version of the module handbook			

Modul 070	History of Natural Science II				M.08.	M.08.275.070	
Compulsory or elective module	Р						
Credit points and workload	9 LP = 270 h						
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
	ре	term	obligation	time	$\mathbf{study}$	points	
a) Vorlesung: Geschichte der Naturwissenschaft I (P)	S	1	Р	2 SWS	129 h	5 LP	
b) Lektürekurs (P)		1	Р	2 SWS	99 h	4 LP	

Modul 070	History of Natur	History of Natural Science II			
To complete the module, the	following achievements n	nust be made:			
Presence					
Active participation	Participation in all s	eminars			
Course achievements	a) Presentation and b) Presentation and				
Module examination	Oral examination (2	0-30 Min)			
Qualification and program go	als / Competences				
Course content					
Entry requirements					
Recommended prerequisites					
Language		Course language English			
Language		Examination language English			
Weighting of the achievement	t in the overall grade	9/180 (BSc) or $9/120$ (M	ISc)		
Module frequency		Every semester			
Reasons for compulsory atten	ndance				
Persons responsible for this r	nodule	Prof. Dr. Sauer			
Applicable to the following p	rograms	BSc. Physik, MSc Physik	ζ		
Miscellaneous		Course language: Germa Further details can be for version of the module ha	ound in the german		

# 3.7.5 Mathematics

Modul 1300	Functional Analysis					M.08.105.1300	
Compulsory or elective module	P						
Credit points and workload	9 LI	P = 270 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Funktional- analysis I"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
To complete the module, the follow	ving a	chievements mus	st be made:				
Presence							
Active participation	Succ	essful completion of ions.	of the exercis	ses and oral	presentat	tion of owr	
Course achievements							
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (	120 min)		
Qualification and program goals $/$	$\mathbf{Comp}$	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	ne ove	rall grade	9/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance	э						
Persons responsible for this module			ist der Studiengangsbeauftragte.				
Applicable to the following program	ns		MSc Physik				
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 1310	Functional Analysis (with Functional Analysis II)       M.08.105.1310						
Compulsory or elective module	P						
Credit points and workload	15 L	P = 450 h					
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points	
Lecture with excercises "Functional Analysis I"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2  SWS			
Lecture "Funktionalanalysis II"	V	1	Р	4 SWS	138 h	6 LP	

Modul 1310	Functional Ana Analysis II)	alysis (with Functional M.08.105.1310
To complete the module, the	e following achievements r	nust be made:
Presence		
Active participation	Successful completion solutions.	on of the exercises and oral presentation of own
Course achievements		
Module examination	Oral examination (2	0-30 min)
Qualification and program g	oals / Competences	
Course content		
Entry requirements		
Recommended prerequisites		
Language		Course language English
Language		Examination language English
Weighting of the achievement	t in the overall grade	15/120
Module frequency		Once per year
Reasons for compulsory atte	ndance	
Persons responsible for this	module	ist der Studiengangsbeauftragte.
Applicable to the following p	orograms	MSc Physik
Miscellaneous		Language: German Further details can be found in the german version of the module handbook

Modul 1320	Partial differential equations				M.08.105.1320		
Compulsory or elective module	Р						
Credit points and workload	9  LP = 270  h						
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Partial differential equations I"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
To complete the module, the follow	ving a	chievements mu	st be made:			1	
Presence							
Active participation	Successful completion of the exercises and oral presentation of own solutions.						
Course achievements							
Module examination	Oral	examination (20-	30 min) or wri	tten exam (	120 min)		
Qualification and program goals $/$	$\mathbf{Comp}$	etences					
Course content							
			_				
Entry requirements							
Recommended prerequisites							
Language			Course language English				
			Examination language English				
Weighting of the achievement in th	ne over	rall grade	9/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance							
Persons responsible for this module			ist der Studiengangsbeauftragte.				
Applicable to the following program	ns		MSc Physi				
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 1330	Partial differential equations (with par- tial differential equations II)M.08.105.1330					
Compulsory or elective module	P					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points
Lecture with excercises "Partial diffe- rential equations I"		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2 SWS		
Lecture "Partial differential equations II"	V	1	Р	4 SWS	138 h	6 LP

Modul 1330	Partial different tial differential e	ial equations (with par- equations II)	
To complete the module, the	following achievements n	nust be made:	
Presence			
Active participation	Successful completic solutions.	n of the exercises and oral presentation of ov	
Course achievements			
Module examination	Oral examination (2	0-30 min)	
Qualification and program go	als / Competences		
Course content			
Entry requirements			
Recommended prerequisites			
Language		Course language English Examination language English	
Weighting of the achievement	in the overall grade	15/120	
Module frequency		Once per year	
Reasons for compulsory atten	dance		
Persons responsible for this n	nodule	ist der Studiengangsbeauftragte.	
Applicable to the following p	ograms	MSc Physik	
Miscellaneous	Language: German Further details can be found in the germa version of the module handbook		

Modul 1340	Fun	damentals in S	M.08.105.1340				
Compulsory or elective module	Р						
Credit points and workload	9  LP = 270  h						
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Introduction to Stochastics"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
To complete the module, the follow	ing a	chievements mu	st be made:				
Presence							
Active participation	Successful completion of the exercises and oral presentation of own solutions.						
Course achievements							
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (	120 min)		
Qualification and program goals /	Comp	etences					
Course content							
			_				
Entry requirements							
Recommended prerequisites							
Language			Course language English				
			Examination language English				
Weighting of the achievement in th	le over	rall grade	9/120				
Module frequency			Once per year				
Reasons for compulsory attendance							
Persons responsible for this module			ist der Studiengangsbeauftragte.				
Applicable to the following program	$\mathbf{ns}$		MSc Physil				
Miscellaneous			<ul><li>Language: German</li><li>Further details can be found in the german</li><li>version of the module handbook</li></ul>				

Modul 1350	Fundamentals in Stochastics				M.08.	M.08.105.1350	
Compulsory or elective module	Р						
Credit points and workload	15 L	P = 450 h					
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
	ре	$\mathbf{term}$	obligation	$\operatorname{time}$	$\mathbf{study}$	points	
Lecture with excercises "Introduction to Stochastics"		1	Р		207 h	9 LP	
Lecture (WP)	V			4  SWS			
Excercises (WP)	Ü			2  SWS			
Lecture "Stochastics I"	V	1	Р	4  SWS	138 h	6 LP	
To complete the module, the follow	ving ad	chievements mus	t be made:				
Presence							
Active participation	Successful completion of the exercises and oral presentation of own solutions.						
Course achievements							
Module examination	Oral	examination (20-30	0 min) or wri	tten exam (1	20 min)		

Modul 1350 Fundamen	tals in Stochastics M.08.105.1350
Qualification and program goals / Competences	3
Course content	
Entry requirements	
Recommended prerequisites	
Language	Course language English
	Examination language English
Weighting of the achievement in the overall gra	de 15/120
Module frequency	Once per year
Reasons for compulsory attendance	
Persons responsible for this module	ist der Studiengangsbeauftragte.
Applicable to the following programs	MSc Physik
	Language: German
Miscellaneous	Further details can be found in the german
	version of the module handbook

Modul 1360	Stochastics I				M.08.105.1360		
Compulsory or elective module	Р						
Credit points and workload	9 LF	P = 270  h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Stochastics I"		1	Р		207 h	9 LP	
Lecture (WP)	V			4  SWS			
Excercises (WP)	Ü			2  SWS			
To complete the module, the follow	ving a	chievements mus	t be made:				
Presence							
Active participation	Succe soluti	essful completion of ions.	of the exercis	ses and oral	presentat	tion of own	
Course achievements							
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (1	120 min)		
Qualification and program goals / ${}^{\circ}$	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	le over	all grade	9/120				
Module frequency			Once per year				
Reasons for compulsory attendance	Э						
Persons responsible for this module			ist der Studiengangsbeauftragte.				
Applicable to the following program	ns		MSc Physik				
Miscellaneous			<ul><li>Language: German</li><li>Further details can be found in the german</li><li>version of the module handbook</li></ul>				

Modul 1370	Stoc	Stochastics I (with Stochastics II)				105.1370
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
	ре	term	obligation	time	study	points
Lecture with excercises "Stochastics I"		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2  SWS		
Lecture "Stochastics II"	V	1	Р	4 SWS	138 h	6 LP
To complete the module, the follow	ving ac	chievements mus	st be made:		•	
Presence						
Active participation		essful completion of	of the exercis	ses and oral	presentati	on of own
	solutions.					
Course achievements						
Module examination	Oral	examination $(20-3)$	0 min) or wri	tten exam (1	$20 \min$ )	

Modul 1370	Stochastics I (with	Stochastics II)	M.08.105.1370						
Qualification and program goals / Competences									
Course content									
Entry requirements									
Recommended prerequisites									
Language		Course language English							
Language		Examination language Eng	ge English						
Weighting of the achievement in th	ne overall grade	15/120							
Module frequency		Once per year							
Reasons for compulsory attendance	e								
Persons responsible for this module	е	ist der Studiengangsbeauftragte.							
Applicable to the following program	ns	MSc Physik							
		Language: German							
Miscellaneous		Further details can be fou	and in the german						
		version of the module hand	dbook						

Modul 580	Stochastics 2 M.08.					.105.580	
Compulsory or elective module	Р						
Credit points and workload	15 L	P = 450 h					
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture "Stochastics II"	V	1	Р	4 SWS	120 h	6 LP	
Lecture "Stochastics III"	V	1	Р	4  SWS	120 h	6 LP	
Oral exam		1	Р		90 h	3 LP	
To complete the module, the follow	ving a	chievements mus	t be made:				
Presence							
Active participation							
Course achievements							
Module examination	Oral	examination $(20-3)$	0 min)				
Qualification and program goals $/$	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	ne over	rall grade	15/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance	Э						
Persons responsible for this module			ist der Studiengangsbeauftragte. Hauptamt- lich				
Applicable to the following program	$\mathbf{ns}$		MSc Physik				
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 1380	Bas	ic Numerics	M.08.105.1380					
Compulsory or elective module	Р							
Credit points and workload	9  LP = 270  h							
<b>Duration</b> according to the study plan	1							
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points		
Lecture with excercises "Basic Numerics"		1	Р		207 h	9 LP		
Lecture (WP)	V			4 SWS				
Excercises (WP)	Ü			2 SWS				
To complete the module, the follow	ving a	chievements mu	st be made:		-			
Presence								
Active participation	Successful completion of the exercises and oral presentation of own solutions.							
Course achievements								
Module examination	Oral	examination (20-3	30 min) or wri	tten exam (	120 min)			
Qualification and program goals $/$	Comp	etences						
Course content								
			-					
Entry requirements								
Recommended prerequisites								
Language			Course language English Examination language English					
Weighting of the achievement in th	ne over	rall grade	9/120					
Module frequency			Once per y	ear				
Reasons for compulsory attendance	Э							
Persons responsible for this module			ist der Studiengangsbeauftragte.					
Applicable to the following program			MSc Physik					
Miscellaneous			Language: German Further details can be found in the german version of the module handbook					

Modul 1390	Basi	c Numerics			M.08.	105.1390		
Compulsory or elective module	Р							
Credit points and workload	15 L	15  LP = 450  h						
<b>Duration</b> according to the study plan	1							
	Ту-	Designated	Degree of	Contact	Self	Credit		
Courses and teaching methods	ре	$\mathbf{term}$	obligation	time	$\mathbf{study}$	$\mathbf{points}$		
Lecture with excercises "Grundlagen der Numerik"		1	Р		207 h	9 LP		
Lecture (WP)	V			4 SWS				
Excercises (WP)	Ü			2 SWS				
Lecture "Numerik gewöhnlicher Diffe- rentialgleichungen"	V	1	Р	4 SWS	138 h	6 LP		

Modul 1390	Basic Numerics		M.08.105.1390
To complete the module, the fo	llowing achievements 1	nust be made:	
Presence			
Active participation	Successful completie solutions.	on of the exercises and oral pr	resentation of own
Course achievements			
Module examination	Oral examination (2	(20-30  min) or written exam $(120)$	min)
Qualification and program goal	s / Competences		
Course content			
Entry requirements			
Recommended prerequisites			
Language		Course language English Examination language Eng	glish
Weighting of the achievement i	n the overall grade	15/120	
Module frequency		Once per year	
Reasons for compulsory attend	ance		
Persons responsible for this mo	dule	ist der Studiengangsbeauf	tragte.
Applicable to the following pro	grams	MSc Physik	
Miscellaneous		Language: German Further details can be fou version of the module han	

Modul 1400	Nun	nerics of differe	M.08.105.1400				
Compulsory or elective module	Р						
Credit points and workload	9 LF	P = 270  h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Numerics of ordinary differential equations"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2  SWS			
To complete the module, the follow	ving a	chievements mus	st be made:				
Presence							
Active participation	Successful completion of the exercises and oral presentation of own solutions.						
Course achievements							
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (	120 min)		
Qualification and program goals /	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	e over	all grade	9/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance	9						
Persons responsible for this module	е		ist der Studiengangsbeauftragte.				
Applicable to the following program	$\mathbf{ns}$		MSc Physik				
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 1410	Numerics of differential equations         M.08.105.14					105.1410		
Compulsory or elective module	Р							
Credit points and workload	15 L	15  LP = 450  h						
<b>Duration</b> according to the study plan	1	1						
	Ty-	Designated	Degree of	Contact	Self	Credit		
Courses and teaching methods	pe	$\mathbf{term}$	obligation	$\mathbf{time}$	$\mathbf{study}$	points		
Lecture with excercises "Numerics of ordinary differential equations"		1	Р		207 h	9 LP		
Lecture (WP)	V			4  SWS				
Excercises (WP)	Ü			2  SWS				
Lecture "Numerics of partial differenti- al equations"	V	1	Р	4 SWS	138 h	6 LP		

Modul 1410	Numerics of diff	Numerics of differential equations					
To complete the module, th	le following achievements r	nust be made:					
Presence							
Active participation	Successful completion solutions.	Successful completion of the exercises and oral presentation of own solutions.					
Course achievements							
Module examination	Oral examination (2	0-30 min) or written exam (120)	min)				
Qualification and program	goals / Competences						
Course content							
Entry requirements							
Recommended prerequisite	s						
Language		Course language English Examination language English	glish				
Weighting of the achieveme	ent in the overall grade	15/120					
Module frequency		Once per year					
Reasons for compulsory att	endance						
Persons responsible for this	module	ist der Studiengangsbeauf	tragte.				
Applicable to the following	programs	MSc Physik					
Miscellaneous		Language: German Further details can be fou version of the module han	0				

Modul 1420	Algebra				M.08.105.1420			
Compulsory or elective module	Р							
Credit points and workload	9  LP = 270  h							
<b>Duration</b> according to the study plan	1							
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points		
Lecture with excercises "Computeralgebra"		1	Р		207 h	9 LP		
Lecture (WP)	V			4 SWS				
Excercises (WP)	Ü			2 SWS				
To complete the module, the follow	ving a	chievements mu	st be made:		-			
Presence								
Active participation	Successful completion of the exercises and oral presentation of own solutions.							
Course achievements								
Module examination	Oral	examination (20-3	30 min) or wri	tten exam (	120 min)			
Qualification and program goals / $\cdot$	Comp	etences						
Course content								
			-					
Entry requirements								
Recommended prerequisites								
Language			Course language English					
			Examination language English					
Weighting of the achievement in th	ne over	rall grade	9/120					
Module frequency			Once per y	ear				
Reasons for compulsory attendance					0			
Persons responsible for this module			ist der Studiengangsbeauftragte.					
Applicable to the following program	ns		MSc Physi					
Miscellaneous			Language: German Further details can be found in the german version of the module handbook					

Modul 1430	Alge	ebra			M.08	.105.1430	
Compulsory or elective module	Р						
Credit points and workload	15 L	P = 450 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
	ре	term	obligation	time	$\mathbf{study}$	points	
Lecture with excercises "Computeralgebra"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
Lecture "Körper, Ringe, Moduln"	V	1	Р	4 SWS	138 h	6 LP	
To complete the module, the follow	ving ad	chievements mus	t be made:				
Presence							
Active participation	Successful completion of the exercises and oral presentation of own solutions.						
Course achievements							
Module examination	Oral	examination (20-30	0 min) or wri	tten exam (1	20 min)		

Modul 1430 Algebra	M.08.105.1430			
Qualification and program goals / Competences				
Course content				
Entry requirements				
Recommended prerequisites				
Language	Course language English			
	Examination language English			
Weighting of the achievement in the overall grade	15/120			
Module frequency	Once per year			
Reasons for compulsory attendance				
Persons responsible for this module	ist der Studiengangsbeauftragte.			
Applicable to the following programs	MSc Physik			
	Language: German			
Miscellaneous	Further details can be found in the german			
	version of the module handbook			

Modul 1440	Topology     M					M.08.105.1440		
Compulsory or elective module	P							
Credit points and workload	9  LP = 270  h							
<b>Duration</b> according to the study plan	1							
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points		
Lecture with excercises "Topology"		1	Р		207 h	9 LP		
Lecture (WP)	V			4 SWS				
Excercises (WP)	Ü			2 SWS				
To complete the module, the follow	ving a	chievements mus	st be made:					
Presence								
Active participation	Successful completion of the exercises and oral presentation of own solutions.					ion of own		
Course achievements								
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (1	120 min)			
Qualification and program goals $/$	Comp	etences						
Course content								
Entry requirements								
Recommended prerequisites								
Language			Course language English Examination language English					
Weighting of the achievement in th	ie ovei	all grade	9/120					
Module frequency			Once per year					
Reasons for compulsory attendance	е							
Persons responsible for this module			ist der Studiengangsbeauftragte.					
Applicable to the following program	ms		MSc Physik					
Miscellaneous	Language: German Further details can be found in the german version of the module handbook							

Modul 1450	Topology (with lecture "Algebraic cur- ves and Riemannian surfaces")M.08.105.1450					105.1450
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Contact	Self	Credit	
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	$\mathbf{study}$	points
Lecture with excercises "Topology"		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2  SWS		
Lecture "Algebraic curves and Rieman- nian surfaces"	V	1	Р	4 SWS	138 h	6 LP
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation	Successful completion of the exercises and oral presentation of own solutions.					
Course achievements						
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (1	20 min)	

Modul 1450	Topology (with ves and Riemann	lecture "Algebraic cur- lian surfaces")	M.08.105.1450
Qualification and program goals /	Competences	I	
Course content			
Entry requirements			
Recommended prerequisites			
Language		Course language English Examination language English	lish
Weighting of the achievement in th	e overall grade	15/120	
Module frequency		Once per year	
Reasons for compulsory attendance	9		
Persons responsible for this module	e	ist der Studiengangsbeauftr	ragte.
Applicable to the following program	ns	MSc Physik	
Miscellaneous		Language: German Further details can be four version of the module hand	•

Modul 1460	Computer algebra			M.08.105.1460			
Compulsory or elective module	Р				I		
Credit points and workload	9 LF	P = 270 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Computer al- gebra"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
To complete the module, the follow	ving a	chievements mu	st be made:	•	•		
Presence							
Active participation	1	Successful completion of the exercises and oral presentation of own solutions.					
Course achievements							
Module examination	Oral	examination (20-3	30 min) or wri	tten exam (	120 min)		
Qualification and program goals $/$	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	ne over	rall grade	9/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance	Э						
Persons responsible for this module			ist der Stud	diengangsbe	auftragte.		
Applicable to the following program			MSc Physil	<u> </u>	~		
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 1470	Computer algebra (with Number Theo- ry) M.08.105.1470					
Compulsory or elective module	Р					
Credit points and workload	15 L	15  LP = 450  h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	time	study	points
Lecture with excercises "Computer al- gebra"		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2 SWS		
Lecture "Number Theory"	V	1	Р	4 SWS	138 h	6 LP

Modul 1470	Computer algeb ry)	Computer algebra (with Number Theo- ry)			
To complete the module, the	following achievements r	nust be made:	1		
Presence					
Active participation	Successful completion solutions.	on of the exercises and oral pr	esentation of own		
Course achievements					
Module examination	Oral examination (2	0-30 min) or written exam (120 $$	min)		
Qualification and program go	als / Competences				
Course content					
Entry requirements					
Recommended prerequisites					
Language		Course language English Examination language Eng	glish		
Weighting of the achievemen	t in the overall grade	15/120			
Module frequency		Once per year			
Reasons for compulsory atter	ndance				
Persons responsible for this r	nodule	ist der Studiengangsbeauft	ragte.		
Applicable to the following p	rograms	MSc Physik			
Miscellaneous		Language: German Further details can be fou version of the module hand	0		

Modul 10050	Differential Geometry and Manifolds M.08.105.					.105.10050
Compulsory or elective module	Р					
Credit points and workload	9 LF	P = 270  h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture with excercises "Differential Geometry and Manifolds"		1	Р		207 h	9 LP
Lecture (WP)	V			4  SWS		
Excercises (WP)	Ü			2 SWS		
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation	Successful completion of the exercises and oral presentation of own solutions.					ion of own
Course achievements						
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (1	120 min)	
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English			
			Examination language English			
Weighting of the achievement in th	le over	rall grade	9/120			
Module frequency			Once per y	ear		
Reasons for compulsory attendance						
Persons responsible for this module				diengangsbea	auftragte.	
Applicable to the following program	ns		MSc Physil			
Miscellaneous			Language: German Further details can be found in the german version of the module handbook			

Modul 10040	Fun	ction Theory			M.08	105.10040
Compulsory or elective module	Р					
Credit points and workload	9 LF	P = 270  h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit
	ре	term	obligation	time	study	points
Lecture with excercises "Function Theory"		1	Р		207 h	9 LP
Lecture (WP)	V			4 SWS		
Excercises (WP)	Ü			2 SWS		
To complete the module, the follow	ving a	chievements mus	t be made:			
Presence						
Active participation		Successful completion of the exercises and oral presentation of own solutions.				
Course achievements						
Module examination	Oral	examination (20-30	0 min) or wri	tten exam (1	20 min)	

Modul 10040 Function Theory	y M.08.105.10040			
Qualification and program goals / Competences				
Course content				
Entry requirements				
Recommended prerequisites				
Language	Course language English			
	Examination language English			
Weighting of the achievement in the overall grade	9/120			
Module frequency	Once per year			
Reasons for compulsory attendance				
Persons responsible for this module	ist der Studiengangsbeauftragte.			
Applicable to the following programs	MSc Physik			
Miscellaneous	Language: German Further details can be found in the german version of the module handbook			

Modul 140	Number Theory			M.08.105.140			
Compulsory or elective module	Р				I		
Credit points and workload	9 LF	P = 270 h					
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Number Theo- ry"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
To complete the module, the follow	ving a	chievements mu	st be made:		•		
Presence							
Active participation	1	Successful completion of the exercises and oral presentation of own solutions.					
Course achievements							
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (	120 min)		
Qualification and program goals $/$	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English				
Weighting of the achievement in th		nall ana da	Examination language English				
Weighting of the achievement in th	le ove	rall grade	9/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance			iat d Ci	l: on mo1	auftma+ -		
Persons responsible for this module			ist der Studiengangsbeauftragte.				
Applicable to the following program	ns		MSc Physil				
Miscellaneous			<ul><li>Language: German</li><li>Further details can be found in the german</li><li>version of the module handbook</li></ul>				

Modul 650	Vertiefungsmodul Analysis			M.08	M.08.105.650	
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
	pe	term	obligation	$\operatorname{time}$	$\mathbf{study}$	points
Lecture "Vertiefungsmodul Analysis I"	V	1	Р	4 SWS	138 h	6 LP
Lecture "Vertiefungsmodul Analysis II"	V	1	Р	4 SWS	138 h	6 LP
Module examination					90 h	
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation						
Course achievements						
Module examination	Oral	examination (20-3	$0 \min)$			
Qualification and program goals / Competences						

Modul 650	Vertiefungsmodul Analysis		M.08.105.650		
Course content					
Entry requirements					
Recommended prerequisites					
Language		Course language English Examination language English			
Weighting of the achievement in th	ne overall grade	15/120			
Module frequency		Once per year			
Reasons for compulsory attendance	е				
Persons responsible for this module	e	ist der Studiengangsbeauftragte.			
Applicable to the following program	ms	MSc Physik			
Miscellaneous		Language: German Further details can be fou handbooks of the Mathema			

Modul 560	Functional Analysis				M.08	.105.560
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
Lecture "Functional Analysis II"	V	1	Р	4 SWS	138 h	6 LP
Lecture "Funktionalanalysis III"	V	1	Р	4 SWS	138 h	6 LP
Module examination					90 h	
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation		Successful completion of the exercises and oral presentation of ow solutions.				
Course achievements						
Module examination	Oral	examination (20-3	$0 \min)$			
Qualification and program goals $/$	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English Examination language English			
Weighting of the achievement in th	ie ovei	all grade	15/120			
Module frequency			Once per y	ear		
Reasons for compulsory attendance	е					
Persons responsible for this modul	e		ist der Studiengangsbeauftragte.			
Applicable to the following program	ms		MSc Physil	ĸ		
Miscellaneous     Language: German       Further details car     version of the mod			tails can be		he german	

Р					
15 L	P = 450 h				
<b>2</b>					
Ty-	Designated	Degree of	Contact	Self	Credit
ре	term	obligation	time	study	points
V	1	Р	4 SWS	138 h	6 LP
V	1	Р	4 SWS	138 h	6 LP
				90 h	
ing ac	hievements mus	t be made:			
Oral	examination (20-30	) min)			
Compe	etences				
	Ty- pe V V ing ac	Ty-     Designated       pe     term       V     1       V     1       ing achievements must	Ty-     Designated term     Degree of obligation       P     term     obligation       V     1     P       V     1     P       ing achievements must be made:	Ty- pe     Designated term     Degree of obligation     Contact time       V     1     P     4 SWS       V     1     P     4 SWS       Image: View of the second	Ty- peDesignated termDegree of obligationContact timeSelf studyV1P4 SWS138 hV1P4 SWS138 hV1P4 SWS138 hing achievements must be made:90 h

Modul 625	Vertiefungsmodul Eichtheorie		M.08.105.625	
Course content			I	
Entry requirements				
Recommended prerequisites				
Language		Course language English Examination language English		
Weighting of the achievement in th	e overall grade	15/120		
Module frequency		Once per year		
Reasons for compulsory attendance	9			
Persons responsible for this module	e	ist der Studiengangsbeauftragte.		
Applicable to the following program	ns	MSc Physik		
Miscellaneous		Language: German Further details can be fou handbooks of the Mathema		

Modul 070	Bas	Basic Numerics				8.105.070	
Compulsory or elective module	Р						
Credit points and workload	12  LP = 360  h						
<b>Duration</b> according to the study plan	1						
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points	
Lecture with excercises "Basic Numerics"		1	Р		207 h	9 LP	
Lecture (WP)	V			4 SWS			
Excercises (WP)	Ü			2 SWS			
	Pr	1	Р	2 SWS	69 h	3 LP	
To complete the module, the follow	ving a	chievements mus	st be made:		-		
Presence							
Active participation	Succ solut	essful completion ions.	of the exercis	ses and ora	l presentat	tion of own	
Course achievements							
Module examination	Oral	examination (20-3	0 min) or wri	tten exam (	120 min)		
Qualification and program goals /	$\mathbf{Comp}$	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English Examination language English				
Weighting of the achievement in th	ie ove	rall grade	9/120				
Module frequency			Once per y	ear			
Reasons for compulsory attendance	е						
Persons responsible for this module			ist der Stud	liengangsbe	auftragte.		
Applicable to the following program			MSc Physik				
Miscellaneous			Language: German Further details can be found in the german version of the module handbook				

Modul 540	Con	Complex Differential Geometry				M.08.105.540		
Compulsory or elective module	Р	P						
Credit points and workload	15 L	P = 450 h						
<b>Duration</b> according to the study plan	2	2						
	Ty-	Designated	Degree of	Contact	Self	Credit		
Courses and teaching methods	ре	term	obligation	$\operatorname{time}$	$\mathbf{study}$	points		
Lecture "Complex Differential Geome- try I"	V	1	Р	4 SWS	138 h	6 LP		
Lecture "Complex Differential Geome- try II"	V	1	Р	4 SWS	138 h	6 LP		
Module examination					90 h			

Modul 540	Complex Differe	Complex Differential Geometry		
To complete the module, th	e following achievements r	nust be made:		
Presence				
Active participation	Successful completion solutions.	on of the exercises and oral pr	resentation of own	
Course achievements				
Module examination	Oral examination (2	0-30 min)		
Qualification and program g	oals / Competences			
Course content				
Entry requirements				
Recommended prerequisites	;			
Language		Course language English Examination language Eng	glish	
Weighting of the achievement	nt in the overall grade	15/120		
Module frequency		Once per year		
Reasons for compulsory atte	endance			
Persons responsible for this	module	ist der Studiengangsbeauft	tragte.	
Applicable to the following	programs	MSc Physik		
Miscellaneous		Language: German Further details can be fou version of the module hand	0	

Modul 500	Algebraic Geometry				M.08	3.105.500
Compulsory or elective module	Р					
Credit points and workload	15 L	P = 450 h				
<b>Duration</b> according to the study plan	2					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	$\mathbf{study}$	points
Lecture "Algebraic Geometry I"	V	1	Р	4 SWS	120 h	6 LP
Lecture "Algebraic Geometry II"	V	1	Р	4 SWS	120 h	6 LP
Oral exam		1	Р		90 h	3 LP
To complete the module, the follow	ving a	chievements mus	st be made:		•	
Presence						
Active participation						
Course achievements						
Module examination	Oral	examination $(20-3)$	0 min)			
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language				guage Englisl on language I		
Weighting of the achievement in th	e ove	rall grade	15/120			
Module frequency			Once per y	ear		
Reasons for compulsory attendance	Э					

Modul 500	Algebraic Geometry		M.08.105.500
Persons responsible for this module	e	ist der Studiengangsbeauft lich	ragte. Hauptamt-
Applicable to the following program	ns	MSc Physik	
Miscellaneous		Language: German Further details can be four version of the module hand	•

# 3.7.6 Meteorology

You can find the description of the modules in the corresponding module handbook of the BSc and MSc Meteorology which you can find at this URL:

https://www.studium.fb08.uni-mainz.de/downloadcenter-meteorologie/

# 3.7.7 Philosophy

Modul 061	Basismodul (historisch) - Philosophie M.05.127.061 der Neuzeit					
Compulsory or elective module	Р					
Credit points and workload	5 LF	P = 150 h				
<b>Duration</b> according to the study plan	1					
	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	$\mathbf{time}$	$\mathbf{study}$	points
a) Oberseminar: Philosophie der Neu- zeit	S	1	Р	2 SWS	99 h	4 LP
Modul examination		1	Р		30 h	1 LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation						
Course achievements						
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)					
Qualification and program goals /	Comp	etences				
Course content						
Entry requirements						
Recommended prerequisites						
Language			Course language English Examination language English			
Weighting of the achievement in th	e ove	rall grade	5/120			
Module frequency			Every seme	ester		
Reasons for compulsory attendance	Э					
Persons responsible for this module	е		UnivProf. amtliche	Dr. Heiner	F. Klem	me Haupt-
Applicable to the following program	$\mathbf{ns}$					
Miscellaneous			Language: German Further details can be found in the german version of the module handbook			

Modul 063	Aufbaumodul (historisch) - PhilosophieM.05.127.063der Neuzeit					127.063
Compulsory or elective module	Р					
Credit points and workload	5  LP = 150  h					
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit
Courses and teaching methods	pe	term	obligation	time	$\mathbf{study}$	points
a) Oberseminar: Philosophie der Neu- zeit	S	2	Р	2 SWS	99 h	4 LP
Modul examination		2	Р		30 h	1 LP

Modul 063	Aufbaumodul (h der Neuzeit	istorisch) - Philosophie M.05.1	27.063			
To complete the module, the follo	wing achievements m	ust be made:				
Presence						
Active participation						
Course achievements						
Module examination		Seminar paper (8-10 pages) or Presentation (+ written report of 8 pages) or written exam (90 Min.) or oral exam (20 Min.) in a)				
Qualification and program goals /	Competences					
Course content						
Entry requirements						
Recommended prerequisites						
Language		Course language English Examination language English				
Weighting of the achievement in t	he overall grade	5/120				
Module frequency		Every semester				
Reasons for compulsory attendant	ce					
Persons responsible for this modu	le	UnivProf. Dr. Heiner F. Klemme Haupt- amtliche				
Applicable to the following progra	ams					
Miscellaneous		Language: German Further details can be found in the germa version of the module handbook				

Modul 065	Vertiefungsmodul (historisch) - Philoso- phie der NeuzeitM.03					.127.065
Compulsory or elective module	Р					
Credit points and workload	5 LF	P = 150 h				
<b>Duration</b> according to the study plan	1					
Courses and teaching methods	Ty- pe	Designated term	Degree of obligation	Contact time	Self study	Credit points
a) Oberseminar: Philosophie der Neu- zeit	S	3	Р	2 SWS	99 h	4 LP
Modul examination		3	Р		30 h	1 LP
To complete the module, the follow	ving a	chievements mus	st be made:			
Presence						
Active participation						
Course achievements						
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)					
Qualification and program goals / Course content	Comp	etences				
Entry requirements						
Recommended prerequisites						
Language			Course language English Examination language English			
Weighting of the achievement in th	le over	rall grade	5/120			
Module frequency			Every semester			
Reasons for compulsory attendance	Э					
Persons responsible for this module			UnivProf. Dr. Heiner F. Klemme Haupt- amtliche			
Applicable to the following program	ns					
Miscellaneous			Language: German Further details can be found in the german version of the module handbook			

# 3.8 interdisciplinary Courses

Modul 130	History of Natural Science I 08.275.13				5.130		
Compulsory or elective module	W				I		
Credit points and workload	3 LF	P = 90 h					
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ty-	Designated	Degree of	Contact	Self	Credit	
Courses and teaching methods	pe	term	obligation	$\operatorname{time}$	study	points	
Lecture: Geschichte der Naturwissenschaft I	V	1	Р	2 SWS	69 h	3 LP	
To complete the module, the follow	ving a	chievements mus	t be made:				
Presence							
Active participation							
Course achievements							
Module examination	Oral	examination (20-30	) Min)				
Qualification and program goals $/$	Comp	etences					
Course content							
Entry requirements							
Recommended prerequisites							
Language			Course language English				
			Examination language English				
Weighting of the achievement in th	le over	all grade	, ,	(1) or $3/120$ (1)	MSc)		
Module frequency			Every seme	ester			
Reasons for compulsory attendance							
Persons responsible for this module			Prof. Dr. S				
Applicable to the following program	$\mathbf{ns}$		BSc. Physik, MSc Physik				
Miscellaneous			Course language: German (maybe English) Further details can be found in the german version of the module handbook				

Modul 140	History of Natural Science II				08.27	08.275.140	
Compulsory or elective module	W						
Credit points and workload	3 LP = 90 h						
<b>Duration</b> according to the study plan	2						
Courses and teaching methods	Ту-	Designated	Degree of	Contact	Self	Credit	
	ре	term	obligation	$\operatorname{time}$	study	points	
Lecture: Geschichte der Naturwissenschaft II	V	1	Р	2 SWS	69 h	3 LP	
To complete the module, the following achievements must be made:							
Presence							
Active participation							
Course achievements							
Module examination	Oral examination (20-30 Min)						
Qualification and program goals / Competences							
Course content							

Modul 140	History of Natural Science II		08.275.140		
Entry requirements					
Recommended prerequisites					
Language		Course language English			
		Examination language English			
Weighting of the achievement in the overall grade		3/180 (BSc)  or  3/120 (MSc)			
Module frequency		Every semester			
Reasons for compulsory attendance	e				
Persons responsible for this module		Prof. Dr. Sauer			
Applicable to the following programs		BSc. Physik, MSc Physik			
		Course language: German	(maybe English)		
Miscellaneous		Further details can be found in the german			
		version of the module handbook			