

Faculty of Physics and Astronomy

Module Manual Master of Science (M.Sc.) in Physics

PO 2021 and PO 2023

Ruhr-Universität Bochum

SoSe 2025 03.04.2025

The examination regulations PO 2021 expire on 30 September 2025. You can take a Master's examination in accordance with these study and examination regulations for the last time on 30 September 2025. The Master of Science in Physics programme has a standard period of study of 4 semesters and a total of 120 credit points (CP). The study programme is divided into different areas. In the first year compulsory elective modules include in-depth modules from experimental and theoretical physics (15-36 CP) as well as diverse modules from the minor subject (5-18 CP). For the specialisation, courses amounting to 15-25 CP must be chosen in one subject area (astronomy/astrophysics, biophysics, solid state physics, nuclear and particle physics or plasma physics). In the area of key competences the obligatory module "project management" has to be chosen and further modules of up to 10 CP can be selected. A list of the approved modules can be found in this module handbook. In the second year compulsory modules amounting to 60 CP cover the subject-specific and interdisciplinary preparation and execution of the final thesis.

The distribution of the 120 CP to be completed in the physics degree programme is illustrated in the following table:

Master of Science	Semester	Experimental physics	Theoretical physics	Focus area	Minor subject	Key qualifications	Master's thesis
		9-18 CP	6-18 CP	15-25 CP	5-18 CP	5-15 CP	60 CP
First year	1	Elective modules experimental physics (astro/biosolid state/ nuclear and particle/plasma)	Elective modules theoretical physics (thermodynamics and statistical/advanced quantum mechanics/general relativity)	Specialised lecture/seminar/ advanced lab work (astro/bio/soldi state/	Physics-related courses of other faculties (e.g. math, engineering, etc.)	e.g. C++ or Scientific Writing	
First	2	Elective modules experimental physics (astro/bio/solid state/ nuclear and particle/plasma)	Elective modules theoretical physics (astro/solid state/plasma)	nuclear and particle/plasma) (oral exam 2 CP)	Physics-related courses of other faculties (e.g. math, engineering, etc.)	Project management	
	3						Knowledge of methods and project planning
yea							Project seminar for the Master's thesis
Second year	4						Master's thesis
Key							
Experin	nental	physics	Theoratical	physics			
Focus a	reas		Minor subje				
Key qua	lificat	ions (choice)	Key qualifica	ations (oblig.)			
Master'	s thes	is and prepatory courses					

Actually two different examination regulations are in force:

- Students who have enrolled **by the summer semester 2023 at the latest** are in the 2021 examination regulations (PO 2021)
- Students who have enrolled **from the winter semester 2023/2024** are in the examination regulations 2023 (PO 2023)

The two examination regulations differ only minimally. The amended rules are marked in each case.

This overview is structured as follows:

- 1. counselling and information services
- 2. study plan
- 3. modularisation concept and examination forms
- 4. list of individual compulsory and elective modules

1. Counselling and information services at the Faculty of Physics and Astronomy

If you have any questions in connection with the subject of physics, please contact the student advisory service for physics. They offer appointments five days a week. There are no regular office hours, so you must make an appointment in person, by phone or by e-mail in advance.

Our student advisors for the Master's programme in Physics:

<u>N</u> ational Students	International Students
General Questions	General Questions
Dr. Ivonne Möller	Dr. Andreas Kreyssig
NB 02/169	NB 4/130
Fon.: +49(0)234-32-29105	Fon.: +49(0)234-32-23648
moeller@physik.rub.de	master-international@physik.rub.de
	Admission process
	Dr. Niklas Fornefeld
	NB 02/171
	Fon.: +49(0)234-32-2
	fornefeld@physik.rub.de

Before starting their studies, every student must attend a counselling appointment. In addition to individual appointments, group appointments are also offered. The students are informed about the appointments by e-mail.

General information and forms are provided in the Moodle course "Physics Study Info". After enrolment all students get access to the course.

2. Study plan:

Modul	Description	Semester	Exam
Modul 1.x 9 -18 CP	One (or two) elective module(s) from one of the following subject areas from experimental physics: astrophysics, bio- physics, solid state physics, nuclear and particle physics or plasma physics. Each module consists of a lecture with exercise as well as experiments from the advanced practical course from the respective subject area.	1.+2.	graded, the partial perfor- mances achieved are weighted with the CP in the module grade. One module from 1a to 1e (of choice) must be com- pleted. A further module can be taken.
Modul 2.x 6 -18 CP	 PO 2021: one (or three) module(s) from "Thermodynamics and Statistical Phys- ics", "Advanced Quantum Mechanics" and "General Relativity" PO 2023: "Thermodynamics and Statistical Physics" has to be chosen, if it hasn't been chosen in the Bachelor already. The modules "Advanced Quantum Me- chanics" and "General Relativity can be chosen in addition. 	1.+2.	Graded, via a module final written exam or an oral ex- amination.PO 2021: one module from 2a to 2c (at choice) must be completed.PO 2023: module from 2c must be completed.PO 2023: module from 2c must be completed.Two further modules can be taken.Graded, the partial perfor- mances achieved are weighted with the CP in the module grade.
Modul 3.x 0-12 CP	One (or two) elective module(s) from one of the following subject areas from experimental physics: astrophysics, solid state physics or plasma physics. Each module consists of a lecture with exercises.	1.+2.	Graded, the partial perfor- mances achieved are weighted with the CP in the module grade. One or two module(s) from 3a to 3c (at choice) can be com- pleted.
Modul 4.x 15-25 CP	One compulsory elective module from one of the following subject areas: Astro- physics, Biophysics, Solid State Physics, Nuclear and Particle Physics or Plasma Physics. Courses from experimental and/or theoretical physics from the re- spective subject area can be selected	3.+4.	Graded, via a final oral module examination (2 CP). A seminar (2 CP) and practicals (advanced lab work) (min. 5 CP) must be proven.

Modul 5.x 5-18 CP	Elective modules of 5- 18 CP from the catalogue of minor subjects (e.g. math- ematics, chemistry, geosciences, ICAMS, neuroscience, engineering sci- ence). A complete list of all modules can be found further on in the module handbook.	14.	Graded, via a final module ex- amination, final oral module examination, seminar lecture, study-related exercises and active participation, protocols, practical exercises or home- work.
Modul 6.x 0-10 CP	Elective modules in the amount of 0-10 CP from the area of key competences	2.+3.	Graded, via a module final ex- amination, oral module final examination, seminar lecture, study-related exercises and active participation, protocols, practical exercises or term pa- per.
Modul 7 5 CP	Project Management	1.+2.	ungraded, via active participation
Modul 8 15 CP	Methodology and Project Planning (M.Sc.)	3.	ungraded, via active participation
Modul 9 15 CP	Project seminar for the Master's thesis	3.+4.	graded, via active participation and seminar talk
Modul 10 30 CP	Master thesis	3.+4.	graded, via two ex- pert reports

3. Modularisation concept and forms of examination:

Examinations can take the form of a written examination, an oral examination, a seminar paper, a presentation, a term paper, a written report, a project, a practical exercise or a tutorial. The form of examination for each module can be found in the module descriptions. In the case of alternative options, a form of examination is determined by the lecturer at the beginning of the module.

All modules are completed with an examination. The compulsory modules "Project Management" and "Methodological Knowledge and Project Planning" remain ungraded. All graded modules are weighted with the CP in the final grade.

The "focus module" (compulsory elective modules 4.a to 4.e) concludes with an oral examination, which is credited with 2 CP. The following applies to all courses in the specialisation module: semester hour per week = CP.

The current range of courses offered by the Faculty of Physics and Astronomy can be found in CampusOffice.

All examinations at the Faculty take place in fixed examination periods. The first examination period is at the end of the lecture period, the second at the end of the lecture free period.

4. List of all modules:

Modules 1 (Elective Modules from Experimental Physics)

•	Module 1a Introduction to Astrophysics	. 7
•	Module 1b Introduction to Biophysics	. 8
•	Module 1c Introduction to Solid State Physics	. 9
•	Module 1d Introduction to Nuclear and Particle Physics	11
•	Module 1e Introduction to Plasma Physics	13

Modules 2 (Elective Modules from Theoretical Physics)

•	Module 2a General Relativity	14
	Module 2b Advanced Quantum Mechanics	
•	Module 2c Thermodynamics and Statistical Physics	16

Quantum Mechanics for Internationals

Module 3 (Elective Modules from Theoretical Physics)

•	Module 3a Introduction to Theoretical Astrophysics17
•	Module 3b Introduction to Theoretical Solid State Physics
•	Module 3c Introduction to Theoretical Plasma Physics

Modules 4 (Elective Modules for the Focus Area)

٠	Module 4a Astrophysics	. 20
•	Module 4b Biophysics	. 35
	Module 4c Solid State Physics	
	Module 4d Nuclear and Particle Physics	
	Module 4e Plasma Physics	

Modules 5 (Elective Modules from the Catalogue for Minor Subjects)

•	Offers from the Faculty of Chemistry and Biochemistry	87
	Offers from the Faculty of Geosciences	
	Offers from the Faculty of Electrical Engineering and Information Technology	
•	Offers from the Faculty of Mechanical Engineering	90
•	Offers from the Faculty of Mathematics	91
•	Offers from the Faculty of Computer Science	92
	Offers from ICAMS (Interdisciplinary Centre for Advanced Materials Simulations)	

Modules 6 (Elective Modules from the Area for Key Competences)

•	Module 6a Computational Physics I	94
•	Module 6b Computational Physics II	95
	Module 6c Presentation Skills	
•	Module 6d Scientific English	97
	Module 6z List of further modules	

Compulsory Modules

•	Module 7 Project Management	. 99
	Module 8 Methodological Knowledge and Project Planning (M.Sc.)	
•	Module 9 Project Seminar for the Master's thesis	. 101
•	Module 10 Master's Thesis	. 102

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Format of Examination At tion (written examination of weekly homework and action	course, basic scier			
tion (written examination of weekly homework and action of the second	e, Exercises, Practi	cal Exercises (Labo	oratory Course)	
course is examined via pra-	of 90 min, oral exa	mination of 45 mi the exercises) for	n or an exercise	certificate with
Requirements for the Attr Passing the written/oral ex exercises. In this case, actives s determined at the begins successfully completed. Bo	amination or obtai re participation in t ning of the course.	ining at least 50% the exercise is also In addition, the a	of the possible o compulsory. T dvanced laborat	points in the weekly he form of examinatio tory course must be
Use of the Module Compu	sory-Elective Mod	ule		
mportance of the Mark fo	r the Final Grade	Weighted accordi	ng to credit poir	nts
Module Supervisor and Ins				

Introduction	to Biophys	sics			
Module 1b	Credits	Workload	Semester	Cycle	Duration
	9 CP	270 h	from 1. Sem.	Winter	1-2 Semesters
Courses			Contact Hours	Self-Study	Group Size
	a) Lecture Introduction to Biophysics		a) 44 h	183 h	a) unlimited
b) Exercises for Introduction to Biophysics		b) 22 h		b) 30	
c) Advanced La	c) Advanced Laboratory Courses for		c) 21 h		c) 2
Physicists (three experiments in Bio-					
physics)					
Requirements f	or Participatio	on			
Formal None			alan) will ba biabl		
Preparation No	-	nysics i-ili (Bach	elor) will be highl	y appreciated	
Learning Outco					
After successful		this module, the	e students		
			r structures of liv	ing matter	
can realise	e the relation	between the ba	sic knowledge fro	m experimental an	d theoretical
		-	al systems, and the	ney can use them to	o describe
•	ms and reaction				
				ng molecular biologi biophysical experim	
		e scientific cont	-		
				molecular biophysi	cs at Ruhr-
University	-			. ,	
				ethods, both guided	and independent,
and they o	can communic	ate their results	both orally and v	written	
Contents					
	-	ter: from the ate	om to the protein		
 Spectroscopi Methods for 		tructures of pro	toins (X-ray cryst	allography NMP of	ectron microscopy)
	-	kinetics and elec		anography, www, er	
Format of Teach	ning Lecture, E	xercises, Practic	cal Exercises (Labo	oratory Course)	
Format of Exam	ination At the	beginning of th	e course, the lect	urer determines th	e form of exami-
=				min or an exercise o	
-			-	the lecture. The ad	vanced labora-
tory course is ex	amined via pr	actical exercises	s and protocols.		
Requirements f	or the Attribu	tion of Credit Po	oints Depending o	on the specified for	m of examination:
-			-	of the possible poir	
	-	-			orm of examination
		-		dvanced laboratory	
				with the CP-weight	eu.
Use of the Mod	ule Compulso	ry-Elective Mod	ule		
Importance of t	he Mark for th	ne Final Grade V	Veighted accordi	ng to credit points	
Module Supervi	isor and Instru	ictor Prof. Dr. G	erwert, Prof. Dr. I	Hofmann	
Further Informa	ation				

Introduction	to Solid St	ate Physics			
Module 1c	Credits 9 CP	Workload 270 h	Semester from 1. Sem.	Cycle Winter	Duration 1-2 Semesters
 Courses a) Lecture Introduction to Solid State Physics b) Exercises for Introduction to Solid State Physics c) Advanced Laboratory Courses for Physicists (three experiments in Solid State Physics) 		Contact Hours a) 44 h b) 22 h c) 21 h	Self-Study 183 h	Group Size a) unlimited b) 30 c) 2	
Requirements for Formal None Content Basic ki Preparation Not	nowledge in P		elor) will be highl	y appreciated	
 macroso Are awa electror achieve Know th Are awa Can see 	ly completing basic understa copic and micr are of the poss nic properties of at least a qua ne fundamenta are of scatterir and apply rela	nding on how quoscopic character ibilities of the ge of solid state ma litive understand al concepts of ap ng phenomena in	uantum mechanic eristics of solid st eneral concepts to otter from the bas ding of those com oplying quantum on the position and atomic and solid s	o derive the optical sic methods of phys	, thermal and ics and to state systems
 (ideal crystal: bonding phenelsed Dynamics of (lattice oscilla scattering ex Electrons in s (Classical free conductors, r tion of band holes and fac 	s, misorder, re nomena) the crystalline ations, phonor periments) solid state mat e electron gas, netallic bondi gaps, semi-con ults, pn-junctic	lattice ns, Bose-Einsteir ter Fermi-Dirac-Dis ng, charges in m nductors, therm on	n-distribution, the stribution, electric agnetic fields, ba al excitation of ch	talline structure via ermal properties of c conductivity, ther nd model, experim narges, effective ma	non-conductors, mal properties of ental determina-
Format of Teach	ning Lecture, E	ixercises, Practic	al Exercises (Labo	oratory Course)	
nation (written	examination o ork and active	f 90 min, oral ex participation in	amination of 45 the exercises) for	curer determines th min or an exercise of the lecture. The ac	certificate with

Requirements for the Attribution of Credit Points Depending on the specified form of examination: Passing the written/oral examination or obtaining at least 50% of the possible points in the weekly exercises. In this case, active participation in the exercise is also compulsory. The form of examination is determined at the beginning of the course. In addition, the advanced laboratory course must be successfully completed. Both grades go into the module grade with the CP-weighted.

Use of the Module Compulsory-Elective Module

Importance of the Mark for the Final Grade Weighted according to credit points

Module Supervisor and Instructor Prof. Dr. Böhmer

Further Information

Module 1d	Credits 9 CP	Workload 270 h	Semester from 1. Sem.	Cycle Winter	Duration 1-2 Semesters
Courses			Contact Hours	Self-Study	Group Size
 a) Lecture Introduction to Nuclear and Particle Physics b) Exercises for Introduction to Nuclear and Particle Physics c) Advanced Laboratory Courses for Physicists (three experiments in Nuclear and Particle Physics) 			a) 44 h b) 22 h c) 21 h	183 h	a) unlimited b) 30 c) 2
Requirements Formal None Content Knowl Preparation No	ledge of Physi) will be expected		
Learning Outco					
 have radi are med knov are adva see can prod Contents Nuclear physic standard mode physics, interact field theory, presents, particle	e a basic unde oactivity aware of the dicine w the fundam familiar with antages and c correlations k evaluate the cesses s processes in el of particle p ction of ponde ocesses of the accelerators,	possible application ental concepts of general measure lisadvantages of petween process place into conte the universe, st of the universe, st swith matter an e strong and ele , applications of	e structure of matter tions of nuclear phr of electromagnetic ement techniques a nuclear physical an ses in the universe xt the results of nu cructure of matter f e and description o	ysical processes , weak, and stro and methods an nd radioactive p and in nuclear a clear physical a from elementar f atomic nuclei, on them, introd on, scattering ar le physics in tecl	in technology and ing interaction d can evaluate rocesses nd particle physics nd radioactive y particles - the relativistic heavy ion uction to quantum nd decay experi-
Format of Tead	ching Lecture,	, Exercises, Pract	tical Exercises (Labo	oratory Course)	
tion (written ex weekly homew	xamination of vork and activ	90 min, oral exa	amination of 45 mi n the exercises) for	n or an exercise	s the form of examina- certificate with e advanced laboratory
Passing the wri exercises. In th	itten/oral exa is case, active	mination or obta participation in	aining at least 50%	of the possible compulsory. T	form of examination: points in the weekly he form of examinatior tory course must be

Use of the Module Compulsory-Elective Module

Importance of the Mark for the Final Grade Weighted according to credit points

Module Supervisor and Instructor Prof. Dr. Wiedner

Further Information

Courses a) Lecture Introc b) Exercises for I Physics c) Advanced Lab Physicists (thr Plasma Physic Requirements fo Formal None Content Knowlee Preparation Non Learning Outcon After successfull	Introduction poratory Cou ree experime cs) or Participat dge of Physic	to Plasma urses for ents in ion	from 1. Sem. Contact Hours a) 44 h b) 22 h c) 21 h	Summer Self-Study 183 h	1-2 Semesters Group Size a) unlimited b) 30 c) 2
 a) Lecture Introd b) Exercises for I Physics c) Advanced Lab Physicists (thr Plasma Physic Requirements for Formal None Content Knowled Preparation Non Learning Outcon After successfully 	Introduction poratory Cou ree experime cs) or Participat dge of Physic	to Plasma urses for ents in ion	a) 44 h b) 22 h c) 21 h	•	a) unlimited b) 30
Formal None Content Knowled Preparation Non Learning Outcon After successfull	dge of Physi ne) will be appreciate	I	
After successfull	nes			ed	
 of descri Are away concepts Know the Are fami Can see 	asic underst bing of plass re of the app s e fundamen liar with the correlations	tanding of the in ma in the single plications of low tal concepts of p e dynamics of pla	nportant character particle model, an and high tempera plasma equilibrium asma a heating and plas	d of the kinetic a ture plasma and	a and of the forms and fluid description I their locking nd can apply physical
•	etohydrodyr	namics, kinetic t	particles in magne heory, boundary la		on interactions, hydro- lasmas, basics of
Format of Teach	ing Lecture,	Exercises, Pract	ical Exercises (Lab	oratory Course)	
tion (written exa	mination of active partici	90 min, oral examption in the ex	amination of 45 mi ercises) for the lec	n or an exercise	s the form of examina- certificate with weekly ced laboratory course i
Passing the writt exercises. In this is determined at	en/oral exa case, active the beginni	mination or obta participation in ng of the course	aining at least 50% the exercise is also	of the possible compulsory. The dvanced laborated by the second	form of examination: points in the weekly he form of examination cory course must be ghted.
Use of the Modu	Ile Compuls	ory-Elective Mo	dule		
Importance of th	ne Mark for	the Final Grade	Weighted accordi	ng to Credit Poir	its
Module Supervis	sor and Inst	ructor Prof. Dr. (Golda		

General Re	lativity				
Modul 2a	Credits 6 CP	Workload 180 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses a) Lecture Ger b) Exercises fo			Contact Hours a) 44 h b) 22 h	Self-Study 114 h	Group Size a) unlimited b) 30
Requirements Formal None Content None Preparation No		ion			
Have aAre awKnow t	Illy completin basic unders are of the po the fundamer	ssibilities of diffentiation of the second s	ne students by as curvature of s erential-geometric gravity and their ap cal ideas and can a	methods oplications	ematic form
 forms); tens Manifolds: (expanding u Curvature: c symmetries Gravitation: mological cc The Schwar ics of the Sc Cosmology: 	sors; Maxwell Gravity as a guiverse; Caus covariant deri and Killing ve physics in cu onstant; alter zschild solutio hwarzschild so Maximally sy	equations; ener cometric proper sality; Tensor de vative; parallel t ectors; maximally rved spacetime; native theories on: the Schwarzs olution; black ho mmetric univers	y symmetric spaces Einstein equations schild metric; Birkh bles; the maximally	nsor; classical fie fold; Vectors, ten forms; Integrat esics; the Riema s; geodesic diven s; Lagrangian for off's theorem; s extended Schw ker metric; the F	Id theory. nsors, metrics; An ion inn curvature tensor; gence mulation; the cos- ingularities; geodes- varzschild solution riedmann equation;
Format of Tead	ching Lecture	, Exercises			
			the course, the lect examination of 30 r		s the form of examina- dule.
Requirements	for the Attrik	oution of Credit	Points Passing the	examination	
		ory-Elective Mo			
-			Weighted accordi	ng to Credit Poir	nts
-		ructor Prof. Dr.	Grauer		
Further Inform	ation				

 a) Lecture Adva Mechanics b) Exercises for Mechanics Requirements formal None Content Knowlet (Bachelor) will b 	anced Quantu r Advanced C	ım	from 1. Sem. Contact Hours a) 44 h b) 22 h	Winter Self-Study 114 h	1 Semester Group Size
Requirements f Formal None Content Knowle (Bachelor) will k	or Dorticiast	b) Exercises for Advanced Quantum		114 11	a) unlimited b) 30
Preparation No	edge of the co be expected		duction to Quantu	ım Mechanics ar	nd Statistics"
 analyse Can see and its Have ar and can Are fam particle Gained 	ly completing o understand complex phy and apply fu underlying m o overview of apply them alliar with sca s	ing of advanced vsical phenomer adamental corr athematical for the most impor independently t ttering theory a	concepts of quant	symmetries in qu e methods of qu henomena echanical treatn	antum mechanics antum mechanics nent of identical
-	eir applicatio		-		rules, approximation s, field quantisation,
Format of Teac	hing Lecture,	Exercises			
			the course, the lect n or oral examinat		
Requirements f	or the Attrib	ution of Credit	Points Passing the	examination	
Use of the Mod	ule Compuls	ory-Elective Mo	dule		
Importance of t	he Mark for	the Final Grade	Weighted according	ng to Credit Poin	its
Module Superv	isor and Inst	ructor Prof. Dr.	Epelbaum		

Statistical Pl	hvsics (unti	l SoSe 2023)			
	•	•	ysics (from So	oSe 2024)	
Modul 2c	Credits 6 CP	Workload 180 h	Semester from 1. Sem.	Cycle Summer	Duration 1 Semester
Courses a) Lecture Ther Physics b) Exercises for tical Physics	·		Contact Hours a) 44 h b) 22 h	Self-Study 114 h	Group Size a) unlimited b) 30
Requirements f Formal None Content Knowle (Bachelor) will k Preparation No	edge of the cor be expected		duction to Quanti	um Mechanics a	nd Statistics"
 Know th Are fam physics 	ly completing basic understa ne fundamenta niliar with fund	nding of the cor al concepts of qu amental definiti	ncepts of statistic Jantum statistics	nd quantum me	chanical statistical
is the simple sta statistics with a	atistics of many pplications	y particles, therr			ations. Starting point Afterwards quantum
Format of Teac	hing Lecture, E	xercises			
Format of Exam	nination Writte	en examination	of 120 min		
Requirements f	or the Attribu	tion of Credit Po	oints Passing the	examination	
Use of the Mod	ule Compulso	ry-Elective Mod	ule		
Importance of t	he Mark for t	ne Final Grade V	Veighted accordi	ng to Credit Poir	nts
Module Superv	isor and Instru	ictor Prof. Dr. Ei	remin		
Further Information and Statistical P		ule "Statistical F	Physics" is equiva	lent to the modu	ule "Thermodynamics

	Credits	Workload	Semester	Cycle	Dauer
	6 CP	180 h	from 1. Sem.	Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
) Lecture Introduction to Theoretical		a) 44 h	114 h	a) unlimited	
Astrophysi	Astrophysics		b) 22 h		b) 30
b) Exercises for	or Introductior	n to Theoretical			
Astrophysi	CS				
Requirement	s for Participat	tion			
Formal None					
Content Basic	knowledge of	theoretical phys	sics (Bachelor level) is highly appre	eciated
Preparation N	lone				
Learning Outo	comes				
After successf	ully completin	g this module, th	ne students		
Have	a basic unders	tanding of theor	etical astrophysics		
 Are av 	ware of the po	ssibilities of the u	used mathematisa	tion and model	ling
 Know 	the fundamer	tal concepts for	describing astroph	nysical environn	nents
 Are fa 	miliar with dif	ferent theoretica	al methods		
 Can set 	ee and success	fully apply corre	lations between a	strophysics, res	pective examples and
differ	ent branches c	of physics (nuclea	ar and particle phy	sics, plasma phy	/sics)
<u></u>					
contents					
	results of astro	ophysics are intro	oduced for selecte	d astrophysical	systems and discusse
Methods and		• •		• •	systems and discusse following topics: As-
Methods and in connection	with current r	esearch results.	Focal points are se	lected from the	•
Methods and in connection trophysics: de	with current r finition and fu	esearch results. I ndamentals (the	Focal points are se latter are provide	lected from the d in short digre	following topics: As-
in connection trophysics: de Stars: state va structure and	with current r finition and fu riables, forma interaction wi	esearch results. I ndamentals (the tion, structure, e th the interstella	Focal points are se latter are provide volution and final r medium; Stellar	lected from the d in short digres states; Stellar w atmospheres: S	following topics: As- ssions as required); vinds: acceleration, tructure and radiative
Methods and in connection trophysics: de Stars: state va structure and transfer; Stella	with current r finition and fu riables, forma interaction wi ar winds: accel	esearch results. ndamentals (the tion, structure, e th the interstella leration, structur	Focal points are se latter are provide volution and final r medium; Stellar re and interaction	lected from the d in short digre states; Stellar w atmospheres: S with the interst	ssions as required);
Methods and in connection trophysics: de Stars: state va structure and transfer; Stella Way, galaxies	with current r finition and fu riables, forma interaction wi ar winds: accel structure; Cos	esearch results. I ndamentals (the tion, structure, e th the interstella leration, structur smic rays: accele	Focal points are se latter are provide volution and final r medium; Stellar	lected from the d in short digre states; Stellar w atmospheres: S with the interst	following topics: As- ssions as required); vinds: acceleration, tructure and radiative
Methods and in connection trophysics: de Stars: state va structure and transfer; Stella Way, galaxies	with current r finition and fu riables, forma interaction wi ar winds: accel	esearch results. I ndamentals (the tion, structure, e th the interstella leration, structur smic rays: accele	Focal points are se latter are provide volution and final r medium; Stellar re and interaction	lected from the d in short digre states; Stellar w atmospheres: S with the interst	following topics: As- ssions as required); vinds: acceleration, tructure and radiative
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Methods and in connection trophysics: de Stars: state va structure and transfer; Stella Way, galaxies Format of Tea Format of Exa tion (written e	with current r finition and fu riables, forma interaction wi ar winds: accel structure; Cos ching Lecture, mination At th examination of	esearch results. I ndamentals (the tion, structure, e th the interstella leration, structur smic rays: accele , Exercises he beginning of t 5 90 min, oral exa	Focal points are se latter are provide volution and final r medium; Stellar e and interaction ration and transpo he course, the lect mination of 45 mi	lected from the d in short digres states; Stellar w atmospheres: S with the intersto ort. turer determine n or an exercise	following topics: As- ssions as required); /inds: acceleration, tructure and radiative ellar medium; Milky
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Introduction	to Theoret	ical Solid Sta	te Physics		
Modul 3b	Credits 6 CP	Workload 180 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses a) Lecture Introd State Physics b) Exercises for I Solid State Phy	ntroduction to		Contact Hours a) 44 h b) 22 h	Self-Study 114 h	Group Size a) unlimited b) 30
Requirements fo Formal None Content Knowled	-		uding the content	ts of "Introduction t	o Quantum
Mechanics and S Preparation Non	tatistics" (Bach	• •	-		
 Have a back properties scopic be scopic be Are family sudden back of the suden back of the sudden back of the suden back of the sudden back	v completing the e fundamental asic understan es of oscillation chaviour of the liar with the m preaking of syn e and interpret ucture of the s disorder, reci he crystal lattic ons, phonons, periments) ne solid state electron gas, F netallic bondin, n of band gaps,	concepts of soli ding of the micr h, and the electr e solid state athematical rep metry, phase to typical exercise solid procal lattice, cr Bose-Einstein d Fermi-Dirac distr g, charge carrier , semiconductor	id state theory oscopic properties onic properties a resentation of so ransition, elemen es of solid state th rystal structure de istribution, thern sibution, electrica rs in the magnetic s, thermal excitation		n the macro- uantification, raction, bonding e non-conductor, nal properties of experimental ers, scattering
Format of Teachi	•		course the last	urar datarminas tha	form of ovamina
	mination of 90	min, oral exam	ination of 45 min	urer determines the or an exercise certi ure.	
Passing the writte exercises. In this is determined at	en/oral examiı case, active pa the beginning	nation or obtain articipation in th of the course.	ing at least 50% o e exercise is also	n the specified form of the possible point compulsory. The fo	s in the weekly
Use of the Modu Importance of th				g to Credit Points	
Module Supervis		tor Dr. Lecherm	ann		
Further Informat	ion				

Modul 3c	Credits	Workload	Semester	Cycle	Duration
	6 CP	180 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
 a) Lecture Introduction to Theoretical Plasma Physics b) Exercises for Introduction to Theoretical Plasma Physics 		a) 44 h b) 22 h	114 h	a) unlimited b) 30	
Requirements Formal None Content Basic appreciated Preparation No	knowledge of		ics, especially elect	trodynamics (Ba	chelor level), is highly
Learning Outco					
 have g completed completed	ained a basic usex many-partic niliar with the es and are able the basic math ped in the mo niliar with resp t of astrophys there ained initial ex ntext of the pr	cle system. descriptions of p e to assess the po ematical technic dule pective plasma-p ics and space ph sperience in the	the problems of t blasmas on the bas ossibilities and limi ques for working w hysical application ysics and have an i	sis of kinetic and itations of such vithin the framew ns of the theorie insight into the p ng of plasma-ph	I fluid dynamic models work of the theories s and methods in the parameter regimes ysical processes in
magnetohydro space-physical Format of Tea Format of Exam tion (written e	dynamics, equ context, nume ching Lecture, mination At th xamination of	ilibrium theory, erical modelling Exercises, nume e beginning of tl 90 min, oral exa	rical computer sim he course, the lect mination of 45 mir	lities, application nulation urer determines n or an exercise	
	•		ercises) for the lect		<u></u>
Passing the wr exercises. In th	itten/oral exar iis case, active	nination or obta	ining at least 50% the exercise is also	of the possible p	form of examination: points in the weekly ne form of examinatio
Use of the Mo	dule Compulso	ory-Elective Mod	lule		
	the Mark for	the Final Grade	Weighted accordir	ng to Credit Poin	ts
Importance of					
-		uctor Prof. Dr. T	jus		

Modul 4a	Credits	Workload	Semester	Cycle	Duration
	15-25 CP	450-750 h	12. Sem.	Winter & Summer	2 Semesters
Courses			Contact Hours	Self-Study	Group Size
a) Lecture			Each at least.	min. 309 h	a) unlimited
b) Exercises			a) 44 h		b) 30
c) Seminar (at	least 2 CP)		b) 44 h		c) 30
d) Advanced La	aboratory Cou	rses	c) 22 h		d) 2
(at least 5 Cl	P)		d) 35 h		
A complete ove					
found in the cu		-			
CP of the indivi					
semester hours	-	nour per se-			
mester week =	1 CP)				
Requirements	for Participati	on			
Formal None					
Content Basic k	knowledge of a	astronomy/astro	physics will be ex	xpected	
 have le physics 	omes Ily completing arned to apply b) to the often	'exotic' conditio	edge from differents of space comp		
Learning Outco After successfu have le physics Have g different know t are info are abl	omes Ily completing arned to apply to the often ained a basic u nt phenomena he basic theor ormed about c e to read, und e to write thei	y physical knowl 'exotic' conditio inderstanding of a in the universe etical concepts o urrent astrophy erstand and clas	edge from different ns of space comp f the most import of modern astron sical issues ssify astrophysica	oared to Earth. tant physical process oomy and astrophysic	es describing the

Format of Examination Oral examination of 45 minutes

Requirements for the Attribution of Credit Points Passing the oral examination.

The specialisation module must include: advanced laboratory courses (5 CP) and a seminar (2 CP). Including the final oral module examination (2 CP), 15-25 CP can be achieved.

Achievements made after the final module examination no longer count towards the module. **Use of the Module** Compulsory-Elective Module

Importance of the Mark for the Final Grade Weighed according to Credit Points

Module Supervisor Prof. Dr. Bomans

Examiners Prof. Dr. Bomans, Prof. Dr. Franckowiak, Prof. Dr. Hildebrandt, Prof. Dr. Riseley, Prof. Dr. Tjus, PD Dr. Fichtner

Further Information For advice and coordination of the courses, please contact the module supervisor.

Course	Туре	No.	Semester
Advanced Laboratory Course for Dhusisiste	Laboratori	100250	Winter
Advanced Laboratory Course for Physicists	Laboratory	160250	Summer
Advanced Laboratory: Observational Astronomy	Laboratory	160624	Winter
Advanced Laboratory. Observational Astronomy			Summer
Astroparticle Physics	Lecture	160614	Summer
· · ·	Exercises	160615	
Astrophysical Fluids, Plasmas and Shocks	Lecture	160623	Winter
Chaos, Turbulence and Stochastic Systems	Lecture	160532	Summer
	Exercises	160533	
Cosmology	Lecture	160611	Winter
	Exercises	160612	
		160665	Winter
Crossing the Desert	Seminar	160661	Summer
			not in 25
		160615	Winter
Fluid Dynamics in Astrophysics	Lecture	160605	Summer
			not in 25
Galaxy Clusters	Lecture	160618	Summer
Gamma-ray Astronomy	Seminar	160667	Summer
Interstellar Medium Astrophysics	Lecture	160601	Summer
Introduction to Space Physics	Lecture	160618	Winter
introduction to space ringsics	Exercises	160619	Winter
Introduction to Statistics for Astronomers and Physicists	Lecture	160613	Summer
		160610	Winter
Methods in Theoretical Astroparticle Physics	Seminar	100022	Summer
		160623	not in 25
Modelling of Atomic Populations in the Spectroscopy of	Lecture	160511	Currente e r
Laboratory and Astrophysical Plasmas II	Exercises	160512	Summer
Madelling Transport and Interactions of Coursis Dave	Lecture	160616	Summer
Modelling Transport and Interactions of Cosmic Rays	Exercises	160617	not in 25
Multi Mavalangth Astronousics	Sominar	160666	Winter
Multi-Wavelength Astrophysics	Seminar	160662	Summer
Observational Cosmology	Cominen	160661	Winter
Observational Cosmology	Seminar	160650	Summer
Radio Astronomy	Lecture	160613	Winter
Research Topics in Heliophysics	Seminar	160663	Winter
Selected Topics of Astronomy	Seminar	160621	Winter
Selected Topics of Astronomy II	Seminar	160620	Summer

Stars, Winds, Nebulae	Lecture	160608	Winter
The Milky Way and External Galaxies	Lecture	160602	Winter
	Seminar	160609	Winter
Theoretical Heliophysics	Seminar	160624	Summer
	Seminar	100024	not in 25
Theoretical Neutrino Astrophysics	Lecture	160616	Winter
Theoretical Neutrino Astrophysics	Exercises	160617	Winter
Variabilities and Instabilities in Stars	Lecture	160660	Summer
X-ray Astronomy	Lecture	160610	Summer

Cosmology					
	Credits 4 CP	Workload 120 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses a) Seminar Cosr	nology	- ·	Contact Hours a) 33 h	Self-Study 76 h	Group Size a) Unlimited
o) Exercises for	Cosmology		b) 11 h		b) 30
Requirements formal None Formal None Content Introdu Preparation Price	ction to Ast	rophysics	an astronomy intr	oductory lecture	2
 have an are awa know th backgro are fami and gala are read Contents The lecture start Friedmann-Lema observational away thermal history of the mation and evol structures we see and understood galaxy evolution	understand re of the phy e physical co und liar with the xy evolution y to work or to work or to work or to work or to work or to or the unive above ment ution are dis e in the unive based on the	ysics of the therr oncepts of cosm e basics of the in- n n a master thesis scription of the p ison-Walker univ onstrain such mo rse is covered, co tioned homogen scussed, starting verse today. The nese concepts. Co	rties of a homogen mal history of the u ic structure format flationary universe s with a cosmologic whysics of homogen verses. Their conten dels are discussed. onnecting insights eous, isotropic wo from tiny primord cosmic microwave osmic inflation, re-	universe tion and the cost , re-ionisation, g cal topic neous, isotropic nts, past and fut Starting from the from particle pherical rid models. Next lial fluctuations are background (C ionisation, gravi	mic microwave gravitational lensing universes, a.k.a. ure evolution, and he hot big bang, the hysics, thermody- t, structure for- all the way to the
vations. Format of Teach	ing Lecture	, Exercises			
Format of Exam	-				
Requirements for completion of th			Points Active partie	cipation in the e	xercises and successfu
Use of the Mod	ule Courses	in Physics Major			
mportance of t		the Final Grade	Graded, but does	not contribute t	o the weighted
viodule Supervi	sor and Inst	ructor Prof. Dr.	Hildebrandt		

	Credits	Workload	Semester	Cycle	Duration
	2 CP	90 h	from 1. Sem.	Winter & Summer (not in 25)	1 Semester
Courses	÷		Contact Hours	Self-Study	Group Size
a) Seminar Cr	ossing the De	esert	a) 22 h	68 h	a) Unlimited
Requirements	for Participa	tion			
Formal None					
	edge from "I	ntroduction to N	luclear and Particle	Physics" as well as "	Astroparticle
Physics"					
Preparation No					
Learning Outco					
After successfu	-		from actronarticle	nhucies independent	h.,
				physics independent	-
		ch landscape	derstand specialist	articles by scientists f	rom the
			l discussion on toni	cs of particle physics	hevond
	indard Mode			cs of particle physics	beyond
Contents					
				utrino and gamma as	•
				of analysing the large	e amounts of
data generated	in this field (can also be cove	red.		
Format of Tea	ching Semina	r			
Format of Exa	nination Pres	sentation			
Requirements	for the Attrik	oution of Credit	Points Active partion	cipation and presenta	ation
Use of the Mo	dule Courses	in Physics Major	-		
Importance of	the Mark for	the Final Grade	Graded, but does	not contribute to the	weighted
average final g	rade				
Module Super	visor and Inst	t ructor Prof. Dr.	Rhode		
			•	25, purely digital for	Bochum and
Dortmund, Cou	urse offered b	by TU Dortmund	with RUB participa	tion	

Dortmund, Course offered by TU Dortmund with RUB participation

	Credits	Workload	Semester	Cycle	Duration
	3 CP	90 h	from 1. Sem.	Winter	1 Semester
Courses a) Lecture Intro b) Exercises fo Physics		• •	Contact Hours a) 22 h b) 11 h	Self-Study 57 h	Group Size a) Unlimited b) 30
Requirements Formal None Content Basic H Preparation No	nowledge of	tion Theoretical Phy	sics		I
 studen modell studen process studen 	l completion ts have a bas ts are aware ing ts know the b ses and syste	ic understanding of the capabilitie pasic concepts fo ms and can appl	g of Space Physics es of the correspon or the quantitative o y them successfully ections between sp	description of sp /	bace physical
be discussed in ics: the Sun, the (magnetospher	the context e quiet and d e as well as t	of current reseau isturbed solar w	rch. Focus areas wi vind and its interact nedium (heliospher	ll be selected fro tion with the ter	sical systems and will om the following top- restrial environment irbulence in the solar
Format of Teac	hing Lecture	s and exercises			
	duration, or		the course the doce in duration, or seve		ofexam (e.g., written tiple choice) tests
Passing the wri tasks. In this ca	tten/oral exa se, active par	im or obtaining a	exercise is also ma	possible points i	form of examination: n the weekly exercise rm of examination wil
Use of the Moo	dule Courses	in Physics Major			
	the Mark for	the Final Grade	Graded, but does	not contribute t	o the weighted aver-
Importance of age final grade					
age final grade		r uctor PD Dr. Fic	chtner		

	Credits	Workload	Semester	Cycle	Duration
	3 CP	90 h	from 1. Sem.	Summer	1 Semester
				(not in 25)	
Courses	I		Contact Hours	Self-Study	Group size
	odelling Transp	ort and Inter-	a) 22 h	57 h	a) 20
	Cosmic Rays		b) 11 h	57 11	b) 20
	for Modelling T	ransport and	,		,
	ns of Cosmic Ra				
		-			
•	ts for Participat	tion			
Formal None					
	-		following programm	ing languages Pyt	hon, C++, and Fortrar
	recommended	•			
Preparation	None				
earning Out	comes				
-	ourse, the stude	ents will:			
-			to model the trans	port and interaction	on of cosmic rays
-			antages of different		
	ics problems				
• •	•	to set up and r	un various software	tools to model CF	transport
		-	s into physical quant		
			he simulation mode		irements of CR
-	rvables			is based on measu	
0030	TVUDICS				
Contents					
 Ultra 	high-energy co	smic rays: Singl	e particle propagati	on and efficient n	uclei-photon inter-
	n modelling	, 0	1 1 0		•
	-	: Complex mag	netic field models (c	oherent + turbule	ent), ensemble aver-
	•		chastic differential e		•
• Sour	ce physics: Non	linear time evo	olution of energy sp	ectra, tabulated ir	nteraction rates,
matr	ix methods				
From	simulation to	physics values:	Re-weighting, norm	alization, compari	son with observables
^c ormat of Te	eaching Lecture	, Exercises			
				-	tten exam, 45 min ora
exam or wee	kly homework	including active	e participation) at th	e beginning of the	e course.
Requiremen	ts for the Attrik	oution of Credit	t Points Depending of	on the kind of exa	mination: Passing
•			50 % of the possible		-
		-	•	• • •	atory, too. The form
-			ning of the course.	- •	-
lso of the M	Iodule Elective	Module			
	LICCUVE	wiodule			
•	of the Mark for	^r the Final Grad	e Graded, but does	not contribute to	the weighted average
final grade					
Module Sup	ervisor and Inst	tructor Dr. Mer	ten, Prof. Dr. Tjus		
Module Sup Further Info		tructor Dr. Mer	ten, Prof. Dr. Tjus		

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter & Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
	ulti-Wavelen	gth Astrophysics	a) 22 h	38 h	a) Unlimited
Requirements	for Participat	ion			
F ormal Work o	n a bachelor ,	/ master thesis in		ngth astronomy grou	р
		stronomy", "Astr e module astron		is recommended	
-					
Learning Outco After successfu		of the module stu	ıdents		
	-			ti-messenger astroph	nysics
	•		n international gro	• •	
			among internation	•	
• nave a	cquired the sk	cliset to complete	e their bachelor /	master theses	
This weekly ser covers topics o modelling of m	f neutrino ast ulti-waveleng	ronomy, gamma- gth data. We discu	ray astronomy, op uss recent papers	wavelength astrophy ptical astronomy and concerning the topic	numerical and members
This weekly ser covers topics o modelling of m of the group re large collabora	f neutrino ast ulti-waveleng gularly preser tions, have op	ronomy, gamma- th data. We discunt their work. The	ray astronomy, o uss recent papers e students get first	ptical astronomy and	numerical and members er workings of
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covers topics o modelling of m of the group re large collabora work to the gro Formats of Tea Format of Exar students' work Requirements At this stage, i. additional cred ticipation as de Use of the Moo Importance of average final gr	f neutrino ast ulti-waveleng gularly presen tions, have op oup. aching Semina nination Regu , discussions w for the Attrib e. after the st it points. How etailed above. dule Courses i the Mark for rade	in Physics Major	ray astronomy, op uss recent papers e students get first ceract with internation pation in the form embers and subse pints or/master thesis, s still be awarded if Graded, but does i	otical astronomy and concerning the topic t insights into the inn ational colleagues an of short presentatio equent follow-up.	numerical and members er workings of d present their ns of the not require ir active par-

	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Winter & Summer	Duration 1 Semester
Courses a) Seminar Ob	servational (Cosmology	Contact Hours a) 22 h	Self-Study 38 h	Group Size a) Unlimited
Content Lecture Astronomy" (ba	n a bachelor/ e "Cosmolog ichelor)	master thesis in	-	cosmology group ics" (master); lecture	e "Basics of
 have a pare fam are fam have leader of the can comprofess have accomproteed of the cam, get in 	good underst iliar with the arned to pres duct scientif ional advice quired the sl eting brings t ems, and cur uput from the	e interactions in a sent their work t ic discussions, re for their work; killset to comple together all men rent topics. It is eir peers, and im	ork in a research g an international re- to their peers in a re- espond to question te their bachelor/n nbers of the observ expected that stud prove their work th	search team; egular setting; s and criticism, and t	roup to discuss eekly progress to oductive criticism
giving the stude	ents first insig	ghts into the inn	er workings of such	n collaborations, potent of their work to a wic	entially with op-
Format of Teac	hing Semina	r			
	-	•	•	n of short presentatic bsequent follow-up.	
At this stage, i.e	e. after the st t points. How	vever, points car	lor/master thesis, s	students typically do f necessary for regula	•
Use of the Mod	l ule Courses	in Physics Major			
Importance of t		the Final Grade	Graded, but does	not contribute to the	e weighted
average final gr		-			
average final gr Module Superv	isor and Inst	ructor Prof. Dr.	Hildebrandt		

Courses a) Lecture Radio Astronomy Contact Hours Self-Study Group Size a) Lecture Radio Astronomy a) 22 h 38 h a) Unlimited Requirements for Participation Formal None a) Understanding of Fourier Transforms Learning Outcomes After successful completion of the module students have a basic understanding of radio astronomical imaging techniques • Students have a basic understanding of radio astronomical imaging techniques students have a basic concepts of emission and absorption mechanisms of astronomical bodies radiating in the radio regime • are familiar with radio astronomical polarisation measurements students are able to recognize connections between plasma physics, high energy particle physics and radio astronomy • students are able to perform their Master Thesis within the area of radio astronomy such as receiver and correlator technology and explain the mathematical principles needed for generating interferometric radio images. Data calibration methods will be illustrated and imaging algorithms introduced as well as methods to analyse radio interferometric data products. The second half of the lecture gives an overview of the astronomical science radio astronomy is mostly associated with such as magnetic fields, star-formation, active supermassive galactic nuclei and time domain radio astronomy. Format of Teaching Lecture Format of Teaching Lecture Format of Teaching Lecture Format of Teaching Lecture Format of Teaching Le		Credits	Workload	Semester	Cycle	Duration
a) Lecture Radio Astronomy a) 22 h 38 h a) Unlimited Requirements for Participation Formal None Content None Preparation Introduction to Astrophysics and a good understanding of Fourier Transforms Learning Outcomes After successful completion of the module • • students have a basic understanding of radio astronomical imaging techniques • Students are aware of the capabilities of modern radio telescopes and receivers • students know the basic concepts of emission and absorption mechanisms of astronomical bodies radiating in the radio regime • are familiar with radio astronomical polarisation measurements • students are able to recognize connections between plasma physics, high energy particle physics and radio astronomy • students are able to perform their Master Thesis within the area of radio astronomy such as receiver and correlator technology and explain the mathematical principles needed for generating interferometric radio images. Data calibration methods will be illustrated and imaging algorithms introduced as well as methods to analyse radio interferometric data products. The second half of the lecture gives an overview of the astronomical science radio astronomy is mostly associated with such as magnetic fields, star-formation, active supermassive galactic nuclei and time domain radio astronomy. Format of Teaching Lecture Format of Teaching Lecture Format of the Attribution of Credit Points Passing the oral exam Use of the Module Courses in Physics Major		2 CP	60 h	from 1. Sem.	Winter	1 Semester
Requirements for Participation Formal None Content None Preparation Introduction to Astrophysics and a good understanding of Fourier Transforms Learning Outcomes After successful completion of the module • students have a basic understanding of radio astronomical imaging techniques • Students are aware of the capabilities of modern radio telescopes and receivers • students have a basic concepts of emission and absorption mechanisms of astronomical bodies radiating in the radio regime • are familiar with radio astronomical polarisation measurements • students are able to recognize connections between plasma physics, high energy particle physics and radio astronomy • students are able to perform their Master Thesis within the area of radio astronomy such as receiver and correlator technology and explain the mathematical principles needed for generating interferometric radio images. Data calibration interferometric data products. The second half of the lecture gives an overview of the astronomical science radio astronomy is mostly associated with such as magnetic fields, star-formation, active supermassive galactic nuclei and time domain radio astronomy. Format of Teaching Lecture Format of Teaching Lecture Ise of the Module Courses in Physics Major	Courses				Self-Study	•
Formal None Content None Preparation Introduction to Astrophysics and a good understanding of Fourier Transforms Learning Outcomes After successful completion of the module • students have a basic understanding of radio astronomical imaging techniques • Students are aware of the capabilities of modern radio telescopes and receivers • students know the basic concepts of emission and absorption mechanisms of astronomical bodies radiating in the radio regime • are familiar with radio astronomical polarisation measurements • students are able to recognize connections between plasma physics, high energy particle physics and radio astronomy • students are able to perform their Master Thesis within the area of radio astronomy such as receiver and correlator technology and explain the mathematical principles needed for generating interferometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio images. Data calibration methods will be illustrated and imaging algorithms interdecometric radio astronomy. Format of Teaching Lecture Format of Teaching Lecture Format of Examination Oral exam 45 min Requirements for the Attribution of Credit Points Passing the oral exam Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted aver age final grade	a) Lecture Rad	io Astronomy	1	a) 22 h	38 h	a) Unlimited
 Learning Outcomes After successful completion of the module students have a basic understanding of radio astronomical imaging techniques Students are aware of the capabilities of modern radio telescopes and receivers students know the basic concepts of emission and absorption mechanisms of astronomical bodies radiating in the radio regime are familiar with radio astronomical polarisation measurements students are able to recognize connections between plasma physics, high energy particle physics and radio astronomy students are able to perform their Master Thesis within the area of radio astronomy students are able to perform their Master Thesis within the area of radio astronomy such as receiver and correlator technology and explain the mathematical principles needed for generating interferometric radio images. Data calibration methods will be illustrated and imaging algorithms introduced as well as methods to analyse radio interferometric data products. The second half of the lecture gives an overview of the astronomical science radio astronomy is mostly associated with such as magnetic fields, star-formation, active supermassive galactic nuclei and time domain radio astronomy. Format of Teaching Lecture Format of Teaching Lecture Format of Teaching Lecture Format of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted average final grade 	Formal None Content None	·		d a good understar	nding of Fourier	Transforms
The first half of the lecture will introduce students to the technical part of radio astronomy such as receiver and correlator technology and explain the mathematical principles needed for generating interferometric radio images. Data calibration methods will be illustrated and imaging algorithms introduced as well as methods to analyse radio interferometric data products. The second half of the lecture gives an overview of the astronomical science radio astronomy is mostly associated with such as magnetic fields, star-formation, active supermassive galactic nuclei and time domain radio astronomy. Format of Teaching Lecture Format of Teaching Lecture Format of Examination Oral exam 45 min Requirements for the Attribution of Credit Points Passing the oral exam Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted average final grade	After successfu studen Studen studen bodies are fan studen physics	Il completion ts have a bas its are aware ts know the b radiating in t niliar with rac ts are able to s and radio as	ic understanding of the capabilitie pasic concepts of he radio regime lio astronomical recognize conne tronomy	es of modern radio emission and abso polarisation measu ections between pl	telescopes and orption mechani urements asma physics, hi	receivers sms of astronomical igh energy particle
Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted aver age final grade	Contonto					
Requirements for the Attribution of Credit Points Passing the oral exam Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted aver age final grade Module Supervisor and Instructor Dr. Adebahr	The first half of receiver and co interferometric introduced as w The second hal mostly associat and time doma	orrelator tech c radio image well as metho f of the lectu ted with such in radio astro	nology and expla s. Data calibratio ds to analyse rac re gives an overv as magnetic fiel	ain the mathemation on methods will be dio interferometric view of the astrono	cal principles nee illustrated and i data products. mical science ra	eded for generating maging algorithms dio astronomy is
Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted aver age final grade	The first half of receiver and co interferometric introduced as w The second hal mostly associat and time doma Format of Teac	orrelator tech c radio image well as metho f of the lectu ted with such ain radio astro ching Lecture	nology and expla s. Data calibratio ds to analyse rad re gives an overv as magnetic fiel pnomy.	ain the mathemation on methods will be dio interferometric view of the astrono	cal principles nee illustrated and i data products. mical science ra	eded for generating maging algorithms dio astronomy is
age final grade	The first half of receiver and co interferometric introduced as w The second hal mostly associat and time doma Format of Teac Format of Exar	orrelator tech cradio image well as metho if of the lectu ted with such in radio astro ching Lecture mination Ora	nology and expla s. Data calibratio ids to analyse rad re gives an overv as magnetic fiel pnomy. I exam 45 min	ain the mathematic on methods will be dio interferometric view of the astrono ds, star-formation,	cal principles nee illustrated and i data products. mical science ra active superma	eded for generating maging algorithms dio astronomy is
Module Supervisor and Instructor Dr. Adebahr	The first half of receiver and co interferometric introduced as w The second hal mostly associat and time doma Format of Teac Format of Exar Requirements	orrelator tech c radio image well as metho if of the lectu ted with such in radio astro ching Lecture mination Ora for the Attrik	nology and expla s. Data calibratio ods to analyse rac re gives an overv as magnetic fiel- onomy. I exam 45 min oution of Credit I	ain the mathematic on methods will be dio interferometric view of the astrono ds, star-formation, Points Passing the	cal principles nee illustrated and i data products. mical science ra active superma	eded for generating maging algorithms dio astronomy is
	The first half of receiver and co interferometric introduced as w The second hal mostly associat and time doma Format of Teac Format of Exar Requirements Use of the Moo	orrelator tech c radio image well as metho if of the lectu ted with such in radio astro ching Lecture mination Ora for the Attrik dule Courses the Mark for	nology and expla s. Data calibratio ods to analyse rac re gives an overv as magnetic fiel- onomy. I exam 45 min oution of Credit I in Physics Major	ain the mathematic on methods will be dio interferometric view of the astrono ds, star-formation, Points Passing the	cal principles nee illustrated and i data products. mical science ra active superma	eded for generating maging algorithms dio astronomy is ssive galactic nuclei

2 Courses a) Seminar Resea Requirements for Formal None Content None	Credits 2 CP arch Topics in	Workload 60 h	Semester from 1. Sem. Contact Hours a) 22 h	Cycle Winter Self-Study	Duration 1 Semester
Courses a) Seminar Resea Requirements for Formal None Content None	arch Topics ir		Contact Hours		1 Semester
a) Seminar Resea Requirements for Formal None Content None		n Heliophysics		Colf Study	
Requirements for Formal None Content None		n Heliophysics	a) 22 h	Sell-Study	Group Size
Formal None Content None	Participatio			38 h	a) Unlimited
Content None	•	n			
Duenewetten Mene					
Preparation None					
 heliophysi students w thesis) to students w specialized students a 	ompletion of will have an o ics group will have pres the other gro vill have lear d audience are able to su	overview of the sented their ow oup members ned to make ar	n ongoing work (in oral presentation mprehensively pr	urrently being inve resulting in a B.Sc., n of their current v esent, and to critic	, M.Sc., or Ph.D. work to a
In a series of talks results of their the discussions are tri audience an overv	esis-related v ggered that l	vork on helio- a nelp the presen	nd astrophysical t ter to improve he	opics. Thereby foo r/his work and giv	cused scientific
Format of Teachir	ng Seminar				
Format of Examin	ation Oral pi	resentation			
Requirements for	the Attribut	ion of Credit Po	pints Oral present	ation	
Use of the Module	e Courses in	Physics Major			
Importance of the age final grade	e Mark for th	e Final Grade G	Graded, but does i	not contribute to t	he weighted aver-
Module Superviso	or and Instru	ctor PD Dr. Fich	itner		
Further information	on				

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter & Summer	1 Semester
Courses a) Seminar Sele	ected Topics o	of Astronomy	Contact Hours a) 22 h	Self-Study 38 h	Group Size a) Unlimited
"Grundlagen de	lid knowledge er Astronomie Previous atte	e of the foundat e" and attendan	ce of the lecture "li	l is needed, as present ntroduction to Astrop nomy/Astrophysics le	physics" highly
Learning Outco The seminar is i		ive the students	•	ng edge Astronomical	
science topics, knowledge leve	l of their fello	ow students, and	• •	presentation of scier owing each of the pre .)	
science topics, s knowledge leve requires the pa Contents In the seminar to selected by the the Astronomic be presented in presenting one	I of their fello rticipation in the students s full-time lect al Institute. N their semina talk, plus listo	ow students, and at least most of select from a list urers and there With help of the In talk and are pl	discuss them follo the seminar dates. of topical papers to fore reflect mostly respective advisor rovided with help for ssing the other talk	wing each of the pre	he topics are rely pursued at re the topics to ation. Result of
science topics, knowledge leve requires the pa Contents In the seminar to selected by the the Astronomic be presented in presenting one of some topical	I of their fello rticipation in the students s full-time lect al Institute. N their semina talk, plus listo research in A	ow students, and at least most of select from a list urers and there With help of the ir talk and are pr ening and discus Astronomy/Astro	discuss them follo the seminar dates. of topical papers to fore reflect mostly respective advisor rovided with help for ssing the other talk	the one to present. T the work topics activ s the students prepar or the actual present	he topics are rely pursued at re the topics to ation. Result of
science topics, knowledge leve requires the pa Contents In the seminar to selected by the the Astronomic be presented in presenting one of some topical Format of Teac	I of their fello rticipation in the students s full-time lect al Institute. N their semina talk, plus listo research in A hing Seminar	ow students, and at least most of select from a list urers and there With help of the r talk and are pr ening and discus Astronomy/Astro	discuss them follo the seminar dates. of topical papers to fore reflect mostly respective advisor rovided with help for ssing the other talk ophysics.	wing each of the pre the one to present. T the work topics activ s the students prepa or the actual present	esentations. (Thi he topics are rely pursued at re the topics to ation. Result of provide a view
science topics, s knowledge leve requires the pa Contents In the seminar to selected by the the Astronomic be presented in presenting one of some topical Format of Teac Format of Exan Requirements	I of their fello rticipation in the students s full-time lect al Institute. No their semina talk, plus listo research in A hing Seminar hination Oral	ow students, and at least most of select from a list urers and there With help of the r talk and are pr ening and discus Astronomy/Astro presentation ar	d discuss them follo the seminar dates. of topical papers to fore reflect mostly respective advisor rovided with help for sing the other talk ophysics.	bwing each of the pre the one to present. T the work topics activ s the students prepa or the actual present s of the seminar will	he topics are ely pursued at re the topics to ation. Result of provide a view
science topics, s knowledge leve requires the pa Contents In the seminar to selected by the the Astronomic be presented in presenting one of some topical Format of Teac Format of Teac Requirements to active participa	I of their fello rticipation in the students s full-time lect al Institute. No their semina talk, plus listo research in A hing Seminar hination Oral for the Attrib tion	ow students, and at least most of select from a list urers and there With help of the r talk and are pr ening and discus Astronomy/Astro presentation ar	d discuss them follo the seminar dates. of topical papers t fore reflect mostly respective advisor rovided with help f ssing the other talk ophysics. d activity in the dis Points Successful p	bwing each of the pre the one to present. The the work topics activ s the students prepar or the actual present s of the seminar will scussions after the ta	he topics are ely pursued at re the topics to ation. Result of provide a view
science topics, s knowledge leve requires the pa Contents In the seminar to selected by the the Astronomic be presented in presenting one of some topical Format of Teac Format of Teac Format of Exan Requirements to active participa	I of their fello rticipation in the students s full-time lect al Institute. N their semina talk, plus listo research in A hing Seminar hination Oral for the Attrib tion	ow students, and at least most of select from a list urers and there With help of the r talk and are pr ening and discus Astronomy/Astro presentation ar ution of Credit I n Physics Major	d discuss them follo the seminar dates. of topical papers t fore reflect mostly respective advisor rovided with help f sing the other talk ophysics. d activity in the dis Points Successful p	bwing each of the pre the one to present. The the work topics activ s the students prepar or the actual present s of the seminar will scussions after the ta	esentations. (Think to pics are easily pursued at rethe topics to ation. Result of provide a view easily provide a view easily be a view easil

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter	1 Semester
Courses a) Lecture Sta	ars, Wind Nebu	ulae	Contact Hours a) 22 h	Self-Study 38 h	Group Size a) Unlimited
Formal None Content None			e.g. Introduction to	D Astronomy cou	Jrse) necessary
	get a broader v		ar evolution and co heoretical concept	-	-
Contents The course co	oncentrates on	stellar evolution	of stars of all mass		von on the narame
ture addresse Beside the ob mation of circ lecture. In this	es the topic fro servational cha cumstellar neb	ution – in particu m an observation aracteristics also ula from stellar v	lar the stellar mass nal point of view bu the mechanism of vinds and possible	loss and its con ut also theoretic stellar winds ar shell ejections is	sequences. The lec- cal models presented. e addressed. The for- s another topic of the ses of the Interstellar
ture addresse Beside the ob mation of circ lecture. In thi medium.	es the topic fro servational cha cumstellar neb	ution – in particu m an observation aracteristics also ula from stellar v ecture briefly tac	lar the stellar mass nal point of view bu the mechanism of vinds and possible	loss and its con ut also theoretic stellar winds ar shell ejections is	sequences. The lec- al models presented. e addressed. The for- s another topic of the
ture addresse Beside the ob mation of circ lecture. In thi medium. Format of Tea	es the topic fro servational cha cumstellar neb s context the le aching Lecture	ution – in particu m an observation aracteristics also ula from stellar v ecture briefly tac	lar the stellar mass nal point of view bu the mechanism of vinds and possible	loss and its con ut also theoretic stellar winds ar shell ejections is ots and properti	sequences. The lec- cal models presented. The addressed. The for- s another topic of the s of the Interstellar
ture addresse Beside the ob mation of circ lecture. In thi medium. Format of Tea Format of Exa	es the topic fro servational cha cumstellar neb s context the le aching Lecture amination Pose	ition – in particu m an observation aracteristics also ula from stellar v ecture briefly tac sible are an oral	lar the stellar mass nal point of view bu the mechanism of vinds and possible kles several concep exam, a short oral p	loss and its con ut also theoretic stellar winds ar shell ejections is ots and properti presentation or	sequences. The lec- cal models presented. re addressed. The for- s another topic of the res of the Interstellar
ture addresse Beside the ob mation of circ lecture. In thi medium. Format of Tea Format of Exa Requirement	es the topic fro servational cha cumstellar neb s context the le aching Lecture amination Pose s for the Attrik	ition – in particu m an observation aracteristics also ula from stellar v ecture briefly tac sible are an oral	lar the stellar mass nal point of view bu the mechanism of vinds and possible kles several concep exam, a short oral p Points Active partic	loss and its con ut also theoretic stellar winds ar shell ejections is ots and properti presentation or	sequences. The lec- cal models presented. re addressed. The for- s another topic of the res of the Interstellar written essay
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ture addresse Beside the ob mation of circ lecture. In thi medium. Format of Tea Format of Exa Requirement Use of the Me Importance o age final grad	es the topic fro iservational cha cumstellar neb s context the le aching Lecture amination Pose s for the Attrik odule Courses if the Mark for e	ition – in particu m an observation aracteristics also ula from stellar v ecture briefly tac sible are an oral bution of Credit in Physics Major	lar the stellar mass nal point of view bu the mechanism of vinds and possible kles several concep exam, a short oral p Points Active partic G raded, but does p	loss and its con ut also theoretic stellar winds ar shell ejections is ots and properti presentation or cipation and a su	sequences. The lec- cal models presented. The addressed. The for- s another topic of the s of the Interstellar written essay uccessful examination

	Credits	Workload	Semester	Cycle	Duration
	3 CP	90 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture The Galaxies	e Milky Way a	and External	a) 33 h	57 h	a) Unlimited
-	lid knowledg lagen der Ast	e of the foundati ronomie". Previo	ions of Astronomy ous attendance of t		it is presented in the oduction to Astro-
structure, kiner part of the lect	ssful complet matics, and e ure the prope	volution of our N erties and evolut		Using these cond axies will explore	er understanding of cepts, in the second ed and a coherent
Contents The course con	sists of the tw	vo maior narts [,] t	he exploration of t	he physical prov	
Galaxy and the rive a consister results for the s sented and app	extension to nt picture for structure, kin	the various type the evolution of ematics, star for	s of external galax	ies, both the une early universe to d chemical evolu	derlining goal to de- today. Methods and ition will be pre-
Galaxy and the rive a consister results for the s sented and app types derived.	extension to nt picture for structure, kin blied to the di	the various type the evolution of ematics, star for	s of external galax galaxies from the e mation history, and	ies, both the une early universe to d chemical evolu	derlining goal to de- today. Methods and ition will be pre-
Galaxy and the rive a consister results for the sented and app types derived. Format of Teac Format of Exar	extension to nt picture for structure, kin blied to the di ching Lecture nination Usu	the various type the evolution of ematics, star for fferent galaxy ty ally a short oral p	es of external galax galaxies from the e mation history, and pes and conclusior	ies, both the une early universe to d chemical evolu ns for the evolut	derlining goal to de- today. Methods and ition will be pre-
Galaxy and the rive a consister results for the s sented and app types derived. Format of Teac Format of Exar written essay o	extension to at picture for structure, kin blied to the di ching Lecture nination Usu- or an oral exam	the various type the evolution of ematics, star for fferent galaxy ty ally a short oral p n	es of external galax galaxies from the e mation history, and pes and conclusior presentation, altern	ies, both the un early universe to d chemical evolu ns for the evolut natively (if speci	derlining goal to de- today. Methods and ition will be pre- ion of the galaxy
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	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Winter & Summer (not in 25)	Duration 1 Semester
Courses a) Seminar Theoretical Heliophysics		Contact Hours a) 22 h	Self-Study 38 h	Group Size a) Unlimited	
Requirements Formal None Content None Preparation No	-	tion			
 student or more student interest student 	l completion ts will have a ts will have fa te research pu ts will have le ted audience	basic insight inte amiliarized them ublication(s) earned to make a	selves with one top an oral presentatio	f contemporary helio bic in more detail on n of a chosen scientif cally discuss the esse	the basis of one
physical studies vided on the ba	are critically sis of topics o conveyed h	v discussed. Ther that are in the fo now a scientific p	eby an introductio ocus of current rese	ious heliophysical and n into theoretical hel earch activities. Besid I be structured and m	iophysics is pro- es the scientific
	-		n (or, in exceptiona	al cases, the term pap	oer) will be
Passing the write tasks. In this ca	tten/oral exa se, active par	m or obtaining a	exercise is also ma	on the specified form possible points in the indatory. The form of	weekly exercise
Use of the Mod	lule Courses	in Physics Major			
Importance of	the Mark for	the Final Grade	Graded. but does	not contribute to the	weighted aver-
age final grade			,		C

Further information

Biophysics							
Modul 4b	Credits 15-25 CP	Workload 450-750 h	Semester 12. Sem.	Cycle Winter & Summer	Duration 2 Semesters		
Courses a) Lecture b) Exercises c) Seminar (at least 2 CP) d) Advanced Laboratory Courses (at least 5 CP) A complete overview of the courses can be found in the current course catalogue. The CP of the individual courses result from the semester hours per week (1 hour per se- mester week = 1 CP).			Contact Hours Each at least. a) 44 h b) 44 h c) 22 h d) 35 h	Self-Study min. 309 h	Group Size a) unlimited b) 30 c) 30 d) 2		
Requirements Formal none Content Knowl Preparation no	edge from "In		ophysics" will be e	expected			
 have a Universe are ablicommunication can indexide are processing Contents 	deeper insigh sity Bochum e to work out unicate them o lependently fin oficient in anal	t into current res scientific conten confidently orally nd and use inform ysing data on pro	ts, theories and m and in writing mation in the rele otein sequence an	olecular biophysics a nethods independent	ly and to able programmes		
		nics simulation, e ent problems, bio		on, FTIR and Raman s	scattering,		
			ar, Laboratory Wo	ork			
Requirements The specialisati	for the Attribution module mod	ust include: adva le examination (oints Passing the inced laboratory c 2 CP), 15-25 CP ca	oral examination. courses (5 CP), a semi in be achieved. Achie ards the module.			
made after the							
made after the Use of the Moo	dule Compulso	ory-Elective Mod	ule				
made after the Use of the Moo Importance of	dule Compulso	ory-Elective Mod	ule Weighted accordii	ng to Credit Points			
made after the Use of the Moo Importance of Module Superv	dule Compulso the Mark for t visor Prof. Dr.	ory-Elective Mod t he Final Grade Gerwert, Prof. D	ule Weighted accordii				

Course	Туре	No.	Semester
Advanced Laboratory Course for Dhusics Students	ts Laboratory	160250	Winter
Advanced Laboratory Course for Physics Students			Summer
Basics and Current Topics of Protein Crystallography	Literature Seminar	160835	Winter
Bioinformatics	Seminar	160857	Summer
Biophotonics	Literature Seminar	160830	Winter
Biophysics	Seminar	160820	Summer
Dianky size II	Lecture	160801	Summer
Biophysics II	Exercises	160802	
Colloquium Biophysics	Colloquium	160853	Summer
Computer Simulation of Proteins	Seminar	160852	Summer
FTIR in Biophysics	Seminar	160858	Summer
Laboratory Biophysics: Molecular Biology of Proteins for Physics Students	Laboratory	160821	Winter
Laboratory Biophysics: Selected Topics of Molecular Bi- ophysics for Physics Students	Laboratory	160823	Winter
Literature Seminar: Basics and Current Topics of Proteincrystallography	Seminar	160856	Summer
Methods and Applications in Structural Bioinformatics	Seminar	160854	Summer
Proteincrystallography	Seminar	160855	Summer
Research Laboratory: Selected Topics of Molecular Bio- physics	Laboratory	160859	Summer

	Credits	Workload	tural Bioinforn Semester		Duration
	2 CP	60 h	from 1. Sem.	Summer	1 Semester
	2 01	0011			i semester
Course			Contact Hour	Self-Study	Group Size
a) Seminar M Structural	lethods and A Bioinformatio	••	a) 22 h	38 h	a) unlimited
Requirements Formal None	for Participa	tion			
Content None					
Preparation No	one				
field of	f theoretical b	piophysics and st	tructural bioinform	atics.	applications in the
 acquire Contents During the sem of theoretical k 	ed the basic c ninar, literatu piophysics an	re on current ap d structural bioir	od literature prese	hodological deve	lopments in the field
acquire Contents During the sem of theoretical b Format of Teace	ed the basic c ninar, literatu piophysics an ching Semina	re on current ap d structural bioir	pod literature prese	hodological deve	lopments in the field
acquire Contents During the sem of theoretical b Format of Teac Format of Example	ed the basic o ninar, literatu piophysics an ching Semina mination Pres	re on current ap d structural bioir r sentation	plications and met	hodological deve presented and dis	lopments in the field scussed.
acquire Contents During the sem of theoretical b Format of Teac Format of Example	ed the basic on hinar, literatu biophysics an ching Semina mination Pres for the Attril	re on current ap d structural bioir r sentation oution of Credit	plications and met	hodological deve presented and dis	lopments in the field
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Modul 4c	Credits	Workload	Semester	Cycle	Duration
	15-25 CP	450-750 h	12. Sem.	Winter & Summer	2 Semesters
Courses a) Lecture b) Exercises c) Seminar (at d) Advanced La CP) A complete over found in the cu CP of the indivis semester hours mester week =	aboratory Cour erview of the co rrent course ca dual courses re s per week (1 h	ourses can be atalogue. The esult from the	Contact Hours Each at least. a) 44 h b) 44 h c) 22 h d) 35 h	Self-Study min. 309 h	Group Size a) unlimited b) 30 c) 30 d) 2
Requirements	for Participatic	on			
Formal none Content Basic k Preparation no	-	olid state physic	cs will be expected		
• are awa	are of the poss			ch areas and specialis	sations of
 are away theoret know theoret are fam re able 	are of the poss tical and experi he basic conce niliar with basic to recognise co	ibilities within t imental solid sta pts of the theor experimental p prrelations betw	he different resear ate physics retical description o procedures for mea ween the microscop		perties lid body and
 are away theorem know theorem are fam re able its mace Contents Deepening of k superconducting places the main number of speed ductivity, Semice	are of the poss tical and experi he basic conce hiliar with basic to recognise co roscopic prope nowledge in th ng properties. T n areas of solid cial lectures are conductor Physics of	ibilities within t imental solid sta pts of the theor experimental p orrelations betw erties and apply e main areas of heoretical solid state physics of e offered for in- sics and Semico Thin Films, Nan	he different resear ate physics retical description of procedures for mea ween the microscop these to estimate t f solid state physics I state physics deals n a solid quantum r depth study: Surfac nductor Devices, Ph ostructuring and Sp	f the solid state suring solid state pro pic structure of the so	operties lid body and y hagnetic and problem and ddition, a n, Supercon- al Physics,
 are away theorem know theorem are fam re able its mace Contents Deepening of k superconducting places the main number of speed ductivity, Semiod Scattering Physern experiment	are of the poss tical and experi he basic conce hiliar with basic to recognise co roscopic prope nowledge in th ng properties. T n areas of solid cial lectures are conductor Physics tics, Physics of tal and theoret	ibilities within t imental solid sta pts of the theor c experimental p orrelations betw erties and apply de main areas of theoretical solid state physics of e offered for in- sics and Semico Thin Films, Nan- ical solid state p	he different resear ate physics retical description of procedures for mea ween the microscop these to estimate t f solid state physics I state physics deals n a solid quantum r depth study: Surfac nductor Devices, Ph ostructuring and Sp	f the solid state suring solid state pro- bic structure of the so rechnological usability , especially optical, m s with the many-body nechanical basis. In a re Physics, Magnetism hase Transitions, Met intronics, and other a	operties lid body and y hagnetic and problem and ddition, a n, Supercon- al Physics,
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 are away theorem know theorem are fam are fam re able its mac Contents Deepening of k superconducting places the main number of speciductivity, Semic Scattering Physern experiment Format of Teace Format of Example specialisati cluding the final specialisati cluding the specialisati cluding the final specialisati cluding the final specialisati cluding the	are of the poss tical and experi- he basic conce- hiliar with basic to recognise co- roscopic prope- nowledge in the g properties. The areas of solid cial lectures are conductor Physics cics, Physics of T cal and theoret thing Lecture, E hing Lecture, E hing Lecture, E nination Oral e for the Attribu on module mu al oral module of nodule examin	ibilities within t imental solid sta- pts of the theor c experimental p orrelations between rties and apply the main areas of theoretical solid state physics of e offered for in- sics and Semico Thin Films, Nami ical solid state p exercises, Semir examination of 4 tion of Credit P st include: adva examination (2) ation no longer	he different researd ate physics retical description of procedures for mea- ween the microscop these to estimate t f solid state physics deals n a solid quantum r depth study: Surfac nductor Devices, Ph ostructuring and Sp physics. har, Laboratory Wor 45 minutes Points Passing the o anced laboratory co CP), 15-25 CP can b count towards the	f the solid state suring solid state pro- bic structure of the so rechnological usability , especially optical, m s with the many-body mechanical basis. In a re Physics, Magnetism hase Transitions, Met intronics, and other a rk ral examination. ourses (5 CP), a semin e achieved. Achieven	ar (2 CP). In-

Module Supervisor Prof. Dr. Hägele

Examiners Prof. Dr. Böhmer, Prof. Dr. Botti, Prof. Dr. Drautz, Prof. Dr. Eremin, Prof. Dr. Hägele, Prof. Dr. Liebscher, Prof. Dr. Scherer, Prof. Dr. Sulpizi, Prof. Dr. Wieck

Further Information For advice and coordination of the courses, please contact the module supervisor. Please see the course list below.

Course	Туре	No.	Semester
Advanced Laboratory Course for Physics Students	Laboratory	160250	Winter
	Laboratory	100230	Summer
Advanced Electron Microscopy NEW	Lecture	160334	Summer
	Exercises	160335	Junner
Advanced Physics of 2-Dimensional Materials NEW	Lecture	160337	Summer
Advanced Solid State Theory	Lecture	160311	Summer
	Exercises	160312	Juminer
Advanced Techniques in Transmission Electron	Seminar	160336	Summer
Microscopy NEW	Seminar	100550	Summer
CODEFI Seminar NEW	Seminar	440524	Summer
Compact Course: Practical Exercises in Semiconductor	Compact	160305	Winter
Technology	Laboratory	100505	Winter
Computer Simulations in Statistical Physics	Lecture	160332	Summer
	Exercises	160333	
		160324	Winter
Journal Club: Applied Solid State Physics	Seminar	160322	Summer not in 25
	Lecture	160303	
Introduction to Solid State Physics II	Exercises	160304	Summer
Introduction to Statistics for Astronomers and Physicists	Lecture	160613	Summer
Introduction to X-Ray and Neutron Scattering	Lecture	160315	Summer
,	Seminar	160350	Winter
Quantum Materials	Lecture	160317	
	Exercises	160318	Summer
	Lecture	160328	Summer
Quantum Optics	Exercises	160329	not in 25
	Lecture	160319	Summer
Physics of Complex Phase Transitions in Solids	Exercises	160320	not in 25
	Lecture	160311	
Physics of Quantum Cascade Lasers	Seminar/ Ex-		Winter
•	ercises	160312	
Physical Principles of Electron Microscopy	Lecture	160313	Winter
· · · ·	Lecture	160330	
Physical Principles of Quantum Information	Exercises	160331	Summer
	Lecture	160301	14/1-1
	Exercises	160302	Winter
Scientific Methods of Semiconductor Physics	Lecture	160306	2
	Exercises	160307	Summer
		160322	Winter
Selected Topics of Applied Solid State Physics	Seminar	160353	Summer
		160327	Winter
Selected Topics of Solid State Physics Theory	Seminar	160354	Summer
Semiconductor Band Structures	Seminar/ Lecture	160351	Winter

	Seminar	160321	Summer
Comissenductor Dhusies I	Lecture	160303	\\/intor
Semiconductor Physics I	Exercises	160304	Winter
Semiconductor Physics II: Experiments with Semiconduc-	Lecture	160309	Summor
tor Quantum Devices	Exercises	160310	Summer
Seminar on Quantum Materials	Seminar	160326	Summer
	Seminar	100320	(not in 25)
Solid State Physics Theory	Seminar	160325	Winter
Solid State Theory	Seminar	160323	Summer
Chintronics and Ultrafast Chartrascony	Seminar	160323	Winter
Spintronics and Ultrafast Spectroscopy	Seminar	160358	Summer
Superconductivity	Seminar	160327	Summer
Surface Physics and Chemistry	Lecture	160510	Summer
Theory of Electronic Excitations in Materials NEW	Lecture	440523	Summer

Courses a) Lecture "Advanced Electron Microscopy" b) Exercise "Advanced Electron Microscopy" b) 11 h Self-Study a) 57 h b) 19 h Group Size a) Unlimite b) 19 h Requirements for Participation Formal None Content Basic knowledge of optics, solid state physics and quantum mechanics Preparation None Formal None Content Basic knowledge of optics, solid state physics and quantum mechanics Preparation None Learning Outcomes After successful completion of the module • students know the basic working principles of electron microscopes and crystallography a focus on transmission electron microscopy • students learn to differentiate between high resolution transmission electron microscop and scanning transmission electron microscopy • students learn to differentiate between high resolution transmission electron imcroscop and scanning transmission electron microscopy • students understand how to interpret and simulate atomic resolution images • students obtain knowledge in advanced electron tomography and spectroscopy • students obtain knowledge in advanced electron tomography and spectroscopy • students obtain knowledge in advanced electron microscopes with a focus on transmission electron microscopy. The basic principles of electron microscopes with a focus on transmission electron microscopy. The basic principles of electron microscopes with a focus on transmission electron microscopy. The basic principles of electron microscopes with a focus on transmission electron microscopy. The basic principles of electron microscopes with a focus on transmission electron microscopy. The basic principles of physteriation between before explaining the mechanism of atomic resolution images before explaining the mechanism of atomic resolution images and use computer simulations to gain quantitati insights in the atomic structure of solid state materials. The students will be discussion there		Credits	Workload	Semester	Cycle	Duration
a) Lecture "Advanced Electron Microscopy" a) 33 h b) 13 h b) 19 h a) 57 h b) 19 h b) Exercise "Advanced Electron Microscopy" b) 11 h b) 19 h b) 19 h b) Unlimite Requirements for Participation Formal None Formal None Formal None Content Basic knowledge of optics, solid state physics and quantum mechanics Preparation None Learning Outcomes After successful completion of the module Students knowledge in aberration-corrected electron microscopes and crystallography a focus on transmission electron microscopy s students gain knowledge in aberration-corrected electron optics students gain knowledge in aberration-corrected electron optics s students learn to differentiate between high resolution transmission electron microscopy and scanning transmission electron microscopy students understand how to interpret and simulate atomic resolution images s students are familiar with differential phase contrast imaging and electronic diffraction be explained. Students will learn to describe the electron wave propagation and related approxirions in crystalline materials. The concepts of aberration-correction electron optics will be discus pefore explaining the mechanism of atomic resolution imaging by high resolution transmission electron microscopy. With this knowledge, students earn how to interpret atomic resolution images and use computer simulations to gain quantitation sign in the atomic structure of solid state materials. The students will gain first insights into a vanced interferometric imaging methods su		8 CP	120 h	from 1. Sem.	Summer	1 Semester
b) Exercise "Advanced Electron Microscopy" b) 11 h b) 19 h b) Unlimited Requirements for Participation Formal None	Courses			Contact Hours	Self-Study	Group Size
Requirements for Participation Formal None Content Basic knowledge of optics, solid state physics and quantum mechanics Preparation None After successful completion of the module • students know the basic working principles of electron microscopes and crystallography a focus on transmission electron microscopy • students understand the basics of electron wave propagation in solids • students gain knowledge in aberration-corrected electron optics • students learn to differentiate between high resolution transmission electron microscop and scanning transmission electron microscopy • students understand how to interpret and simulate atomic resolution images • students are familiar with differential phase contrast imaging and electronic ptychograph • students are familiar with differential phase contrast imaging and electronic ptychograph • students obtain knowledge in advanced electron microscopes with a focus on rransmission electron microscopy. The basic principles of electron microscopes with a focus on rransmission electron microscopy. The basic principles of crystal lattices and electron diffraction be explained. Students will learn to describe the electron wave propagation and related approxir ions in crystalline materials. The concepts of aberration-correction electron optics will be discus before explaining the mechanism of atomic resolution imaging by high resolution transmission electron microscopy and scanning transmission electron microscopy. With this knowledge, students earn how to interpret atomic resolution images and use computer simulations to gain quantitati nsights in the atomic structure of solid state materials. The students will gain first insights into a vanced interferometric imaging methods such as electron ptychography to image the atomic stru- cure of weak scattering objects (light elements). Electron tomography will be introduced and stu- tents will learn how to obtain three-dimensional information from samples down to the atomic ever. The students will obtain knowledge in atomic level	a) Lecture "Adv	vanced Electr	on Microscopy"	a) 33 h	a) 57 h	a) Unlimited
Formal None Content Basic knowledge of optics, solid state physics and quantum mechanics Preparation None Learning Outcomes After successful completion of the module students know the basic working principles of electron microscopes and crystallography a focus on transmission electron microscopy students understand the basics of electron wave propagation in solids students gain knowledge in aberration-corrected electron optics students understand the basics of electron microscopy students understand how to interpret and simulate atomic resolution images students understand how to interpret and simulate atomic resolution images students are familiar with differential phase contrast imaging and electronic ptychograph students obtain knowledge in advanced electron tomography and spectroscopy Contents The course starts with explaining the working principles of electron microscopes with a focus on ransmission electron microscopy. The basic principles of electron optics will be discus obfore explaining the mechanism of atomic resolution imaging by high resolution transmission ions in crystalline materials. The concepts of aberration-correction electron optics will be discus before explaining the mechanism of atomic resolution microscopy. With this knowledge, students user of weak scattering objects (light elements). Electron tomography to image the atomic structure of solid state materials. The students will gain first insights into a aranced interferometric imaging methods such as electron ptychography to image the atomic structure of solid state materials. The students will be introduced and students will learn to obtain three-dimensional information from samples down to the atomic evel. The students will be introduced and students will learn how to obtain three-dimensional information from samples down to the atomic ever: Format of Teaching Lecture, Exercise Format o	o) Exercise "Ad	lvanced Elect	ron Microscopy"	b) 11 h	b) 19 h	b) Unlimited
 After successful completion of the module students know the basic working principles of electron microscopes and crystallography a focus on transmission electron microscopy students understand the basics of electron wave propagation in solids students gain knowledge in aberration-corrected electron optics students learn to differentiate between high resolution transmission electron microscopy and scanning transmission electron microscopy students understand how to interpret and simulate atomic resolution images students are familiar with differential phase contrast imaging and electronic ptychograph students obtain knowledge in advanced electron tomography and spectroscopy Contents The course starts with explaining the working principles of electron microscopes with a focus on transmission electron microscopy. The basic principles of crystal lattices and electron diffraction be explained. Students will learn to describe the electron wave propagation and related approxir tions in crystalline materials. The concepts of aberration-correction electron optics will be discus before explaining the mechanism of atomic resolution imaging by high resolution transmission electron microscopy and scanning transmission electron microscopy. With this knowledge, students the learn how to interpret atomic resolution images and use computer simulations to gain quantitati insights in the atomic structure of solid state materials. The students will gain first insights into at vanced interferometric imaging methods such as electron ptychography will be introduced and stu dents will learn how to obtain three-dimensional information from samples down to the atomic level. The students will obtain knowledge in atomic level X-ray and electron microscope. In a exercises, the use of computer-based simulation and analysis tools will be introduced. Students we learn how to simulate and analyse complex multidimensional datasets. Format of Teac	Formal None Content Basic k	nowledge of		Physics and quar	I ntum mechanics	
After successful completion of the module students know the basic working principles of electron microscopes and crystallography a focus on transmission electron microscopy students understand the basics of electron wave propagation in solids students gain knowledge in aberration-corrected electron optics students learn to differentiate between high resolution transmission electron microscopy and scanning transmission electron microscopy students understand how to interpret and simulate atomic resolution images students are familiar with differential phase contrast imaging and electronic ptychograph students obtain knowledge in advanced electron tomography and spectroscopy Contents Contents The course starts with explaining the working principles of electron microscopes with a focus on irransmission electron microscopy. The basic principles of crystal lattices and electron diffraction be explained. Students will learn to describe the electron wave propagation and related approxir is ons in crystalline materials. The concepts of aberration-correction electron optics will be discus before explaining the mechanism of atomic resolution imaging by high resolution transmission electron microscopy. With this knowledge, students using the atomic structure of solid state materials. The students will gain first insights into a vanced interferometric imaging methods such as electron ptychography to image the atomic structure of weak scattering objects (light elements). Electron tomography will be introduced and students will learn how to obtain three-dimensional information from samples down to the atomic evel. The students will be an analyse computer vibrational spectroscopy in the electron microscope. In a exercises, the use of computer-based simulation and analysis tools will be introduced. Students we aren how to simulate and analyse complex multidimensional datasets. Format of Teaching Lecture, Exercise Fo	earning Outco	omes				
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Module Supervisor and Instructor Prof. Dr. Liebscher Further information

	Cualita	2D Materials	Semester	Cycle	Dunation
	Credits 2 CP	Workload 60 h	from 1. Sem.	Summer	Duration 1 Semester
	2 01	0011			1 Semester
Courses		I	Contact Hours	Self-Study	Group Size
a) Lecture "Ad	vanced Physi	cs of 2D	a) 22 h	38 h	a) Unlimited
Materials"					
Requirements	for Participat	tion			
Formal None					
			ics is highly apprec		
Preparation Pa	irticipation in	the module "Int	roduction to Solid	State Physics" is	usetul
Learning Outco	omes				
After successfu	I completion		students have a bas	sic understanding	g of
	mensional ma	aterials			
	pattern				
-	angle bi-layer onductivity ir				
•		limensional mate	erials		
-			thesis of 2D mater	ials. exfoliation t	echniques
•		ns of 2D material			connques
Contents					
	two-dimensi	onal van der Wa	als materials are at	the forefront of	research in con-
					bi-layer graphene has
					esence of long-range
-		nsional van der V	Waals materials ha	s completely ope	ned a new avenue
tor the invectio					
-	-	netism in true 20	D-systems. This lect		e most recent ad-
vancements in	the field of 2	netism in true 2 D-materials start	D-systems. This lect ting from the magic	angle bi-layer g	e most recent ad- raphene (MABLG),
vancements in Moiré pattern,	the field of 2 emerging ma	netism in true 20 D-materials start agnetic van der V	D-systems. This lect ting from the magic Vaals materials and	c angle bi-layer g I their potential i	e most recent ad- raphene (MABLG), for applications. The
vancements in Moiré pattern, experimental t	the field of 2 emerging ma	netism in true 20 D-materials start agnetic van der V	D-systems. This lect ting from the magic Vaals materials and	c angle bi-layer g I their potential i	e most recent ad- raphene (MABLG),
vancements in Moiré pattern, experimental t niques.	the field of 2 emerging ma echniques us	netism in true 20 D-materials start agnetic van der V	D-systems. This lect ing from the magic Vaals materials and these 2D-materials	c angle bi-layer g I their potential i	e most recent ad- raphene (MABLG), for applications. The
vancements in Moiré pattern, experimental t niques. Format of Teac	the field of 2 emerging ma echniques us ching Lecture	netism in true 2 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci	D-systems. This lect ting from the magic Vaals materials and these 2D-materials se	c angle bi-layer g I their potential f together with t	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech-
vancements in Moiré pattern, experimental t niques. Format of Teac Format of Exar tion (written exar	the field of 2 emerging ma echniques us ching Lecture mination At the common state of the sector of	netism in true 20 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci he beginning of t f 90 min or oral e	D-systems. This lect ting from the magic Vaals materials and these 2D-materials se the course, the lect examination of 45 r	angle bi-layer g their potential f together with t urer determines nin)	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech- the form of examina-
vancements in Moiré pattern, experimental t niques. Format of Teac Format of Exar tion (written ex Requirements	the field of 2 emerging ma echniques us ching Lecture mination At the camination of for the Attrik	netism in true 20 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci he beginning of t f 90 min or oral e oution of Credit I	D-systems. This lect sing from the magic Vaals materials and these 2D-materials se the course, the lect examination of 45 r Points Depending of	c angle bi-layer g d their potential f s together with th urer determines nin) on the specified f	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech-
vancements in Moiré pattern, experimental t niques. Format of Teac Format of Exar tion (written ex Requirements	the field of 2 emerging ma echniques us ching Lecture mination At the camination of for the Attrik	netism in true 20 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci he beginning of t f 90 min or oral e oution of Credit I	D-systems. This lect ting from the magic Vaals materials and these 2D-materials se the course, the lect examination of 45 r	c angle bi-layer g d their potential f s together with th urer determines nin) on the specified f	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech- the form of examina-
vancements in Moiré pattern, experimental tr niques. Format of Teac Format of Exar tion (written exar Requirements The form of exar Use of the Moo	the field of 2 emerging ma echniques us ching Lecture nination At the ching the Attrik amination will dule Courses	netism in true 2 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci he beginning of t f 90 min or oral e Dution of Credit I Il be determined in Physics Major	D-systems. This lect sing from the magic Vaals materials and these 2D-materials se the course, the lect examination of 45 r Points Depending of at the beginning o	angle bi-layer g their potential f together with th urer determines nin) on the specified f f the course.	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech- the form of examina- form of examination:
vancements in Moiré pattern, experimental tr niques. Format of Teac Format of Exar tion (written exar Requirements The form of exar Use of the Moo	the field of 2 emerging ma echniques us ching Lecture mination At the camination of for the Attrik amination will dule Courses the Mark for	netism in true 2 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci he beginning of t f 90 min or oral e Dution of Credit I Il be determined in Physics Major	D-systems. This lect sing from the magic Vaals materials and these 2D-materials se the course, the lect examination of 45 r Points Depending of at the beginning o	angle bi-layer g their potential f together with th urer determines nin) on the specified f f the course.	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech- the form of examina-
vancements in Moiré pattern, experimental tr niques. Format of Teac Format of Exar tion (written exants) The form of exants The form of exants) Use of the Moo Importance of age final grade	the field of 2 emerging ma echniques use ching Lecture mination At the camination of for the Attrik amination will dule Courses the Mark for	netism in true 2 D-materials start agnetic van der V ed to synthesize , Seminar, Exerci he beginning of t f 90 min or oral e Dution of Credit I Il be determined in Physics Major	D-systems. This lect sing from the magic Vaals materials and these 2D-materials se the course, the lect examination of 45 r Points Depending o at the beginning o	angle bi-layer g their potential f together with th urer determines nin) on the specified f f the course.	e most recent ad- raphene (MABLG), for applications. The he exfoliation tech- the form of examina- form of examination:

	Credits 8 CP	Workload 240 h	Semester from 1. Sem.	Cycle Summer	Duration 1 Semester
	o CP	240 11	inom 1. sem.	Summer	1 Semester
Courses) Lecture Adva) Exercises for Theory) Seminar Adva	Advanced Sc	lid State	Contact Hours a) 44 h b) 22 h c) 22 h	Self-Study 152 h	Group Size a) Unlimited b) 25 c) 25
equirements for ormal None content Basic kin esirable Preparation Non earning Outcon	nowledge of		y, statistical mech	anics and quantu	um mechanics is
 physics Student using se observa student: phase tr student: this forr student: 	s have a basic including qua s are able to cond quantiz bles s know the b ransitions in s s are familiar nalism for va s are able to	c understanding antum field theo derive an effecti ation and to con asic concepts of solid state systen with Feynman d rious model syst employ simple n	ry methods and m ve Hamiltonian of npute elementary functional integra ns liagrams at zero ar	any-body theory the given solid s excitations and t I description of t nd finite tempera ns to obtain the	tate systems thermodynamic he thermodynamic atures and can use thermodynamic
contents					
function self-ene - Finite Te Function - Fluctuat The Kub - Phase T criticalit - Coheren mation,	ns); Zero Tem rgy, response emperature M n and Wick's ion Dissipation o Formula, ransitions an y, nt states and	perature Feynm e functions, the F Many Body Physi theorem, Examp on Theorem and d broken symme path integrals, E	RPA (Large-N) elec cs , Imaginary Tim ples of the applica Linear Response T	iman rules in mo tron gas; ne Green Functio tion of the Matsi Theory, Electron dau theory, Theri d Hubbard Strato	mentum space, the uns, Generating ubara Technique, transport Theory, mal Fluctuations and pnovich transfor-
ormat of Teach	ning Lecture,	Exercises, Semir	nar		
amination. (writ	ten exam of active partici	90 min, oral exampation in the exe	m of 45 min or an	exercise certifica ture. The semina	r is examined via a

Requirements for the Attribution of Credit Points Depending on the defined form of examination: Passing the written/oral examination or obtaining at least 50% of the possible points in the weekly exercises. In this case, active participation in the exercise is also mandatory. The form of examination will be determined at the beginning of the course. In addition, the F practical course must be completed successfully. Both grades go into the module grade with the CP weighted

Use of the Module Courses in Physics Major

Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted average final grade

Module Supervisor and Instructor Prof. Dr. Scherer

Further information

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter & Summer	1 semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar "A Transmissi	Advanced Tech on Electron M		a) 22 h	38 h	a) Unlimited
Requirements Formal None	for Participat	tion			
Content Basic	ectron Micros			ired by attending the n Microscopy", but no	
opments and t papers, critical	ill cover recer heir application ly reflect on t	ons. The studen heir content an	ts will learn how to d present the worl	oscopy, discussing ne o understand and su k. They will engage ir pation in most of the	mmarize research active discussion
iques, that ar opics (e.g. mo bared by the st ure research, once. The activ ions will provi	e being devel mentum reso tudents. The s to prepare th re engagemen de the studer	oped at the Inst lved, high energ students will be e content for a nt in the semina nts with a broad	itute of Solid State gy resolution or ul assisted by expert presentation and h r series by followin overview in curre	in electron microsco e Physics are discusse trafast microscopy) a t advisors on how to how to present conte ng other presentation ent technique develop	ed, or selected re being pre- perform litera- ent to an audi- ns and discus-
Format of Tea		-	entation and discus	SSION SKIIIS.	
Format of Exa	mination The	students give a	talk of 30 min plu	s discussion within th	ie seminar group.
Requirements tation with val		oution of Credit	Points Active part	ticipation (>75%) and	successful preser
Use of the Mo	dule Courses	in Physics Majo	r		
		the Final Grade	e Graded, but doe	es not contribute to t	he weighted aver-
Importance of age final grade					
age final grade		ructor Prof. Dr.	Liebscher		

	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Winter	1 week (plus preparation and a presentation of the results
Courses b) Compact Co Semicondu	ourse: Practic ctor Technol		Contact Hours b) 40 h	Self-Study 80 h	Group Size a) 3-5
•	tion of conte provided rticipation in	ent module "Specia	ll Problems in App checked in advan		Physics" is recom-
conduc • Studen ion imp • student	ts have a bas tor chips. An ts are aware lantation. ts know the b	ic understanding d how these fun of the capabilition	ictions are tested.	raphy, device t	are made from semi- esting setups, focused
techniques of se learned. Furthe ties of semicone another focus o characterization	emiconducto rmore, stude ductor hetero of the lab. He n. Each pract rork of the da	or processing, su ents will use focu ostructures. The re, modern, elec ical day is introd ay are explained	used ion implanta electrical charact ctrical measureme luced with a lectu	raphy and wet tion to modify erization of the ent techniques	t transistor. Basic chemical etching, are the electrical proper- e fabricated devices is are used for device minutes, in which the
		exam about con ion after the pra	•	w to measure t	the device (midterm
-			Points Successful		presentation.
			ck in Courses in P		
Importance of age final grade	the Mark for	the Final Grade	e Graded, but doe	s not contribut	te to the weighted aver
Module Superv	isor and Inst	ructor Dr. Ludw	lg		

Computer Si	mulations	in Statistical	Physics		
	Credits	Workload	Semester	Cycle	Duration
	6 CP	180 h	from 1. Sem.	Summer	1 Semester
Courses a) Lecture Comp Statistical Phy b) Exercises for Statistical Phy	ysics Computer Sim		Contact Hours a) 44 h b) 22 h	Self-Study 114 h	Group Size a) Unlimited b) 30
Requirements for Formal None Content None (F Preparation Nor	Recommended		s of classical and s	tatistical mechanic	s)
Learning outcom					
molecul • they wil • they wil	lents will have ar dynamics a l be able to ma l have the kno	an understandi nd Monte Carlo ake computer p	simulations in Sta rograms to perfor	ms used to perform tistical Physics m and analyse thos ailable program pa	e simulations
duction Classical barostat Monte C equation Grand-c Quantur Hands-c	to error analy I molecular dy ts, Ewald sumr Carlo and kine n anonical simu m mechanical	sis namics (MD): in nation tic Monte Carlo: lations and free approaches and /D simulations o	tegration algorith importance samp energy methods density functiona	s, statistical mecha ms, accuracy, therr pling, canonical ens al theory nes fluid, MD simula	nostats and emble, master
Format of Teach	ning Lecture, E	xercises			
Format of Exam	ination Oral e	xam 30 min			
Requirements for	or the Attribu	tion of Credit Po	pints Successful or	ral exam	
Use of the Mod	ule Courses in	Physics Major			
Importance of t age final grade	he Mark for th	ne Final Grade G	Graded, but does r	not contribute to th	e weighted aver-
Module Supervi	isor and Instru	ictor Prof. Dr. Si	ulpizi / Dr. Settann	i	
Further informa	tion Language	e English			

Journal Club	: Applied S	Solid State P	hysics		
	Credits 1 CP	Workload 30 h	Semester from 1. Sem.	Cycle Winter & Summer (not in 25)	Duration 1 Semester
Courses a) Seminar Jou State Physic		plied Solid	Contact Hours a) 11 h	Self-Study 19 h	Group Size a) Unlimited
Requirements for Formal None Content None Preparation Rea Physics" is recor	d articles and		n module "Special	Problems in Applied	Solid State
simplify Student: student: student: 	completion of s have a basic its content a s are aware of ty bibliograph s know the basic questions	c understanding nd present it in of the capabilitie nic system	a compact and cor es to access journal scientific presenta	d understand a scien ncise way. l articles behind a pay ntion of content, ask l	ywall from the
journals. One pa group has read.	rticipant of t Then, the con ne experimen	he club present ntent is discusse tal design, critie	s a summary of the ed. Attendees ask o que the methods, j	research published i e chosen paper that t clarifying questions, c udge the writing style	he whole liscuss differ-
Format of Teach	iing Seminar				
Format of Exam					
•			•	cipation and presenta	ition of a paper.
Use of the Mod		, ,			
Importance of t age final grade	he Mark for t	the Final Grade	Graded, but does	not contribute to the	weighted aver-
Module Supervi	sor and Instr	uctor Dr. Ludwi	g		
Further informa	tion				

	2 CP	60 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar Q	uantum Mate	orials	a) 22 h	38 h	a) Unlimited
			a) 22 11	5011	a) oninnited
Requirements	for Participat	tion			
Formal None					
Content None					
Preparation Pa	rticipation in	the module "Int	troduction to Solid	State Physics" is	recommended
Learning Outco		- f the second d			
After successfu	•				
			g of the solid-state		
	•	•	ize themselves with	h an advanced to	pic in the field
		s of quantum ma			
	-	•	literature research		
 student 	ts are familia	r with creating a	nd giving scientific	presentations	
Contents					
Quantum mate	rials are mate	erials whose pro	perties are decisive	ely determined b	y quantum mechan-
			his seminar will pro	•	
•		• •	•	-	uperconductors and
•		•			itter physics, we will
			chniques that were		• •
-	-	•	standing a new mat		
			ults and their interp		. ,
Format of Teac	hing Semina	r			
Format of Exan	nination Pres	sentation, evalua	ated according to th	ne criteria below	
•				-	e seminar presenta-
-	-				n slides, the quality o
			ons about the prese	entation.	
Use of the Mod	lule Courses	in Physics Major	-		
Importance of	the Mark for	the Final Grade	Graded, but does	not contribute to	the weighted aver-
age final grade					
Module Superv	visor and Inst	ructor Prof. Dr.	Böhmer		

	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Summer (not in 25)	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Phy	sics of Compl	ex Phase	a) 30 h	60 h	a) 20
Transitions	in Solids		b) 30 h		b) 20
b) Exercise Ph	ysics of Comp	lex Phase			
Transitions					
Requirements	for Participat	tion			
Formal None					
Content None					
•	-	•	echanics / solid sta	te physics and th	ermodynamics /
statistical phys	sics is recomm	ended			
Learning Outc	omes				
After successfu	ul completion	of the module			
 studer 	nts possess a c	conceptional unc	lerstanding of com	plex phase transi	tions in solid state
mater	ials (e.g. supe	rconducting and	ferroic phases)		
			e art analytical and	d numerical scale	-bridging modelling
metho	ds in this field	ł			
 studer 	nts can judge,	compare and ut	ilize these concepts	s and methods	
 studer 	nts can identif	y the underlying	physical properties	S	
Contents					
 Introd 	uction to com	plex phase trans	itions in solid state	materials (e.g. n	nagnetic, ferro-
electri	c and superco	onducting phases	5)		
 Classif 	ication of pha	se transitions an	d critical phenome	na	
 Model 	s and simulat	ion methods (e.g	g. spin models, Land	dau theory)	
Format of Tea	ching Lecture	, Exercises			
Format of Exa	_		ect work and short	oral examinatior	related to the
Format of Exa project	mination Pres	sentation of proj			
Format of Exa project Requirements	mination Pres	sentation of proj	ect work and short Points Taking part i		
Format of Exa project Requirements presentation c	for the Attrik for the project	entation of proj	Points Taking part i		
Format of Exa project Requirements presentation c	for the Attrik for the project	sentation of proj	Points Taking part i		
project Requirements presentation c Use of the Mo	for the Attrik f the project dule Courses the Mark for	sentation of projontion of Credit I Dution of Credit I in Physics Major	Points Taking part i	in the exercises, s	successful oral
Format of Exa project Requirements presentation of Use of the Mo Importance of average final g	for the Attrik f the project dule Courses the Mark for grade	entation of proj oution of Credit in Physics Major the Final Grade	Points Taking part i	in the exercises, s	successful oral

		Credits	Workload	Semester	Cycle	Duration
		3 CP	90 h	from 1. Sem.	Winter	1 Semester
<u> </u>				Contact Hours	Colf Study	Crown Size
	urses	cies of Quant	um Cascada	a) 22 h	Self-Study 57 h	Group Size a) Unlimited
a)	Lasers	sics of Quant		b) 11 h	57 11	a) Ommitted
b)		Physics of Ou	antum Cascade	5) 1111		
5)	Lasers					
	quirements f	or Participat	on			
	r mal None					
	ntent None		c .			
Pre	eparation Price	or knowledge	e of quantum mee	chanics is highly re	ecommended	
Lea	arning Outco	mes				
Aft	er successful	completion	of the module			
			-	of the physics nec		
	 Student 	s are aware o	of the capabilities	and applications	of quantum case	ade lasers
			•	• •	s, optical and lase	r physics that are
		•	sign of quantum			
		s are familia	with different q	uantum cascade la	aser designs	
	ntents					
		•	• •	•		ers. Quantum cas-
						and transitions. The
				•		conventional diode
				rband transitions		
		-	-	•		s of repeating serie
-				-	•	axy (MBE) or Meta
			-		-	and levels should b
	-		-	•••	-	educe parasitic scate equires a thorough
TOP	ing maximize	a intection in	o the linner lase	מומומ המב ובעבו י		

understanding of the optical properties of two-dimensional semiconductors, and electron transport and scattering in semiconductor heterostructures. In addition to these topics, the course will review basic laser theory and survey different types of waveguides.

Outline

Basic Laser theory: spontaneous emission, stimulated emission, absorption, Einstein A and B coefficients, Rate equations, 3 and 4 level laser systems, laser threshold, gain clamping / saturation, homogeneous and inhomogeneous broadening, multi-mode and single mode lasers, spatial hole burning, longitudinal and transverse modes, spontaneous emission noise and laser line width, frequency pulling, Q-switching, mode-locking line width, different types of lasers.

Wave functions and effective mass: Review of tight binding model, nearly free-electron model, and the formation of bands. Bloch's theorem, envelope approximation, effective mass approximation, hetero-structure effective mass theory - modifications of the continuity conditions and the kinetic operator in the envelope approximation

Idealized potentials parabolic well, infinite square well, finite square well, finite hetero-structure square well, superlattices and minibands, Bloch oscillations, coupled quantum wells, Stark effect **Refinements of effective mass theory:** k dot p method, Kane 2 and 3 band models, non-parabolicity **Optical properties of quantum wells**: Interband and intraband transitions, absorption in quantum wells, selection rules, oscillator strength – sum rules, depolarization shift, gain and loss, modification of sum rules and transition dipole moments from non-parabolicity

QCL design strategies: two-dimensional rate equations, slope efficiency, importance of lifetimes, parasitic scattering, Bragg confinement, resonant tunneling (qualitative treatment), backfilling and

self-heating, bound-to-continuum designs, LO-phonon designs, chirped supper-lattice and phase space designs

Resonant tunneling injection and extraction: coupled quantum wells, resonant tunneling diodes, density matrix - two and three-level models, coherent and incoherent transport regimes, scattering assisted injection, electric field domains

Carrier scattering: phonon scattering, electron-electron scattering, impurity scattering, interface roughness, elevated electron temperatures

Waveguides/mode confinement: TE and TM modes, dielectric slab waveguides, surface plasmon waveguides, photonic crystals, distributed brag reflectors, mode coupling, orthogonality/completeness of modes, mode overlap factor

Format of Teaching Lecture and exercise/discussion session

Format of Examination Weekly exercises will be assigned. Students are expected to write notes on the lecture material. The grade for the course will be based on a final examination.

Requirements for the Attribution of Credit Points Active participation during the weekly lecture and exercise session is required. Students are required to submit weekly exercises and handwritten lecture notes to Module. The final examination will be written and take approximately 90 minutes to complete. A single grade will be given for both the lecture and exercises.

Use of the Module Courses in Physics Major

Importance of the Mark for the Final Grade The grade will be determined by the final examination.

Module Supervisor and Instructor Dr. Jukam (email: Nathan.Jukam@rub.de)

Further information

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Phy Microscopy	-	es of Electron	a) 22 h	38 h	a) Unlimited
Requirements f Formal None Content Basic k Preparation No	nowledge of		e physics and quar	ntum mechanics	
earning Outco	mes				
After successful student	l completion of the second s	the basic eleme	nts of electron mi	croscopes	
-	owledge in el viliar with elev	ectron optics ctron-specimen i	nteractions		
		•	ing and diffraction	n theory	
			nation with image	•	tation
 obtain f 	first insights i	nto spectroscopi	c techniques		
Students will lea	arn to descrik	e the basic elem	ents of electron m	nicroscopes (elect	ron guns. electro-
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use	The course v us on elastic of phase cont y of electron xamples. The ed to analyse	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi	tering. Details of i ibed to be able to iffraction will be e	inisms of electror mage formation interpret image xplained and will to spectroscopic	l wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use Format of Teac Format of Exam	The course v us on elastic of phase cont y of electron xamples. The ed to analyse hing Lecture	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi the composition	indamental mecha itering. Details of i ibed to be able to iffraction will be ex de first insights in	inisms of electron mage formation interpret image xplained and will to spectroscopic ucture of solid sta	I wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how te materials.
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use Format of Teac Format of Exam group	The course v us on elastic of phase cont y of electron xamples. The ed to analyse hing Lecture	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi the composition	indamental mecha itering. Details of i ibed to be able to iffraction will be ei de first insights in and electronic stru alk of 45 min. plus	nisms of electror mage formation interpret image xplained and will to spectroscopic ucture of solid sta discussion withir	I wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how ate materials.
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use Format of Teac Format of Exam group Requirements f	The course v us on elastic of phase cont y of electron xamples. The ed to analyse hing Lecture hination The for the Attrib	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi the composition	indamental mecha itering. Details of i ibed to be able to iffraction will be ei de first insights in and electronic stru alk of 45 min. plus	nisms of electror mage formation interpret image xplained and will to spectroscopic ucture of solid sta discussion withir	I wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how te materials.
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use Format of Teac Format of Exan group Requirements f tation with valio	The course v us on elastic of phase cont y of electron xamples. The ed to analyse hing Lecture hination The for the Attrib d discussion.	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi the composition	indamental mecha itering. Details of i ibed to be able to iffraction will be ei de first insights in and electronic stru alk of 45 min. plus	nisms of electror mage formation interpret image xplained and will to spectroscopic ucture of solid sta discussion withir	I wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how ate materials.
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use Format of Teac Format of Exam group Requirements f tation with valio Use of the Mod	The course v us on elastic of phase cont y of electron xamples. The ed to analyse hing Lecture hination The for the Attrib d discussion. lule Courses i the Mark for	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi the composition students give a ta ution of Credit P n Physics Major	indamental mecha itering. Details of i ibed to be able to iffraction will be ei de first insights in and electronic stru alk of 45 min. plus	inisms of electror mage formation interpret image xplained and will to spectroscopic ucture of solid sta discussion withir cipation (>75%) a	I wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how ate materials. In the lecture and successful preser
magnetic lenses electron optics. tions with a foc to scattering an The basic theor experimental ex they can be use Format of Teac Format of Teac Format of Exam group Requirements f tation with valid Use of the Mod Importance of t average final gr	The course v us on elastic of phase cont y of electron xamples. The ed to analyse hing Lecture hination The for the Attrib d discussion. lule Courses i the Mark for ade	tectors) and are vill explain the fu and inelastic scat rast will be descr scattering and di course will provi the composition students give a ta ution of Credit P n Physics Major	indamental mecha itering. Details of i fibed to be able to iffraction will be ei de first insights in and electronic stru alk of 45 min. plus points Active partic	inisms of electror mage formation interpret image xplained and will to spectroscopic ucture of solid sta discussion withir cipation (>75%) a	I wave nature of a specimen interac- mechanisms related contrast formation. be demonstrated by techniques and how ate materials. In the lecture and successful preser

	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Phys	sical Principle	es of	a) 22 h	76 h	a) Unlimited
Quantum In	formation		b) 22 h		b) Unlimited
b) Exercises for	r Physical Prir	nciples of			
Quantum In	formation				
Requirements	for Participat	ion		- L	L
Formal None					
	-	r algebra, quantı	um mechanics		
Preparation No	one				
Learning Outco	omes				
Understanding	of the physic	al principles of q	uantum informatio	n and quantum	engineering with
quantum super	conducting c	ircuits			
Contents	A .				
		•	ples of quantum inf		-
	•	-	uantum computing		•
chine learning,	quantum sim	iulations, etc., w	ill be addressed. Th	e second nart of	the course will be
	articular reali		m information devi		
devoted to a pa circuits.	articular reali				
circuits.					
circuits. Recommended	literature:	zation of quantu	m information devi	ces, i.e., super-c	onducting qubits
circuits. Recommended • M. A. N	literature: lielsen, I. Chu	zation of quantu ang, "Quantum	m information devi	ces, i.e., super-c uantum informa	onducting qubits tion"
circuits. Recommended • M. A. N • D. Heis	literature: lielsen, I. Chu s, "Fundamer	zation of quantu ang, "Quantum ntals of quantum	m information devi	ces, i.e., super-c uantum informa	onducting qubits tion"
circuits. Recommended • M. A. N • D. Heis decohe	literature: lielsen, I. Chu s, "Fundamer erence and all	zation of quantu ang, "Quantum ntals of quantum I that"	m information devi computation and qu n information: quant	ces, i.e., super-c uantum informa tum computatio	onducting qubits tion"
circuits. Recommended • M. A. N • D. Heis decohe	literature: lielsen, I. Chu s, "Fundamer erence and all	zation of quantu ang, "Quantum ntals of quantum I that"	m information devi	ces, i.e., super-c uantum informa tum computatio	onducting qubits tion"
circuits. Recommended • M. A. N • D. Heis decohe	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al.	zation of quantu ang, "Quantum ntals of quantum I that" "Superconductir	m information devi computation and qu n information: quant	ces, i.e., super-c uantum informa tum computatio	onducting qubits tion"
circuits. Recommended • M. A. N • D. Heis decohe • M. Kjae	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al. :hing Lecture,	zation of quantu ang, "Quantum ntals of quantum that" "Superconductir , Exercises	m information devi computation and qu n information: quant	ces, i.e., super-c uantum informa tum computatio	onducting qubits tion"
circuits. Recommended M. A. N D. Heis decohe M. Kjae Format of Teac	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al. hing Lecture, nination Oral	zation of quantu ang, "Quantum ntals of quantum that" "Superconductir , Exercises exam 30 min	m information devi computation and qu n information: quant	ces, i.e., super-c uantum informa tum computatio	onducting qubits tion"
circuits. Recommended M. A. N D. Heis decohe M. Kjae Format of Teac Format of Exan Requirements	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al. hing Lecture, nination Oral for the Attrib	zation of quantu ang, "Quantum ntals of quantum that" "Superconductir , Exercises exam 30 min	m information devi computation and qu n information: quant ng qubits: Current st Points Successful or	ces, i.e., super-c uantum informa tum computatio	onducting qubits tion"
circuits. Recommended M. A. N D. Heis decohe M. Kjae Format of Teac Format of Exan Requirements Use of the Moo Importance of	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al. hing Lecture, nination Oral for the Attrik	zation of quantu ang, "Quantum ntals of quantum that" "Superconductir , Exercises exam 30 min pution of Credit I in Physics Major	m information devi computation and qu n information: quant ng qubits: Current st Points Successful or	ces, i.e., super-c uantum informa tum computatio cate of play" al exam	onducting qubits tion" n, communication,
circuits. Recommended M. A. N D. Heis decohe M. Kjae Format of Teac Format of Teac Format of Exan Requirements Use of the Moo	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al. hing Lecture, nination Oral for the Attrik	zation of quantu ang, "Quantum ntals of quantum that" "Superconductir , Exercises exam 30 min pution of Credit I in Physics Major	m information devi computation and qu n information: quant ng qubits: Current st Points Successful or	ces, i.e., super-c uantum informa tum computatio cate of play" al exam	onducting qubits tion"
circuits. Recommended M. A. N D. Heis decohe M. Kjae Format of Teac Format of Teac Format of Exan Requirements Use of the Moo Importance of age final grade	literature: lielsen, I. Chu s, "Fundamer erence and all ergaard et al. ching Lecture, nination Oral for the Attrib dule Courses the Mark for	zation of quantu ang, "Quantum ntals of quantum that" "Superconductir , Exercises exam 30 min pution of Credit I in Physics Major	m information devi computation and qu n information: quant ng qubits: Current st Points Successful or	ces, i.e., super-c uantum informa tum computatio cate of play" al exam	onducting qubits tion" n, communication,

	Credits	Workload	Semester	Cycle	Duration
	3 CP	90 h	from 1. Sem.	Winter & Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
 a) Lecture Scie conductor F b) Exercises fo Semiconductor 	Physics r Scientific N		a) 22 h b) 11 h	57 h	a) Unlimited b) 30
Requirements f	or Participat	ion		•	
ormal None					
Preparation No	ne				
 Student student charge are fam student mobility 	s know the b carrier densit iliar with elec s are able to y and electric osition of sem	asic concepts of ties and excitation ctron and hole d recognize conne- tal conductivity a niconductors from	thermodynamics of ons in solids ynamics in semicol ections between th and apply this know m the periodic tabl	e materials and band /ledge to all semicon e, bandgaps, pn-junc	on rates, electri gaps, doping, ductors tion, Shockley-
ent-voltage (IV) measureme	ents, temperatur	e dependence of t	ransistor, field-effect he electric carrier de feedback operation	
inearization of ypical and pop ng of individua heir problems,	non-linear ac ular semicon l or connecte sustainability	tive devices, noi ductor devices w d devices, typica y aspects and pla	vith hints for their and failures in electro	pectrum analyser, loc applications in labora onics, electrolytic cap e including strategies	k-in amplifier, tory life, check- acitors and
linearization of typical and pop ing of individua	non-linear ac ular semicon l or connecte sustainability s of electroni	tive devices, noi ductor devices w d devices, typica y aspects and pla c equipment	ise, oscilloscope, sp vith hints for their a al failures in electro	pectrum analyser, loc applications in labora onics, electrolytic cap	k-in amplifier, tory life, check- acitors and
inearization of typical and pop ing of individua their problems, repair strategies Format of Teac Format of Exam about a self-def and the profess	non-linear ac ular semicon l or connecte sustainability s of electroni hing Lecture, hination In th ined subject or. If this is n	tive devices, noi ductor devices w d devices, typica y aspects and pla c equipment Exercises e last part of the in the vicinity of	ise, oscilloscope, sp vith hints for their a al failures in electro anned obsolescenc e semester, each st the lecture's conte dministrative reaso	pectrum analyser, loc applications in labora onics, electrolytic cap	k-in amplifier, tory life, check- acitors and s how to react, k of 45 min. hole auditorium
inearization of cypical and pop ng of individua heir problems, repair strategie format of Teac format of Exam about a self-def and the profess an individual or	non-linear ac ular semicon l or connecte sustainability s of electroni hing Lecture, hination In th ined subject or. If this is n al examinatio	tive devices, noi ductor devices w d devices, typica y aspects and pla c equipment Exercises le last part of the in the vicinity of ot possible for a on of 45 min. wil	ise, oscilloscope, sp vith hints for their a al failures in electro anned obsolescenc e semester, each st the lecture's conte dministrative reaso	bectrum analyser, loc applications in labora onics, electrolytic cap e including strategies udent performs a tal ents in front of the w ons (e.g. not enough	k-in amplifier, tory life, check- acitors and s how to react, k of 45 min. hole auditorium
inearization of typical and pop ing of individual their problems, repair strategie Format of Teac Format of Exam about a self-def and the profess an individual or Requirements f	non-linear ac ular semicon l or connecte sustainability s of electroni hing Lecture, hination In th ined subject or. If this is n al examinatio	tive devices, noi ductor devices w d devices, typica y aspects and pla c equipment Exercises le last part of the in the vicinity of ot possible for a on of 45 min. wil	ise, oscilloscope, sp vith hints for their a al failures in electro anned obsolescenc e semester, each st the lecture's conte dministrative reaso I be performed	bectrum analyser, loc applications in labora onics, electrolytic cap e including strategies udent performs a tal ents in front of the w ons (e.g. not enough	k-in amplifier, tory life, check- acitors and s how to react, k of 45 min. hole auditorium
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Courses Self-Study Group Size a) Seminar Selected Topics of Applied Solid a) 22 h 38 h a) Unlimit State Physics a) 22 h 38 h a) Unlimit Requirements for Participation Formal None Formal None Format Sof the Applied Instruments/machines. An Imp		Credits	Workload	Semester	Cycle	Duration
 a) Seminar Selected Topics of Applied Solid a) 22 h 38 h a) Unlimit State Physics Requirements for Participation Formal None Content None Preparation None or "Participation in solid state physics module is recommended." Learning Outcomes After successful completion of the module students have a basic understanding of applied solid state physics Students are aware of the capabilities of semiconductors in transport and optics students know the basic concepts of molecular beam epitaxy and focused ion beam technology are familiar with experimental techniques of actual semiconductor raterials and their applications Contents Talks and discussions on actual topics of applied solid state research. In particular, molecular be epitaxy and focused ion beam technology including the preparation of semiconductor devices a technical aspects of the applied instruments/machines. An important issue is the creation of ultiphy acuum for most of the preparative techniques. Frequently discussed subjects are quantum devices like single photon sources, quantum dots and low-dimensional electrical carrier systems general. Format of Teaching Lecture, talks, discussions Format of Examination The student performs a talk of 45 min. plus discussion within the resear group Requirements for the Attribution of Credit Points Successful talk with valid discussion Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted and the state and the sear data data data data data data data da		2 CP	60 h	from 1. Sem.	Winter & Summer	1 Semester
State Physics Image: Content State Physics Requirements for Participation Formal None Formal None Preparation None or "Participation in solid state physics module is recommended." Learning Outcomes After successful completion of the module • students have a basic understanding of applied solid state physics • Students are aware of the capabilities of semiconductors in transport and optics • students know the basic concepts of molecular beam epitaxy and focused ion beam technology • are familiar with experimental techniques of actual semiconductor research • students are able to recognize connections between semiconductor materials and their applications Population of the preparation of semiconductor devices a technical aspects of the applied instruments/machines. An important issue is the creation of ult high vacuum for most of the preparative techniques. Frequently discussed subjects are quantum devices like single photon sources, quantum dots and low-dimensional electrical carrier systems general. Format of Teaching Lecture, talks, discussions Format of Examination The student performs a talk of 45 min. plus discussion within the resear group Requirements for the Attribution of Credit Points Successful talk with valid discussion Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted ar	Courses		·	Contact Hours	Self-Study	Group Size
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 After successful completion of the module students have a basic understanding of applied solid state physics Students are aware of the capabilities of semiconductors in transport and optics students know the basic concepts of molecular beam epitaxy and focused ion beam technology are familiar with experimental techniques of actual semiconductor research students are able to recognize connections between semiconductor materials and their applications Contents Talks and discussions on actual topics of applied solid state research. In particular, molecular be epitaxy and focused ion beam technology including the preparation of semiconductor devices a technical aspects of the applied instruments/machines. An important issue is the creation of ult high vacuum for most of the preparative techniques. Frequently discussed subjects are quantum devices like single photon sources, quantum dots and low-dimensional electrical carrier systems general. Format of Teaching Lecture, talks, discussions Format of Examination The student performs a talk of 45 min. plus discussion within the resear group Requirements for the Attribution of Credit Points Successful talk with valid discussion Use of the Module Courses in Physics Major	Formal None Content None			ate physics modul	e is recommended."	I
Talks and discussions on actual topics of applied solid state research. In particular, molecular be epitaxy and focused ion beam technology including the preparation of semiconductor devices a technical aspects of the applied instruments/machines. An important issue is the creation of ult high vacuum for most of the preparative techniques. Frequently discussed subjects are quantum devices like single photon sources, quantum dots and low-dimensional electrical carrier systems general. Format of Teaching Lecture, talks, discussions Format of Examination The student performs a talk of 45 min. plus discussion within the resear group Requirements for the Attribution of Credit Points Successful talk with valid discussion Use of the Module Courses in Physics Major Importance of the Mark for the Final Grade Graded, but does not contribute to the weighted ar	After successfu studen Studen studen techno are fan studen	l completion ts have a basi ts are aware ts know the b logy hiliar with exp ts are able to	ic understanding of of the capabilities basic concepts of r perimental technic	of semiconducto nolecular beam e ques of actual sen	rs in transport and o pitaxy and focused ic niconductor research	on beam
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Module Supervisor and Instructor Dr. Ludwig, Prof. Dr. Wieck	general. Format of Teac Format of Exar group Requirements Use of the Moo Importance of	nination The for the Attrib dule Courses	student performs oution of Credit Po in Physics Major	a talk of 45 min. Dints Successful ta	alk with valid discussi	on

	Credits 1 CP	Workload 30 h	Semester from 1. Sem.	Cycle Winter & Summer	Duration 1 Semester
	1 01				2 ochiester
Courses a) Seminar Ser	niconductor	Band Structures	Contact Hours a) 11 h	Self-Study 19 h	Group Size a) Unlimited
Requirements f Formal None Content None Preparation Par mended.			Problems in Appli	ed Solid State Physics	s" is recom-
 Student simulat student 	completion s have a bas s are aware ions s know the b	ic understanding o of the capabilities pasic concepts of h	s of software pack	band structure calcu ages to perform com evices nd structure and func	plex device
the periodic tab enabled the cre sources and ulti crystal matrix el the electrostation late the quantiz electron mobilition will be in close re source, and sing	ele of element ation of high rafast electro lements and c potential and ed states and cy transistor relation to st gle electron s	its in perfect cryst aly efficient and m pnic components. dopants resulting nd (quantized) en- d the band structu and diode structu ructures used for source Leviton dev	alline arrangement iniaturized optoe Key to this is the g in the band struct ergy states of carr ure of different de res. The structure quantum experim	ning different constit nts is a huge technolo lectronic devices like control of the arrang cture, the spatial arra riers. In the seminar v evices like quantum w es developed in practionents with e.g. qubit,	ogical leap. It laser light ement of the ngement of we will calcu- vells, high ical exercises
Format of Teac	-	•			
			-	f an own simulation	
Requirements f	or the Attrik	oution of Credit Po	oints Active partic	cipation and presenta	ition
Use of the Mod	ule Courses	in Physics Major			
Importance of t age final grade	he Mark for	the Final Grade G	Graded, but does	not contribute to the	weighted aver-
Module Superv	isor and Inst	r uctor Dr. Ludwig	5		

	ctor Physic			1	
	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Ser	niconductor	Physics I	a) 33 h	76 h	a) Unlimited
b) Exercises fo	or Semicondu	ictor Physics I	b) 11 h		b) 30
Requirements	for Participat	tion			
Formal None					
Content None					
Preparation No	one				
Learning Outco					
After successfu	•		of crystals, doning	, alactropic trap	sport band
		ic understanding	g of crystals, doping tors	g, electronic trans	sport, band
				els applied to de	scribe semiconducto
physics		er me capacitation			
		pasic concepts of	selected semicond	ductor devices	
• studen	ts are familia	r with semicond	uctors		
achieve a basic	understandi	ng in these conce	epts. Models to des	scribe and metho	tors are covered to ods to produce semi- miconductor devices
Format of Teac	hing Lecture	, Exercise			
Format of Exan	nination Ora	l examination at	the end of the lect	ure	
Requirements the oral exam	for the Attrik	oution of Credit	Points Active partic	cipation in the tra	aining class and pass
		in Physics Major			
Use of the Moo	uie courses				
		the Final Grade	Graded, but does	not contribute to	the weighted aver-
Importance of age final grade	the Mark for	the Final Grade ructor Dr. Ludwi		not contribute to	o the weighted aver-

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter	1 Semester
Courses a) Seminar S	olid State Phy	sics Theory	Contact Hours a) 22 h	Self-Study 38 h	Group Size a) 25
Requirements Formal None Content Basic desirable Preparation N	knowledge of		ry, statistical mech	anics and quant	um mechanics is
 stude theor Stude exper stude 	ul completion hts have devel / nts are able to imental solid s hts know the b	work independ tate physics and	•	ern literature or esentations on a	theoretical and
 topole basics conce Coher 	of the quantu pts of Phase T ent states and	eory and its appl im information a	ication to the nove and qubits realization roken symmetry	•	rials
Format of Tea	ching Semina	r			
	mination The to the moderr		iined via a presenta	ation by the stud	lent on the selected
Passing the w exercises. In t	ritten/oral exanis case, active nis case, active nined at the be	mination or obta e participation in eginning of the c	aining at least 50 % the exercise is also	of the possible mandatory. Th the F practical co	orm of examination: points in the weekly e form of examination ourse must be com- d.
pleted succes					
pleted success Use of the Mo	dule Courses	in Physics Major	•		
Use of the Mo	f the Mark for			not contribute to	o the weighted aver-
Use of the Mo Importance o age final grad	f the Mark for		Graded, but does	not contribute to	o the weighted aver-

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter & Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar Sp Spectrosco		l Ultrafast	a) 22 h	38 h	a) Unlimited
Requirements Formal Lecture Content None Preparation Ph	e Physik Illa/b			1	I
	Il completion ts have a bas	ic understanding		of time-resolved spea measurement outco	
	onic devices.	-			
spintro Contents Time-resolved noise spectroso	pump-probe copy. Second	spectroscopy wi order frequency	•	al resolution. Non-lin Higher order polyspe	ear optics. Spin
spintro Contents Time-resolved noise spectroso measurement.	pump-probe copy. Second Quantum Po	spectroscopy wi order frequency lyspectra. Optica	resolved spectra.	al resolution. Non-lin Higher order polyspe	ear optics. Spin
spintro Contents Time-resolved noise spectroso measurement. Format of Teac	pump-probe copy. Second Quantum Po ching Semina mination The	spectroscopy wi order frequency lyspectra. Optica r talks by studen student prepare	resolved spectra. I al spin injection. Sp ts and instructors	al resolution. Non-lin Higher order polyspe	ear optics. Spin ctra and their
spintro Contents Time-resolved noise spectroso measurement. Format of Teac Format of Exar is prepared for	pump-probe copy. Second Quantum Po ching Semina mination The a subsequen for the Attrik	spectroscopy wi order frequency lyspectra. Optica r talks by studen student prepare t discussion.	resolved spectra. al spin injection. Sp ts and instructors es and delivers a tal	al resolution. Non-lin Higher order polyspe in-transport.	ear optics. Spin ctra and their 45 Minutes) and
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Modul 4d	Credits	Workload	Semester	Cycle	Duration
	15-25 CP	450-750 h	12. Sem.	Winter & Summer	2 Semesters
Courses			Contact Hours	Self-Study	Group Size
a) Lecture			Each at least.	min. 309 h	a) unlimited
b) Exercises			a) 44 h		b) 30
c) Seminar (at l	least 2 CP)		b) 44 h		c) 30
d) Advanced La	boratory Cour	rses (at least 5	c) 22 h		d) 2
CP)			d) 35 h		
A complete ove	rview of the c	ourses can be			
found in the cu		-			
CP of the indivi	dual courses re	esult from the			
semester hours		iour per se-			
mester week =					
Requirements f	or Participatio	on			
Formal None					
	-	roduction to Nu	clear and Particle	Physics" will be expec	cted
Preparation No	ne				
Learning Outco					
After successfu	lly completing	the module, the	e students		
 underst 	tand both how	the Standard N	lodel of particle ph	nysics was developed	and its
predict	ive power				
 can ma 	ke the connec	tion between qu	antum field theor	y predictions and exp	eriments
 have a 	deeper unders	standing of the e	electromagnetic, w	eak and strong intera	ictions
 are fam 	iliar with and	can interpret No	bel Prize experime	ents in nuclear and pa	article physics
 are able 	e to make the	connection betv	veen symmetries a	nd experimental obse	ervations
 possess 	a knowledge	of open questio	ns and current res	earch topics in the fie	ld of nuclear
and nar	ticle physics				
anu par					
		ection between J	particle physics and	d the development of	f the universe
•		ection between (particle physics and	d the development of	f the universe
can exp Contents	lain the conne			d the development of diagrams, Yukawa int	
• can exp Contents Dirac equation,	spin, antipart	icles, conservation	on laws, Feynman	·	eraction,
 can exp Contents Dirac equation, strangeness, group 	spin, antipart	icles, conservation	on laws, Feynman bsch-Gordon coeff	diagrams, Yukawa int	eraction, s, Breit-Wigner
can exp Contents Dirac equation, strangeness, gr resonances, col	spin, antipart oup theory an ours in QCD, c	icles, conservation d symmetry, Cle harm, confinem	on laws, Feynman bsch-Gordon coeff ent, Global and loc	diagrams, Yukawa int ficients, meson nonet	eraction, s, Breit-Wigner on structure,
can exp Contents Dirac equation, strangeness, gro resonances, col parton model, o	spin, antipart oup theory an ours in QCD, c deep inelastic	icles, conservation d symmetry, Cle harm, confinem scattering and so	on laws, Feynman bsch-Gordon coeff ent, Global and loc cale behaviour, ne	diagrams, Yukawa int ficients, meson nonet cal symmetries, hadro	eraction, s, Breit-Wigner on structure, WW, mixing
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can exp Contents Dirac equation, strangeness, gra resonances, col parton model, o states, Higgs ma theories, solitor tectors, hadron current topics. I Format of Teac Format of Teac Format of Exam Requirements module must in module examin amination no lo Use of the Mod Importance of the	spin, antipart oup theory an ours in QCD, c deep inelastic echanism of m ns. In addition physics, neuti Practical expen- hing Lecture, I hination Oral e for the Attrib nclude: advan- ation (2 CP), 1 onger count to lule Compulso the Mark for t	icles, conservation d symmetry, Cle harm, confinem scattering and so ass production, special events a rino physics, as w riments compler Exercises, Semin examination of 4 ution of Credit ced laboratory of .5-25 CP can be wards the modu ry-Elective Mod	on laws, Feynman bsch-Gordon coeff ent, Global and loc cale behaviour, ner physics beyond th are offered in the f well as theoretical ment the theoretical ar, Laboratory Wo 5 minutes Points Passing the courses (5 CP), a s achieved. Achieven le. ule Weighted accordin	diagrams, Yukawa int ficients, meson nonet cal symmetries, hadro utrino physics, weak V e Standard Model, qu form of lectures and s nuclear and particle p al knowledge. rk e oral examination. T eminar (2 CP). Includ ments made after the	reraction, s, Breit-Wigner on structure, WW, mixing Jantum field aeminars on de- ohysics or other The specialisati ling the final o
can exp Contents Dirac equation, strangeness, gro resonances, col parton model, o states, Higgs mo theories, solitor tectors, hadron current topics. Format of Teac Format of Teac Format of Exam Requirements module must ir module must ir module examin amination no lo Use of the Mod Importance of t Module Superv	spin, antipart oup theory an ours in QCD, c deep inelastic echanism of m ns. In addition physics, neutr Practical expen- hing Lecture, I nination Oral e for the Attrib nclude: advan- ation (2 CP), 1 onger count to lule Compulso the Mark for t	icles, conservation d symmetry, Cle harm, confinem scattering and so ass production, special events a rino physics, as w riments compler Exercises, Semin examination of 4 ution of Credit ced laboratory of .5-25 CP can be wards the modu ry-Elective Mod he Final Grade W	on laws, Feynman bsch-Gordon coeff ent, Global and loo cale behaviour, ner physics beyond th are offered in the f well as theoretical nent the theoretic ar, Laboratory Wo 5 minutes Points Passing the courses (5 CP), a s achieved. Achiever ile. ule <u>Weighted accordin</u> pr. Epelbaum	diagrams, Yukawa int ficients, meson nonet cal symmetries, hadro utrino physics, weak V e Standard Model, qu form of lectures and s nuclear and particle p al knowledge. rk e oral examination. T eminar (2 CP). Includ ments made after the	reraction, s, Breit-Wigner on structure, WW, mixing Jantum field teminars on de- ohysics or other The specialisati ling the final o e final module e

Further Information For advice and coordination of the courses, please contact the module supervisor. Please see the <u>course list</u> below.

Course	Туре	No.	Semester
Advanced Laboratory Course for Physics Students	Laboratory	160250	Winter
	Laboratory	100230	Summer
Current Topics in the Standard Model and Beyond	Seminar	160429	Winter
Data Analysis in High Enorgy Dhysics	Lecture	160430	\\/intor
Data Analysis in High Energy Physics	Exercises	160431	Winter
Detectors and Algorithms for Charged Track Reconstruc-	Lecture with		
tion	integrated	160412	Winter
	Exercises		
Detectors for Particle Physics	Seminar	160421	Winter
Effective Field Theories	Seminar	160429	Summer
Eventimental Methods in Nuclear and Particle Physics	Seminar	160420	Winter
Experimental Methods in Nuclear and Particle Physics	Seminar	160420	Summer
Hadron Dhysics	Lecture	160414	Summer
Hadron Physics	Exercises	160415	Summer
Hadrons at Large Hadron Collider	Seminar	160432	Winter
Hadrons at Large Hadron Collider	Semiliar	100432	Summer
Introduction into Chiral Porturbation Theory	Lecture	160427	Winter
Introduction into Chiral Perturbation Theory	Exercises	160428	winter
Introduction to Nuclear and Darticle Dhusics II	Lecture	160401	Current or
Introduction to Nuclear and Particle Physics II	Exercises	160402	Summer
Introduction to Statistics for Astronomers and Physicists	Lecture	160613	Summer
Lettice Field Theory, NFN4	Lecture	160416	6
Lattice Field Theory NEW	Exercises	160417	Summer
	Lecture with	100101	Minter
Nucleosynthesis in Nuclear Astrophysics	Exercises	160424	Winter
	Lecture	160401	Mintor
	Exercises	160402	Winter
Quantum Field Theory I	Lecture	160403	Summer
	Exercises	160404	not in 25
Output un Field Theory II	Lecture	160405	Contract
Quantum Field Theory II	Exercises	160406	Summer
Deutliele Detectory familiations Director 5 and 1	Lecture	160412	Contract
Particle Detectors for Hadron Physics Experiments	Exercises	160413	Summer
Particle Physics Detectors	Seminar	160421	Summer
Selected Topics of Hadron Physics I	Seminar	160422	Winter
Selected Topics of Hadron Physics II	Seminar	160426	Summer
· · · ·	C	160418	Winter
Seminar on Hadron Physics	Seminar	160419	Summer
		160406	Winter
Symbolic Computation in Mathematica	Lecture	160411	Summer
	Lecture	160409	Summer
Theoretical Hadron Physics	Exercises	160410	not in 25
	Lecture	160616	
Theoretical Neutrino Astrophysics	Exercises	160617	Winter

Current Top	ics in the S	Standard Mo	del and Beyon	d	
	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar Curr Model and B	•	the Standard	a) 22 h	38 h	a) 30
	sful participa Introduction	tion in the cours	e Advanced Quant Hadron Physics will		and Quantum Field ous.
are fam shortcolStudent	ly completing iliar with the mings as wel s have a dee	l as current rese per understandi	e students andard Model of pa arch topics in parti ng of the scientific ng and giving a scie	cle physics issues in the ch	osen focus area.
chromodynamic the Standard Me The seminar ser	es, theory of t odel, neutrin ves the elabo nded out by eveloped and	the electroweak o physics, physic oration of a conc the supervisors I presented.	interaction, anom cs beyond the Stan crete topic. At the b	alies, QCD metl dard Model, et peginning of the	bics such as quantum nods, precision tests of c. e seminar, different seminar series, individ-
Format of Exam					
			Points Active partic	cipation in the s	essions, presentation
Use of the Mod			•		, -
Importance of t	he Mark for	the Final Grade	Graded, contributi	ion to the final	mark weighed for CP
Module Supervi	isor and Insti	ructor Prof. Dr.	Epelbaum,		
Further Informa					

Data Analys	is in High E	nergy Physic	S		
-	Credits	Workload	Semester	Cycle	Duration
	3 CP	90 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Data	Analysis in Hi	gh Energy	a) 22 h	a) 38 h	a) Unlimited
Physics			b) 11 h	b) 19 h	b) 30
b) Exercises to	Data Analysis i	in High Energy			
Physics	<u> </u>				
Requirements f Formal None	or Participatio	on			
	ancy in calculu	s and basic prog	ramming skills are	a recommended	
Preparation No	•	s and basic prog		e recommended.	
Learning Outco					
•		the module, the	students will be a	able to:	
				high-energy physic	s experiments
		•	nethods to particle	0 0/1 /	
			•	using real experime	ntal data
•	•	•	experimental me	•	
 utilize n 	nachine learni	ng techniques fo	or classification of	particle reactions	
• fit theo	retical models	to experimenta	l data and evaluat	e quality of the fit	
 gain har 	nds-on experie	ence with LHCb o	data and particle-	physics analysis too	ls
 learn ba 	asics of Julia pr	rogramming lang	guage		
 complete 	te an independ	dent data analys	is project, demon	strating the applica	ition of learned
techniq	ues				
 present 	and effectivel	ly communicate	analysis results to	peers.	
Contents					
This course prov	vides a compre	ehensive journe	y from statistical r	modelling to advand	ed data analysis
				ows in particle phys	
	•	•	•	stimation, hypothes	-
		•	-	or particle classifica	
-		•		by hands-on applica	•
				will progressively be erpreting uncertain	
		-		ern computational 1	
		e		ect support for adv	•
				s will complete an i	
				proficiency in high	
data analysis.					
Format of Teac	h ing Lecture, E	Exercises			
Format of Exam	ination Prese	ntation of result	s of the data anal	ysis project develop	oed during the
semester.					
-				ipation (> 75 %) the	exercise,
			n the weekly exer	cises.	
Use of the Mod					
-		he Final Grade	iraded, but does i	not contribute to th	e weighted
average final gra		Inter Dref Dr. 1	Aikhacanka		
Module Superv	isor and Instru	actor Prof. Dr. N	лікпазепко		
Further Informa	ation Recomm	ended literature	2:		
- "Data Analy	sis in High Ene	ergy Physics: A P	ractical Guide to S	Statistical Methods	' by O. Behnke, K.
Kröninger, (G. Schott, and	T. Schörner-Sad	enius		

- "Statistical Data Analysis" by Glen Cowan

Detectors fo	or Particle P	hysics			
	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter	1 Semester
Courses a) Seminar De	tectors for Par	ticle Physics	a) 22 h	Self-Study 38 h	Group Size a) 30
			a, 22 m	50 11	4, 50
Requirements f	or Particinatio	n			
Formal None					
Content None					
Preparation No	ne				
Learning Outco	mes				
Students will					
			atomic particles		
	•	tions of detector	is are composed fr	omsubuelectors	
			nics and data acqu	isition systems	
			nysics goals and ta		its.
	саа. спо посогр	,			
Contents					
	-	•	-		s. The relevance of
		•	•	•	terplay between the
	•	-	of a complete det s at accelerators a	•	ored to very specific
				nu then achieven	
Format of Teac	ning Seminar t	alks by the stud	lents		
Format of Exam	nination Prepa	ration and subs	equent presentat	ion of a seminar t	alk to the whole
group.					
Requirements f	or the Attribu	tion of Credit P	oints Independen	t preparation of a	a seminar talk about
			•	· ·	n of the material to
the seminar par	ticipants.				
Use of the Mod	ule Courses in	Physics Maior			
importance of t	ne Mark for t	ne Final Grade	Graded, contribut	ion to the final m	ark weighed for CP
Module Superv	isor and Instru	uctor Prof. Dr. \	Wiedner, Prof. Dr.	Heinsius	
Further Informa	ation				

	Credits		Cycle	Duration	
	2 CP	60 h	from 1. Sem.	Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar E	Effective Field	Theories	a) 22 h	38 h	a) 30
-	s for Participa	tion:			
Formal None	.				
					participation in the
	itum Field The	ory I and/or Intro	oduction to Theore	tical Hadron Ph	sics will be advanta-
geous. Preparation N	lone				
Learning Out					
0		g the module, th	ne students		
		-		nd their applicat	ions in nuclear and
	le physics.				
•		eper understandi	ing of the scientific	issues in the ch	osen focus area.
		•	ng and giving a scie		
The course de	ais with the D				Id theories (EET)
Standard Moo tion, EFT for t The seminar i are handed o	de application del as EFT, pior he treatment o s designed to v	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi	cs include the in n and renormali EFT of gravity, e nning of the ser	etc.
Standard Moo tion, EFT for t The seminar i are handed o are developed	de application del as EFT, pior he treatment s designed to v ut by the supe	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl ed.	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi	cs include the in n and renormali EFT of gravity, e nning of the ser	terpretation of the sation group equa- etc. ninar, different topics
Standard Moo tion, EFT for t The seminar i are handed of are developed Format of Tea	de application del as EFT, pior he treatment o s designed to v ut by the supe d and presente	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl ed.	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi	cs include the in n and renormali EFT of gravity, e nning of the ser	terpretation of the sation group equa- etc. ninar, different topics
Standard Moo tion, EFT for t The seminar i are handed of are developed Format of Tea Format of Exa	de application del as EFT, pior he treatment o s designed to v ut by the supe d and presente aching Semina	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl ed. r	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi ly discussed. Withir	cs include the in n and renormali EFT of gravity, e nning of the ser n the seminar se	terpretation of the sation group equa- etc. ninar, different topics
Standard Moo tion, EFT for t The seminar i are handed of are developed Format of Tea Format of Exa Requirement	de application del as EFT, pior he treatment o s designed to v ut by the supe d and presente aching Semina amination Pres s for the Attrik	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl ed. r	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi ly discussed. Withir Points Active partic	cs include the in n and renormali EFT of gravity, e nning of the ser n the seminar se	terpretation of the sation group equa- etc. ninar, different topics ries, individual topics
Standard Moo tion, EFT for t The seminar i are handed of are developed Format of Tea Format of Exa Requirement Use of the Mo	de application del as EFT, pior he treatment o s designed to v ut by the supe d and presente aching Semina amination Pres s for the Attrik odule Courses	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl ed. r sentation oution of Credit in Physics Major	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi ly discussed. Withir Points Active partic	cs include the in n and renormali EFT of gravity, e nning of the ser n the seminar se	terpretation of the sation group equa- etc. ninar, different topics ries, individual topics
Standard Moo tion, EFT for t The seminar i are handed of are developed Format of Tea Format of Exa Requirement Use of the Mo Importance o	de application del as EFT, pior he treatment o s designed to v ut by the supe d and presente aching Semina amination Pres s for the Attrik odule Courses if the Mark for	in almost all are nless and chiral E of halo nuclei, EF work on a specifi rvisors and briefl ed. r sentation oution of Credit in Physics Major	as of physics. Topic FT, renormalisation T for BSM physics, c topic. At the begi ly discussed. Withir Points Active partic	cs include the in n and renormali EFT of gravity, e nning of the ser n the seminar se cipation in the se ion to the final r	terpretation of the sation group equa- etc. ninar, different topics ries, individual topics

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter & Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar Ex Nuclear and	perimental M d Particle Phys		a) 22 h	38 h	a) 30
Requirements f	or Participati	on		1	I
Formal None					
Content None					
Preparation No	ne				
Learning Outco	mes				
Students will					
			topics in nuclear an	nd particle physics	
•	•	ng theoretical co	•		
	•	ion of experime			
		-	nd particle physics		
 be awa 	re of the prec	ision of measur	ements and the qu	estion of statistics	
Contents					
Strong and wea	k interactions	. Heavy ion and	I neutrino physics.	Quantum field theory	/ as underlying
theoretical con	cept. Statistic	al interpretatior	n of data.		
	hing Seminar	talks by the stu	dents.		
Format of Teac		aration and sub	soquent presentati	ion of a seminar talk	to the whole
	nination Prepa		sequent presentati		
Format of Exan	nination Prepa		sequent presentati		
Format of Exan group.			· · ·	t preparation of a ser	
Format of Exan group. Requirements 1	for the Attrib	ution of Credit I	Points Independen	t preparation of a ser sive presentation of	ninar talk about
Format of Exan group. Requirements f particle detecto	for the Attribution of the start of the star	ution of Credit I	Points Independen	• •	ninar talk about
Format of Exan group. Requirements f particle detecto the seminar par	or the Attrib ors and their p rticipants.	u tion of Credit I hysics goals. Cle	Points Independen ear and compreher	• •	ninar talk about
Format of Exan group. Requirements f particle detecto the seminar par Use of the Mod	for the Attribution of the Attribution of the Attribution of the second	u tion of Credit I physics goals. Cle n Physics Major	Points Independen ear and compreher	• •	ninar talk about the material to
Format of Exan group. Requirements f particle detecto the seminar par Use of the Mod	for the Attributors and their participants. Iule Courses in the Mark for the Mark f	ution of Credit I physics goals. Cle n Physics Major the Final Grade	Points Independen ear and compreher Graded, contributi	nsive presentation of	ninar talk about the material to

Hadron Phy					
	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Summer	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Had	lron Physics		a) 22 h	22 h 76 h	a) unlimited
b) Exercise for Hadron Physics		b) 22 h		b) 30	
Requirements	for Participat	tion			
Formal None					
	•	-	•		s, classical mechanics
	-		particle and nuclea		
-	-		c programming skill	Is are needed to o	effectively engage
		s of the course.			
Learning Outco		- f the second of			
	•		tudents will be able		D
		-	of the fundamental	I principles of QC	D and its relation to
	ark Model (Q	•		. fl	ta in One
			s, relation betweer		
		•	nass spectrum usin	• •	, characterize
			m to properties of p		
	-	-	ling event generati	-	
-	-		e tetraquarks, penta	•	-
		• •	effective field theo	ories and compute	ational methods
	QCD) in had				
	•	•	ents in hadron phys	sics, and understa	and the role in the
		particle physics		.	
• identif	y potential re	search projects a	and opportunities f	for internships	
Contents					
This course in H	Hadron Physic	cs is an extensive	e program designed	d to provide stude	ents with a funda-
mental and pra	actical unders	tanding of Quan	ntum Chronodynam	nics (QCD) in a con	nfined regime of
hadronic matte	er. Beginning	with the introdu	iction to the basics	of QCD, including	g quarks, gluons,
					a solid theoretical
			•		structure, covering
barvons, meso	ns. the quark	model, and flav	our symmetry. A sig	gnificant portion	of the course is de-

colour confinement, asymptotic freedom, and gauge invariance, the course sets a solid theoretical foundation. It then progresses into a detailed study of hadron classification and structure, covering baryons, mesons, the quark model, and flavour symmetry. A significant portion of the course is devoted to experimental techniques in hadron physics, with a focus on particle detectors, and data processing, particularly LHCb, COMPASS, and BES experiments. This includes practical aspects of event generation, detection, and data analysis, alongside addressing common experimental challenges. Spectral analysis and reaction theory is explored, elucidating particle interaction, resonance phenomena. Students will also delve into the spectroscopy of hadrons, learning about excitation spectra of mesons and baryons, as well as exotic structures like tetraquarks, pentaquarks, glueballs, and hybrids. Theoretical tools and computational methods will be discussed in the second half of the course. The course also addresses current and future experiments in hadron physics, exploring their role in the broader context of particle physics. Finally, the course wraps up with ethical and practical considerations in research, offering guidance on collaboration in large-scale experiments, student projects, research opportunities, and career paths in hadron physics.

Format of Teaching Lecture, exercises

Format of Examination An oral examination based on a demonstration of the solution to a problem

Requirements for the Attribution of Credit Points Active participation (> 50 %) in exercise classes, presentation of the homework problem at the board at least two times during the semester, oral exam of 30 minutes based on a problem communicated a week before the exam. The form of examination will be determined at the beginning of the course.

Use of the Module Courses in Physics Major

Importance of the Mark for the Final Grade Graded, but does not contribution to the weighted average final grade

Module Supervisor and Instructor Prof. Dr. Mikhasenko

Further Information Recommended literature:

- F. Halzen and A.D. Martin, Quarks and Leptons: An Introductory Course in Modern Particle Physics

- M. Thompson, Modern particle physics (2013)

- A.D. Martin, T.D. Spearman, Elementary particle theory

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Winter &	1 Semester
				Summer	
Courses			Contact Hours	Self-Study	Group Size
a) Seminar Ha Collider	adrons at Larg	ge Hadron	a) 22 h	76 h	a) Unlimited
Requirements	for Participat	tion			
Formal None	ourcowork in	narticle and pu	clear physics is rec	ommondod	
Preparation No		i particle and nu		ommenueu.	
Learning Outco	omes				
After a success	ful completio	n of the course,	students will be ab	ole to:	
	n overview of tions at LHC	state-of-the-art	research topics rel	ated to studies	of hadrons and their
		o effectively pre	esent scientific rese	arch to a group	of experts.
	• •		contribute to scient	• ·	
Contents					
			cific topic related to		-
Collider. Throu	ghout the ser	nester, they con	duct an in-depth st	udy of their top	ic following recent
Collider. Throu scientific public	ghout the ser cations. The f	mester, they con irst half of the co	duct an in-depth st ourse is dedicated t	udy of their top o independent i	ic following recent research, while
Collider. Throu scientific public students receiv	ghout the ser cations. The f ve guidance a	nester, they con irst half of the co nd feedback from	duct an in-depth st ourse is dedicated t m the instructor. In	tudy of their top to independent i the second half	ic following recent research, while , students present
Collider. Throu scientific public students receiv their findings to	ghout the ser cations. The f ve guidance a o the group ir	nester, they con irst half of the co nd feedback from	duct an in-depth st ourse is dedicated t	tudy of their top to independent i the second half	ic following recent research, while , students present
Collider. Throu scientific public students receiv their findings to open discussion	ghout the ser cations. The f ve guidance a o the group ir ns.	mester, they con irst half of the co nd feedback from n a series of scien	duct an in-depth st ourse is dedicated t m the instructor. In	tudy of their top to independent i the second half	ic following recent research, while , students present
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminal	nester, they con irst half of the co nd feedback from n a series of scien r	duct an in-depth st ourse is dedicated t m the instructor. In ntific presentations	cudy of their top to independent i the second half these sessions	ic following recent research, while , students present are followed by
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac Format of Exar	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminal	nester, they con irst half of the co nd feedback from n a series of scien r	duct an in-depth st ourse is dedicated t m the instructor. In ntific presentations	cudy of their top to independent i the second half these sessions	ic following recent research, while , students present
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac Format of Exar group Requirements	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminal mination The for the Attrik	nester, they con irst half of the co nd feedback froi n a series of scien r student perforn	duct an in-depth stourse is dedicated to m the instructor. In ntific presentations	tudy of their top to independent in the second half these sessions	ic following recent research, while , students present are followed by
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac Format of Exar group Requirements with valid discu	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminar nination The for the Attrik ussion	nester, they con irst half of the co nd feedback from n a series of scient r student perform oution of Credit	duct an in-depth st ourse is dedicated t m the instructor. In ntific presentations ns a talk of 45-90 m Points Active partic	tudy of their top to independent in the second half these sessions	ic following recent research, while , students present s are followed by on within the researc
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac Format of Exar group Requirements with valid discu Use of the Mod	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminal mination The for the Attrik ussion dule Courses	nester, they con irst half of the co nd feedback from n a series of scient student perform oution of Credit in Physics Major	duct an in-depth st ourse is dedicated t m the instructor. In ntific presentations ns a talk of 45-90 m Points Active partic	udy of their top to independent in the second half These sessions in. plus discussions	ic following recent research, while , students present are followed by on within the researc
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac Format of Exar group Requirements with valid discu Use of the Moo Importance of	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminar nination The for the Attrik ussion dule Courses the Mark for	nester, they con irst half of the co nd feedback from n a series of scient student perform oution of Credit in Physics Major	duct an in-depth st ourse is dedicated t m the instructor. In ntific presentations ns a talk of 45-90 m Points Active partic	udy of their top to independent in the second half These sessions in. plus discussions	ic following recent research, while , students present s are followed by on within the researc
Collider. Throu scientific public students receiv their findings to open discussion Format of Teac Format of Exar group Requirements with valid discu Use of the Moo Importance of age final grade	ghout the ser cations. The f ve guidance a o the group ir ns. ching Seminar nination The for the Attrik ussion dule Courses the Mark for	nester, they con irst half of the co nd feedback from n a series of scient student perform oution of Credit in Physics Major	duct an in-depth stourse is dedicated to m the instructor. In ntific presentations hs a talk of 45-90 m Points Active partic	udy of their top to independent in the second half These sessions in. plus discussions	ic following recent research, while , students present are followed by on within the researc

Introduction	to Nuclea	r and Particl	e Physics II		
	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Summer	1 Semester
 Courses a) Lecture Intr Particle Phy b) Exercises fo and Particle 	sics II r Introduction		Contact Hours a) 22 h b) 22 h	Self-Study 76 h	Group Size a) Unlimited b) 30
Requirements f Formal None Content Basic k Preparation No	nowledge of n				
Can studAre studStudent	ul completion n over view ov dents describe dents acquaint s have the kno	er the Standard the most impo ed with the exp owledge of the b	Model of Particle rtant phenomena perimental method pasic principles of d experiment clea	ds and technique detectors for su	es. batomic particles.
modern particle numbers. Detail vation in a histo for the develope discovery of the	physics. The c s of the strong rical context d ment of the fie Higgs boson c	course will expla g and weak inter liscussed. Impor eld are part of th or the observation	ain the connection raction will be pre rtant experimenta ne course includin	a between symm sented and their I discoveries and g important brea cillations. Also in	lay the foundations of netries and quantum r experimental obser- d their consequences akthroughs like the icluded is a look into pals.
Format of Teac	ning Lectures,	exercises and sl	hort presentations	s of the students	;
section at least	50% of all pose ng the semeste	sible points. Stu	dents are asked to	o present solutio	ses. In the homework ons to the problems at summary of the previ-
The students ne and participate ous lecture will	ed to obtain a actively in the be presented i	t least 50% of tl discussion of th in class. In addit	he possible points ne exercises. Also,	in the weekly p twice a short su I practical exerci	orm of examination: ractice assignments mmary of the previ- ses (F-Praktikum) are the grade of the
Use of the Mod	ule Courses in	Physics Major			
Importance of t	he Mark for tl	he Final Grade	Graded, contributi	on to the final n	nark weighed for CP
Module Superv	isor and Instru	Ictor Prof. Dr. V	Viedner		
Further Informa	ation				

		Credits	Workload	Semester	Cycle	Duration
		6 CP	180 h	from 1. Sem.	Summer	1 Semester
 Courses a) Lecture "Introduction to Lattice Field Theory" b) Exercises "Introduction to Lattice Field Theory" 		Contact Hours a) 44 h b) 22 h	Self-Study 114 h	Group Size a) Unlimited b) 30		
	-					
For Coi	quirements f mal None ntent None paration No	or Participat ne	ion			
Lea	rning Outco	mes				
	 have a application are awarithms know the are famosimulation can integration 	basic underst tion of the M are of the com ne theory of iliar with and ion data erpret statist	arkov chain Mor nmonly used dis renormalisation a alysis techniques	ttice regularization nte Carlo method cretisation of QCD and the elimination to determine had tic errors in lattice	, as well as mod n of leading cuto ron masses and	ld theory, as well as ern simulation algo- off effects matrix elements from ons associated with
Rev bos Chi Mo	ionic fields; t ral symmetr nte Carlo alg	he Fermion of y and associa gorithm for C	doubling problen ited Ward identif CD; Multigrid inv	n and its solutions; ties; Heatbath algo	the Symanzik ir prithm for pure g or the Dirac ope	tice regularisation of nprovement program auge theory; Hybrid rator; Autocorrela-
For	mat of Teac	hing Lecture	, exercises			
For				he course, the lect 5 min or project we		s the form of examina
tio	-			Points Depending on uccessful project w	•	form of examination:
Red						
Rec Pas	e of the Mod	l ule Courses	in Physics Major			
Rec Pas Use					not contribute t	o the weighted aver-

	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
c) Lecture Nuc	cleosynthesis	in Nuclear As-	c) 22 h	76 h	10
trophysics			d) 22 h		
d) Exercises fo	r Nucleosynt	thesis in Nuclear			
Astrophysic	S				
Requirements f	or Participat	tion			
Formal None					
	-	nuclear physics.			
Preparation No	ne				
Learning Outco	mes				
After a successf	ul completio	n of the module,	students are fami	liar with	
 the star 	ndard model	of cosmology			
 the evo 	lution of star	rs depending on tl	heir mass		
 the diff 	erent produc	ction mechanisms	of elementary pa	rticles in the dif	ferent mass ranges
 the feat 	ures of neut	rinos			
Contents					
The lecture will	start with ar	n introduction into	o nuclear physics t	to provide the b	asic knowledge
needed for the	rest of the le	cture. It will conti	inue with a descri	ption of the big	band and the big bar
nucleosynthesis	where the l	ightest elements a	are created. The r	next part of the l	ecture will describe
the fusion proce	esses in stars	and their evoluti	on which leads to	the creation of	more heavier ele-
-		-		-	nts via various differ-
	-		r merges. The last	part of the lectu	ure covers our recent
knowledge of n	eutrinos and	their features.			
Format of Teac	hing Lecture	, exercises			
Format of Exan	nination Pres	entation about a	topic selected at	the beginning of	the lecture
•			•		topic in a 25 – 30
minutes presen	tation and A	ctive participatior	n (>75 %) in the le	cture.	
Use of the Mod	ule Courses	in Physics Major			
Importance of tage final grade	he Mark for	the Final Grade	Graded, but does	not contribute to	o the weighted aver-
	isor and Inst	ructor Prof. Dr. F	Ritman, Dr. Stockn	nanns	
Further Informa	ation				

		Credits	Workload	Semester	Cycle	Duration
		2 CP	60 h	from 1. Sem.	Winter & Summer	1 Semester
Со	urses	•		Contact Hours	Self-Study	Group Size
a)	Seminar Sel Physics	lected Topics	of Hadron	a) 22 h	38 h	a) 30
Re	quirements f	for Participat	ion:			1
Fo	mal None					
					o are already familiar	with the basics
	•	•	ective field theo	ries and hadron ph	ysics.	
Pre	eparation No	ne				
Le:	rning Outco	mes				
	-		g the module, th	ne students		
			-		d questions in the fie	ld of theoretical
					ia questions in the he	
		physics.		dag a sate stift.		
	• nave ex	perience in p		ving a scientific pre		
Со	ntents					
Th	e event deals	with curren	t developments	in hadron physics.	External experts are i	ncreasingly
inv	ited to provi	de the broad	est possible ove	rview of the resear	rch topics. Lectures ar	e accompa-
nie	d by intensiv	ve technical d	liscussions and o	offer the opportunit	ty to exchange ideas	with the
	•			••	adron Physics also tal	
•	ent.				,	
			nd doctoral cano	didates have the op	portunity to present	their latest re-
sul	ts and receiv	e feedback.				
Fo	mat of Teac	hing Seminai	r			
Fo	mat of Exan	nination Pres	entation			
Re	quirements f	for the Attrib	oution of Credit	Points Active partic	cipation in the sessior	ns, presentation
	e of the Mod	lule Courses	in Physics Major			
Us		he Mark for	the Final Grade	Graded, contribut	ion to the final mark	weighed for CP
	portance of t					
Im				Epelbaum, PD Dr.	Krebs	

	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Seminar o	n Hadron Phy	sics	a) 22 h	38 h	a) 30
Requirements	for Participa	tion			
Formal None					
Content None					
Preparation N	one				
Learning Outc	omes				
After successfu	ul completion	of the module t	he students are		
		•	cts in the field of Ha	•	
		•	t detector technolog	•	
 know t 	the basic cond	cepts of detector	r readout concepts a	and data process	sing
		-	· · · ·	•	0
			performing data ana	lysis	-
			performing data ana rical important expe	lysis	-
			•	lysis	-
• got an Contents	insight in a se	election of histor	•	lysis riments and find	dings
 got an Contents Selected topics Acquisition and 	insight in a se s in the field c d Detector Co	election of histor of Hadron Physic ontrol System, Ar	rical important expe	lysis riments and find ues, Detector Co	dings omponents, Data
 got an Contents Selected topics Acquisition and	insight in a se s in the field c d Detector Co	election of histor of Hadron Physic ontrol System, Ar	rical important expe	lysis riments and find ues, Detector Co	dings omponents, Data
 got an Contents Selected topics Acquisition and historical import 	insight in a se s in the field c d Detector Co ortant Physics	election of histor of Hadron Physic Introl System, Ar topics	rical important expe	lysis riments and find ues, Detector Co	dings omponents, Data
 got an Contents Selected topics 	insight in a se s in the field c d Detector Co ortant Physics ching Semina	election of histor of Hadron Physic Introl System, Ar topics	rical important expe	lysis riments and find ues, Detector Co	dings omponents, Data
got an Contents Selected topics Acquisition and historical impo Format of Tea Format of Example	insight in a se s in the field c d Detector Co ortant Physics ching Semina mination non	election of histor of Hadron Physic ontrol System, Ar topics r e	rical important expe	lysis riments and find ues, Detector Co a Analysis, Data	dings omponents, Data Interpretation,
got an Contents Selected topics Acquisition and historical impo Format of Tea Format of Example Requirements	insight in a se s in the field c d Detector Co ortant Physics ching Semina mination non for the Attrik	election of histor of Hadron Physic ontrol System, Ar topics r e pution of Credit	rical important expe s: Detector Techniqu nalysis methods, Dat	lysis riments and find ues, Detector Co a Analysis, Data	dings omponents, Data Interpretation, 75% of the contact
 got an Contents Selected topics Acquisition and historical impo Format of Tea Format of Example Requirements hours necessar 	insight in a se s in the field c d Detector Co ortant Physics ching Semina mination non for the Attrik ry, preparatio	election of histor of Hadron Physic ontrol System, Ar topics r e pution of Credit	rical important expensions: Detector Techniques: De	lysis riments and find ues, Detector Co a Analysis, Data	dings omponents, Data Interpretation, 75% of the contact
 got an Contents Selected topics Acquisition and historical imposition Format of Tea Format of Example Requirements hours necessand Use of the Mo 	insight in a se s in the field c d Detector Co ortant Physics ching Semina mination non for the Attrik ry, preparatio dule Courses	election of histor of Hadron Physic ontrol System, Ar topics r e bution of Credit n and giving of c in Physics Major	rical important expensions: Detector Techniques: De	lysis riments and find ues, Detector Co a Analysis, Data ndance, at least nly the Presenta	dings omponents, Data Interpretation, 75% of the contact tion is graded.
got an Contents Selected topics Acquisition and historical impo Format of Tea Format of Exam Requirements hours necessan Use of the Mo Importance of	insight in a se s in the field of d Detector Co ortant Physics ching Semina mination non for the Attrik ry, preparatio dule Courses the Mark for	election of histor of Hadron Physic ontrol System, Ar topics r e bution of Credit n and giving of c in Physics Major	rical important expensions: Detector Techniques: De	lysis riments and find ues, Detector Co a Analysis, Data ndance, at least nly the Presenta	dings omponents, Data Interpretation, 75% of the contact tion is graded.

Plasma Phy					1
Modul 4e	Credits 15-25 CP	Workload 450-750 h	Semester 12. Sem.	Cycle Winter & Summer	Duration 2 Semesters
Courses a) Lecture b) Exercises c) Seminar (at d) Advanced L (at least 5 C A complete ov found in the cu CP of the indiv semester hour mester week =	aboratory Cou P) erview of the o urrent course o idual courses r s per week (11	courses can be atalogue. The result from the	Contact Hours Each at least. a) 44 h b) 44 h c) 22 h d) 35 h	Self-Study min. 309 h	Group Size a) unlimited b) 30 c) 30 d) 2
Requirements Formal None Content Basic Preparation N	knowledge of	on plasma physics v	will be expected		
 are far have a scales can ap know a surface 	deepened und of time and sp ply methods o different fields es of fusion ex	ortant diagnosti derstanding of tl ace f measurement of application o periments	of plasma f plasma, like inter	na epts to describe plasm action with biological	systems or with
-	•			on, plasma etching; wa	• •
	_		nar, Laboratory Wo	rk	
		examination of			
module must i module exami	nclude: advand nation (2 CP), 2	ced laboratory c	ourses (5 CP), a ser achieved. Achiever	oral examination. The ninar (2 CP). Including ments made after the	the final oral
Use of the Mo	dule Compulso	ory-Elective Mod	dule		
Importance of	the Mark for	the Final Grade	Weighted accordin	g to Credit Points	
Module Super					
den, Prof. Dr. v	von Keudell, Pr nation For advi	of. Dr. Tjus, PD I ce and coordina	Dr. Fichtner	Prof. Dr. Innocenti, Pr , please contact the n	

Course	Туре	No.	Semester
Advanced Laboratory Course for Physics Students	Laboratory	160250	Winter
	Laboratory	100230	Summer
Applied Plasma Physics	Seminar	160522	Winter
	Seminar	160523	Summer
Chaos, Turbulence and Stochastic Systems	Lecture	160532	Summer
	Exercises	160533	Junner
Compact Course: "Low Temperature Plasma Physics: Basis and Applications" and Master Class "Low Temper- ature Plasma Physics"	Compact Seminar	160523	Winter
Confinement Concepts and Advanced Materials for Ex- treme Environments	Lecture	160511	Winter
Ion Transport and Fluxes in Low-Temperature Plasmas	Lecture	160531	Summer not in 25
International School on Low Temperature Plasma	Compact	160520	Summer
Physics: Basics and Applications	Seminar	100320	not in 25
Introduction to Hydrodynamics	Lecture	160529	Summer
	Exercises	160530	not in 25
ntroduction to Nuclear Fusion – Plasma-Wall-Interac- tions and Plasma Edge Physics	Lecture	160513	Summer
Introduction to Diacma Dhucias II	Lecture	160501	Winter
Introduction to Plasma Physics II	Exercises	160502	winter
Introduction to Space Physics	Lecture	160618	Winter
	Exercises	160619	winter
Local and Non-local Effects in Plasma Heating and	Seminar	160518	Winter
Transport	Seminar	100318	winter
Magnetohydrodynamic Turbulence and Reconnection	Lecture	160664	Summer not in 25
Modelling of Atomic Populations in the Spectroscopy of	Lecture	160515	Winter
Laboratory and Astrophysical Plasmas	Exercises	160516	winter
Modelling of Atomic Populations in the Spectroscopy of	Lecture	160511	Summor
Laboratory and Astrophysical Plasmas II	Exercises	160512	- Summer
Plasma Chomistry	Lecture	160519	Winter
Plasma Chemistry	Exercises	160520	willer
Plasma Diagnostics	Lecture	160505	Summer
	Exercises	160506	not in 25
Plasma Kinetics for Experimentalists	Seminar	160526	Winter
Problems of Modern Plasma Physics	Seminar	160521	Winter
	Seminal	160522	Summer
Selected Topics of Plasma Theory	Seminar	160517	Winter
Selected Topics of Theoretical Plasma Physics	Seminar	160557	Summer
Seminar on Space Plasma Physics	Seminar	160558	Summer
Surface Physics and Chemistry	Lecture	160510	Summer
Turbulence and Transport in Fusion Plasmas	Lecture	160510	Winter
	Lecture	160527	Cummer
Space Plasma Physics	Exercises	160528	Summer

	Credit	s Workload	Semester	Cycle	Duration
	2 CP	60 h	from 1. Sem.	Summer	1 Semester
				(not in 25)	
Cours	es		Contact Hours	Self-Study	Group Size
	cture Ion transpo mperature plasm	rt and fluxes in low- as	a) 22 h	38 h	a) Unlimited
₹equi	rements for Parti	cipation	L	1	1
-	al None	•			
Conte	nt Basic knowledg	ge of the concepts ar	nd terminology of th	e Plasma physic	s are expected, e.g.
throug	gh participation in	the Module "Introd	uction to Plasma Ph	ysics".	
Prepa	ration Participatio	on in the lecture "Int	roduction to Plasma	Physics II" is rea	commended, but is
not m	andatory.				
Learni	ing outcomes				
	-	tion of the module			
•	•	ve a fundamental ur	derstanding of the i	on production.	their collisional pro-
		on transport in non-	-	•	•
		se processes on the	•	• •	
•		•	•	-	evels of collisionality
•		ow the fundamental	•		
•			•	•	e ion parameters of a
	plasma.				
•	•	e able to recognize t	he relations betwee	n the discharge	conditions (pressure
) and plasma param		-	
		for the estimation o			
	C				
Conte					
1.		and loss processes			
2.		rocesses with charge		cles	
	lon transport in	space charge sheath	าร		
3.		-			
3. 4.	1.4. (1.4	•			
		nd wave phenomena	in plasmas		
4.		•	in plasmas		
4. 5. 6.		nd wave phenomena agnostic methods	in plasmas		
4. 5. 6. Forma	Experimental di at of Teaching Lec	nd wave phenomena agnostic methods	·	topics with a focus of	on one or two of these
4. 5. 6. Forma	Experimental di at of Teaching Lec	nd wave phenomena agnostic methods ture	·	topics with a focus o	on one or two of these
4. 5. 6. Forma Forma topics.	Experimental di at of Teaching Lec at of Examination	nd wave phenomena agnostic methods ture	ithin 45 min ongiven	·	
4. 5. 6. Forma topics. Requi	Experimental di at of Teaching Lec at of Examination rements for the A	nd wave phenomena agnostic methods ture Oral examination wi	ithin 45 min ongiven edit Points Passing t	·	
4. 5. 6. Forma topics. Requi Use of	Experimental di at of Teaching Lec at of Examination rements for the A f the Module Cou	nd wave phenomena agnostic methods ture Oral examination wi	ithin 45 min ongiven edit Points Passing t	he oral examina	tion
4. 5. 6. Forma topics. Requi Use of Impor age fir	Experimental di at of Teaching Lec at of Examination rements for the A f the Module Cou tance of the Mar hal grade	nd wave phenomena agnostic methods ture Oral examination wi ttribution of the Cre rses in Physics Major	ithin 45 min ongiven edit Points Passing t Graded, but does n	he oral examina	tion

Introductio		1 -	Comparter	Cuala	
	Credits	Workload	Semester	Cycle	Duration
	5 CP	120 h	from 1. Sem.	Winter	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Intro	oduction to Pl	lasma Physics II	a) 22 h	76 h	a) unlimited
b) Exercises for	⁻ Introduction	i to Plasma	b) 22 h		b) 30
Physics II					
Requirements	for Participat	ion			
Formal None	-				
Content None					
-	-			. through the le	cture "Introduction to
Plasma Physics	I" desirable b	out not mandator	у.		
Learning Outco	omes				
After successf	ul completior	n of the module			
1. student	s have a basi	c understanding of	of the essential ch	aracteristics of	a low-temperature
plasma					
		-	and ignition pheno	•	
3. studen	ts can assess t	the main fields of	f applications of lo	ow-temperature	plasmas
Contents					
1. Introdu	ction: Overvie	ew of low-pressu	re plasmas, plasm	as and their sur	face layers, plasma
		nical description			
			varm experiments	s, ignition of a pl	asma volume vs.
		, ignition phenom	•		
	-	-		ng, Wave Heatir	ng, Global Model for
	-	Electronegative P		_	
•			lagnetron, HPPMS		
			a, DBD, microplas	smas	
Format of Teac	-				
		0 0			s the form of examina-
tion (oral exam	ination of 30	minutes or active	e participation in t	he exercises) fo	r the lecture.
Requirements	for the Attrib	ution of Credit P	oints Depending o	on the specified	form of examination:
Passing the exa	m/oral exam	or obtaining at le	east 50% of the po	ssible points in	the weekly exercises.
In addition, in t	his case, activ	e participation ir	n the exercise is m	andatory. The f	orm of examination
will be determi	ned at the be	ginning of the co	urse.		
Use of the Moo	lule Courses i	in Physics Major			
Importance of	the Mark for	the Final Grade	Graded, contribut	ion to the final r	nark weighed for CP
Module Superv	visor and Inst	ructor Prof. Dr. k	Keudell		
Further Inform	ation				
untiler morm	auvii				

	Credits 4 CP	Workload 120 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses a) Lecture Loc Plasma Hea		ocal Effects in	Contact Hours a) 44 h	Self-Study 76 h	Group Size a) unlimited
Requirements Formal None Content Introc Preparation N	luction to Plas				
 have be av know be fa be ab 	ful completion a basic under vare of possib the basic con miliar with the le to recogniz	ilities related to acepts of the state e respective phy	tic and statistical m non-local and reso tistical description sical concepts and etween temporal a	nant effects of plasmas the mathematic	al methods
common fluid in detail but a Fokker-Planck and are then a local and non- der charge exc introduced. Th	picture. In the strong focus v equation and pplied to deso ocal electron hange collisio e theoretical	e course, the star vill be on alterna the Langevin eq cribe basic plasm heating in ICPs a ns. Mathematica	tive statistical conc uation. The concep a phenomena. The and the INCA discha	by the Boltzman cepts like the ma ots are derived fr ese include, elect arge and non-loc as physical pictu	n equation is revisited aster equation, the rom first principles tron Landau damping cal ion transport un- ures and concepts are
Format of Tea	•				
Format of Exa	mination Oral	examination of	30 minutes		
Requirements	for the Attrib	oution of Credit	Points Successful p	assing of the ora	al examination
Use of the Mo	dule Courses	in Physics Major			
Importance of	the Mark for	the Final Grade	Graded, contribut	ion to the final n	nark weighed for CP
Module Super	visor and Inst	ructor Prof. Dr.	Czarnetzki		
-					

Magnetohy	/drodynam	nic Turbulenco	e and Reconne	ection	
	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Summer (not in 25)	Duration 1 Semester
Courses a) Lecture Ma lence and F	gnetohydrody Reconnection	ynamic Turbu-	Contact Hours a) 22 h	Self-Study 38 h	Group Size a) unlimited
Requirements Formal None Content None Preparation N		tion		<u> </u>	
 have 	ful completion a basic under		students will turbulence and re d magnetic reconr		
Taylor, tearing Esässer variab tropic turbuler pology change	t,) are discu le,). This is f nce,) and in as well as 2D	ssed. Subsequen followed by the s termittency. Base and 3D reconnee	tly, the MHD turbu pectral properties ed on this, magnet ction are described	lence is introdu (cascades, home ic reconnection J. Current layers	Helmholtz, Rayleigh- ced (Reynolds MHD, ogeneous and aniso- is introduced. The to- , SweetParker and ection is discussed.
Format of Tea	ching Lecture				
			he course, the lect ework) for the lect		the form of examina-
•			Points Achievemen	nt of at least 50 %	6 of the possible
•		ork assignments in Physics Major			
		the Final Grade	Graded, contribut	ion to the final n	nark weighed for CP
Importance of	the Mark for	the Final Grade		ion to the final n	nark weighed for CP

	Credits 4 CP	Workload 120 h	Semester from 1. Sem.	Cycle Summer	Duration 1 Semester
Astrophysica b) Exercises for lations in the	oscopy of Lab I Plasmas II Modelling of	ooratory and Atomic Popu- oy of Laboratory	Contact Hours a) 22 h b) 22 h	Self-Study 76 h	Group Size a) unlimited b) 30
Requirements f Formal None Content None Preparation No	·	ion			
 laborate are awa and plate are fam importa are fam FLYCHK ics.nist. can reconstruction 	ory and astro are of the pos sma physics. iliar with the ant interrelati iliar with mod (https://nlte gov/PhysRef[physical plasmas sibilities of apply basic concepts o onships of plasm dern methods of .nist.gov/FLY/) or Data/ASD/lines_f ctions between a	Fing numerical met f the Stroß radiation a spectroscopy. plasma spectrosco r atomic and spect form.html)	hods in other ar on models and d opy as well as on roscopic databas	-line tools like
topics of atomic portant atomic portant process are taken from partly supporte AUTOSTRUC-TU	c physics are of processes. Pr ses are dealt w fusion and lal d by practical IRE, so that th	explained, which evious knowledg with, which repre- poratory experim exercises using the listeners become	esent the foundation nents and from ast freely available ato	the understandi nechanics is dee on of plasma spe rophysics. The k omic codes such ne current status	
Format of Teac	hing Lecture,	Exercises			
Format of Exam	nination Oral	examination of 4	15 minutes		
Passing the oral	examination se, active part	or obtaining at l ticipation in the e	east 50% of the po	ssible points in t	orm of examination the weekly exercise rm of examination is
determined at t	ine beginning				

Further Information

	Credits	Workload	Semester from 1. Sem.	Cycle Winter	Duration
	3 CP	90 h			1 Semester
Courses	Plasma Chemist	n /	Contact Hours a) 22 h	Self-Study 57 h	Group Size a) Unlimited
-	s for Plasma Che	•	b) 11 h	5711	b) 30
Formal None Content Intr	oduction to Pla	t ion sma Physics I + II Plasma Physics I	+ 11		
 stud plass are a mate stud in pl are f tran stud 	sfully completio lents have a bas ma chemistry aware of the po erial processing lents know the k asma environm familiar with the sport processes lents are able to	ic understanding ssibilities plasma pasic concepts of ents e mathematical d recognize conne		or surface modi inetics, and rea models for pla sma chemistry a	fications and ction mechanisms
Contents This course p		sma and chemica	al processes. Topics	include thermo	
diffusion, su course, stud	rface reactions,	e to understand a	r of ions in plasma e and apply these con		y the end of this dy and manipulatior
diffusion, su course, stud of plasma-ch	rface reactions, ents will be able	e to understand a			•
diffusion, su course, stud of plasma-ch Format of To Format of Ex tion (written	rface reactions, ents will be able nemical systems eaching Lecture camination At t	e to understand a , Exercises he beginning of t n, oral exam of 30	and apply these con	cepts to the stu rer determines	dy and manipulation
diffusion, su course, stud of plasma-ch Format of Te tion (written and active p Requiremen Passing the v	rface reactions, ents will be able nemical systems eaching Lecture kamination At t exam of 90 min articipation in th its for the Attrik written exam, th	e to understand a , Exercises he beginning of t h, oral exam of 30 he exercises). Dution of Credit I he oral exam or o	he course, the lectu 0 min or in the form Points Depending o bbtaining at least 50	rer determines of exercises wi the specified f % of the possibl	dy and manipulation the form of examina th weekly homework orm of examination e points in the
diffusion, su course, stud of plasma-ch Format of Te format of Ex tion (written and active p Requiremen Passing the weekly exerc form of exar	rface reactions, ents will be able nemical systems eaching Lecture kamination At t n exam of 90 min articipation in the sta for the Attrik written exam, the cises. In this cas mination will be	e to understand a , Exercises he beginning of t n, oral exam of 30 he exercises). Dution of Credit I he oral exam or o e, active particip determined at th	he course, the lectu o min or in the form Points Depending o obtaining at least 50 ation (> 75 %) in the ne beginning of the	cepts to the stu arer determines a of exercises wi n the specified f % of the possibl e exercises is als	dy and manipulation the form of examina th weekly homework orm of examination e points in the
diffusion, su course, stud of plasma-ch Format of Te Format of Ex tion (written and active p Requiremen Passing the weekly exerce form of exar Use of the N	rface reactions, ents will be able nemical systems eaching Lecture kamination At t n exam of 90 min articipation in the sta for the Attrik written exam, the cises. In this cas mination will be Module Courses	e to understand a , Exercises he beginning of t n, oral exam of 30 he exercises). Dution of Credit I he oral exam or o e, active particip determined at th in Physics Major	he course, the lectu o min or in the form Points Depending o obtaining at least 50 ation (> 75 %) in the ne beginning of the	cepts to the stu arer determines a of exercises wi n the specified f % of the possibl e exercises is als course.	dy and manipulation the form of examina th weekly homewor orm of examination e points in the o mandatory. The
diffusion, su course, stud of plasma-ch Format of Te format of Ex tion (written and active p Requiremen Passing the weekly exerce form of exar Use of the N	rface reactions, ents will be able nemical systems eaching Lecture xamination At t n exam of 90 min articipation in th the for the Attrik written exam, th cises. In this cas mination will be Module Courses of the Mark for	e to understand a , Exercises he beginning of t n, oral exam of 30 he exercises). Dution of Credit I he oral exam or o e, active particip determined at th in Physics Major	he course, the lectu o min or in the form Points Depending o obtaining at least 50 ation (> 75 %) in the ne beginning of the	cepts to the stu arer determines a of exercises wi n the specified f % of the possibl e exercises is als course.	dy and manipulation the form of examina th weekly homewor orm of examination e points in the

	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 1. Sem.	Summer (not in 25)	1 Semester
Courses			Contact Hours	Self-Study	Group Size
a) Lecture Plas	-		a) 22 h	76 h	a) 30
b) Exercises for	Plasma Diag	nostics	b) 22 h		
Requirements f Formal None Content None Preparation No		ion			
Learning Outco					
-		e module, the st	udents		
	•••	ortant diagnostic			
	•	-	e of a diagnostical r	nethod for the r	neasurement of
	parameters				
Contents					
	oducos tho fi	undomontals of a	optical plasma diagr	postics. The osce	ntial placma and
					on of measurement
	•		om a probe measure	•	
	-	-	can be directly and i	-	
•	•		ssed, and the respec	•	
					ing the experimenta
			•	•	evices. Finally, in ad-
dition to the op	tical method	s, energy-resolve	ed mass spectrosco	py for the detect	tion of atoms, mole-
cules and ions is	s also dealt w	/ith.			
	hing Locture				
Format of Teac		Exercises			
Format of Exan	nination Deliv	very of a coursev	vork The coursewor	rk can take the f	orm of a written test
Format of Teac Format of Exan or an interview	nination Deliv	very of a coursev	vork The coursewor	rk can take the f	orm of a written test
Format of Exan or an interview	nination Deliv with the lect for the Attrib	very of a coursev urer.			orm of a written test at least 50% of the
Format of Exan or an interview Requirements f achievable poin	nination Deliv with the lect for the Attrib	very of a coursev urer.	Points Passing the e		
Format of Exan or an interview Requirements f achievable poin Use of the Mod	nination Deliv with the lect for the Attrib its. lule Courses	very of a coursev urer. Dution of Credit F in Physics Major	Points Passing the e	xamination with	at least 50% of the
Format of Exan or an interview Requirements f achievable poin Use of the Mod Importance of f	nination Deliv with the lect for the Attrib its. lule Courses the Mark for	very of a coursev urer. Dution of Credit F in Physics Major	Points Passing the e Graded, contributio	xamination with	at least 50% of the

	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Summer	Duration 1 Semester
Courses	2.01	0011	Contact Hours	Self-Study	Group Size
a) Seminar on Space Plasma Physics		a) 22 h	38 h	a) unlimited	
Requirements	for Participat	tion			
Formal None	edge of theo	retical mechanic	s and electrodynam	nics	
Preparation No	-			iles	
Learning Outco	moc				
-		e module, the st	tudents will		
			na physics models re	elevant to space	applications
		÷ .	nes of space plasma	•	• •
			iolar system plasma		
 have gate 	ained insight	into key process	ses such as waves ar	nd instabilities	
• be fam	iliar with som	ne theoretical co	oncepts		
 know f 	undamental i	methods in num	erical space plasma	simulation	
Contents					
	eview of the	description of m	agnetized plasmas		
		a phenomena in			
• Formu	ation of theo	oretical models for	or these phenomena	а	
 Fundar 	mentals of nu	merical simulati	on of space plasma		
Overvi	ew over obse	rvational metho	ds and technology		
Format of Tead	hing Semina	r			
Format of Exar	mination Pres	sentation			
Requirements	for the Attrik	oution of Credit	Points Criteria to ob	otain CPs are:	
i) reg			in the seminar, and		
·/ · · · · ·	seeceful prop	aration and pres	entation of a 45 mir	nute talk on a sel	lected topic
	cessiul prepa				
ii) suo		in Physics Major			
ii) sud Use of the Moo	dule Courses	, ,	Graded, contributio	on to the final m	ark weighed for CP
ii) sud Use of the Moo Importance of	dule Courses	the Final Grade			ark weighed for CP

Turbulence	and Trans	port in Fusio	n Plasmas		
	Credits 4 CP	Workload 120 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses a) Lecture Turbulence and Transport in Fusion Plasmas		Contact Hours b) 22 h	Self-Study 38 h	Group Size b) Unlimited	
Requirements f Formal None Content None Preparation Pre	·		ohysics is useful		
have a lbe ablebe fami	lly passing the ne basics of g basic underst to program a liar with impo pplication skill	yrokinetics anding of linear I simple simulat prtant plasma ir	, quasilinear and no	rations	-
Contents Linear and non- resulting heat a	• •			ce in magnetica	lly confined plasmas,
Format of Teac	hing Lecture	and project sem	iinar		
groups (2-3 per tion quality. If d	sons), 15-20 i lesired, indivi	minutes present dual grades fror	•	sessment of con examination can	itent and presenta- be assessed at 50%.
•			Points Passing the e k and presentation.	examination. Act	ive participation
Use of the Mod	l ule Courses i	n Physics Major			
Importance of	the Mark for	the Final Grade	Graded, contributio	on to the final m	nark weighed for CP
Module Superv	isor and Inst	ructor Dr. Pues	chel		
Further Informa	ation Module	is taught in Eng	glish		

Module 5: Elective Modules from the Catalogue for Minor Subjects

Modules amounting to 5-18 CP can be brought in from the range of other faculties and their subjects. However, should you plan to **write the Master's thesis in the minor subject**, 15 CP must be taken in the minor subject in which the thesis is written.

Minor Subject:	Modules	Semester	Language
Inorganic Chemistry	Methods of Structure Analysis II	Summer	English
(Anorganische Chemie)	(Methoden der Strukturanalyse II)	(not in 25)	English
	Inorganic Chemistry II (Anorganische Chemie II)	Summer	German
	Block Courses Inorganic Chemistry (Anorganisch-Chemisches Grundpraktikum)	Summer	German
Biochemistry (Biochemie)	Biochemical Practical Course for Chemists (Biochemisches Praktikum für Chemiker/-innen)	Winter	German
	Introduction to Biochemistry (Einführung in die Biochemie)	Summer	German
	Biochemistry I (Biochemie I)	Winter	German
Physical Chemistry (Physikalische Chemie)	Compact Course: "Lasers and Optics" (Blockkurs: "Laser und Optik")	Winter	English
	Compact Course: "Scanning Probe Microscopy" (Blockkurs: "Rastersondenmikroskopie")	Winter	English
	Biophysical Chemistry I (Biophysikalische Chemie I)	Summer	English
	Biophysical Chemistry II (Biophysikalische Chemie II)	Winter	English
	Physical-Chemical Laboratory (Physikalisch-Chemisches Grundpraktikum)	Summer	German
	Physical Chemistry II (Physikalische Chemie II)	Summer	German
	Concepts of Spectroscopy and Introduction in Laser Spectroscopy (Konzepte der Spektroskopie und Einführung in die Laserspektroskopie)	Winter	English
	Concepts of Spectroscopy II (Konzepte der Spektroskopie II)	Summer	English
Industrial Chemistry (Technische Chemie)	Industrial Chemistry I (Technische Chemie I)	Winter	German
	Industrial Chemistry II (Technische Chemie II)	Winter	English
	Industrial-Chemical Laboratory (Technisch-Chemisches Praktikum)	Summer	German
Theoretical Chemistry (Theoretische Chemie)	Theoretical Chemistry I (Theoretische Chemie I)	Winter	German
	Theoretical Chemistry II (Theoretische Chemie II)	Winter	English
	Electronic and Molecular Structure Theory (Theoretical Chemistry III)	Summer	English
	Theoretical-Chemical Laboratory (Theoretisch-Chemisches Praktikum)	Summer	German

From the range of courses offered by the Faculty of **Chemistry and Biochemistry (Chemie und Biochemie)**:

From the range of courses from the Faculty of **Geosciences (Geowissenschaften)**:

Minor Subject:	Modules	Semester	Language
Geophysics*(Geophysik)	Reservoir Geophysics (Reservoirgeophysik)	Summer	English
	Rock Physics (Gesteinsphysik)	Summer	English
	Geophysical Practical (Geophysikalisches Praktikum)	Winter/	English
		Summer	21.8.011
	Seismologic Data Analysis	Summer	English
	(Seismologische Datenanalyse)	Summer	211811011
	Seismic Waves: Theory and Numerical Modelling		
	(Seismische Wellen: Theorie und numerische Mod-	Summer	English
	ellierung)		
	Geophysical Inverse Problems	Winter	English
	(Geophysikalische inverse Probleme)	white	Linglish
	Seismic and Electromagnetic Field Methods	Winter	Englich
	(Seismische und elektromagnetische Feldmethoden)	white	English
	Physics of Earth Materials (Physik der Erdmaterial-	Winter	English
	ien)	vviitei	LIIGIISII
	Earthquake Seismology and the Seismic Cycle	Winter	English
	(Erdbebenseismology und der Erdbebenkreislauf)	white	

*we recommend an in-person interview with the student counsellor of geophysics (Dr. Maria Kirchenbaur (Studienkoordination-gmg@ruhr-uni-bochum.de), before taking this minor subject!

From the range of courses from the Faculty of **Electrical Engineering and Information Technology** (Elektrotechnik und Informationstechnik):

Minor Subject:	Modules	Semester	Language
Plasmatechnology* (Plasmatechnik)	Plasmatechnology I (Plasmatechnik I)	Winter	German
	Fields, Waves and Particles (Felder, Wellen und Partikel)	Winter	German
Nanoelektronics** (Nanoelektronik)	Solid State Electronics (Festkörperelektronik)	Winter	German
	Nanoelektronics (Nanoelektronik)	Summer (not in 25)	German
Microelektronics (Mikroelektronik)	VLSI-Design (VLSI-Entwurf)	Winter	German
	Integrated Digital Circuits (Integrierte Digitalschaltungen)	Winter	German
Technology of Energy Systems (Energiesystemtechnik)	Introduction to Technology of Energy Systems (Einführung in die Energiesystemtechnik)	Winter	German
	Technology of Regenerative Electric Energy (Regenerative Elektrische Energietechnik)	Winter	German
Communication Technology (Kommunikationstechnik)	Systems of High Frequency Technology (Systeme der Hochfrequenztechnik)	Summer	German
	Digital Processing of Signals (Digitale Signalverarbeitung)	Winter	German
Medical Technology (Medizintechnik)	Ultrasound in Medicine (Ultraschall in der Medizin)	Winter	German
	Tomographical Imaging in Medicine (Tomographische Abbildungsverfahren in der Medizin)	Summer	German
	Image Processing in Medicine (Bildverarbeitung in der Medizin)	Summer	German

* ONLY if the specialisation in physics is NOT in plasma physics

** ONLY if the specialisation in physics is NOT in solid state physics

From the range of courses from the Faculty of **Mechanical Engineering (Maschinenbau)**:

Minor Subject:	Modules	Semester	Language
Laser Application Technology* (Laseranwendungstechniken)	Laser Technology (Lasertechik)	Summer	German
	Laser Metrology (Lasermesstechnik)	Winter	German
	Laser Materials Processing (Laserfertigungstechik)	Summer	German
	Laser Medical Technology (Lasermediz- intechik)	Winter	German
Energy Systems and Energy Econo- mics (Energiesysteme und -wirt- schaft)	Energy Economics (Energiewirtschaft)	Summer	German
	Energy Conversion Systems (Energieumwandlungssysteme)	Winter	German
	Renewable Energy Systems (Erneuerbar Energiesysteme)	Winter	English
	Demand and Supply in Energy Markets (Angebot und Nachfrage in Energiemärkten)	Summer	English
	Energy Consumption and Life Cycle Assess- ment (Energieaufwendung und Ökobilanzie- rung)	Summer	German
	Nuclear Power Plants Engineering (Kernkraftwerkstechnik)	Winter	German
	Reactor Physics (Reaktortheorie)	Summer	German
Material Sciences (Werkstoffwissenschaften)	Materials – Fundamentals (Werkstoffe – Grundlagen)	Winter	German
	Material Science (Werkstoffwissenschaft)	Summer	German
	Polymers & Shape Memory Alloys (Polymere Werkstoffe und Formgedächnisle- gierungen)	Summer	German
	Light Metals and Composites Materials (Leichtmetalle und Verbundwerkstoffe)	Summer	German
	Electron Microscope and X-Ray Diffraction (Elektronenmikroskopie und Rönt- genbeugung)	Summer	German

*All examinations are oral Examinations. A personal registration is required

From the range of courses from the Faculty of Mathematics (Mathematik):

Minor Subject:	Modules	Semester	Language
Algebra (Algebra)	Algebra I (Algebra I)	Winter	German
	Algebra II (Algebra II)	Summer	German
	Number Theory (Zahlentheorie)	Summer	German
	Representation Theory	Summer/	Cormon
	(Darstellungstheorie)	Winter	German
Geometry/Topology (Geometrie/Topologie)	Curves and Surfaces (Kurven und Flächen)	Summer	German
	Differential Geometry I (Differentialgeometrie I)	Winter	German
	Differential Geometry II (Differentialgeometrie II)	Summer	German
	Differential Topology (Differentialtopologie)	Summer (not in 25)	German
	Topology (Topologie)	Summer	German
	Algebraic Topology (Algebraische Topologie)	Irregularly	German
Analysis (Analysis)	Functional Analysis (Funktionalanalysis)	Summer	German
	Complex Analysis I (Funktionstheorie I)	Summer	German
	Complex Analysis II (Funktionsthoerie II)	Winter	German
	Ordinary Differential Equations	Winter	German
	(Gewöhnliche Differentialgleichungen)	vviiitei	German
	Partial Differential Equations	Summer	German
	(Partielle Differentialgleichungen)	(not in 25)	
Numerical Mathematics	Numerics of Ordinary Differential Equations	Winter	German German
(Numerische Mathematik)	(Numerik gewöhnlicher DGLen)		
	Numerics of Partial Differential Equations (Numerik partieller DGLen)	Summer	
	Optimisation (Optimierung)	Irregularly	German
Probability Theory and		Inegulariy	German
Statistics	Probability Theory I		
(Wahrscheinlichkeitsthe-	(Wahrscheinlichkeitsthoerie I)	Winter	German
orie und Statistik)			
	Probability Theory II (Wahrscheinlichkeitstheorie II)	Irregularly	German
	Statistics I (Statistik I)	Summer	German
	Statistics II (Statistik II)	Irregularly	German
	Mathematical Physics (Mathematische Physik)	Irregularly	German
	Introduction to Financial and Acturial Mathematics		
	(Grundlagen der Finanz- und Versicherungsmathe-	Summer	German
	matik)		
	Number Series (Zeitreihen)	Summer	German
		(not in 25)	German
Computer Science	Efficient Algorithms (Effiziente Algorithmen)	Summer	German
(Informatik)			

From the range of courses from the Faculty of **Computer Science (Informatik)**:

Minor Subject:	Modules	Semester	Language
Computer Science (Informatik)	Complexity Theory (Komplexitätstheorie)	Irregularly	English
	Cryptography (Kryptographie)	Winter	German
	Computer Science II (Informatik II)	Summer	German
	Quantum Algorithms (Quantenalgorithmen)		
	Cryptanalysis (Kryptanalyse)	Summer (not in 25)	German
	Theory of Machine Learning (Theorie des maschinellen Lernens)	Summer	German
	Algorithmic Geometry (Geometrische Algorithmen)	Irregularly	German
	Cryptographic Protocols (Kryptographische Protokolle)	Summer	English
	Deep Learning	Winter	German
NEW from 01.10.24: not creditable (nicht anrechenbar)	Theoretical Computer Science (Theoretische Informatik – Informatik 3)	Winter	German
Computational Neurosci- ence (Neuroinformatik)	Computational Neuroscience: Neural Dynamics (Computergestützte Neurowissenschaft: Neurale Dy- namik)	Winter	English
	Computational Neuroscience: Vision and Memory (Computergestützte Neurowissenschaft: Vision und Gedächnis)	Summer	English
	Machine Learning: Unsupervised Methods (Maschinelles Lernen: Unüberwachte Methoden)	Winter	English
	Machine Learning: Supervised Methods (Maschinelles Lernen: Überwachte Methoden)	Summer (not in 25)	English
	Machine Learning: Evolutionary Algorithms (Maschinelles Lernen: Evolutionäre Algorithmen)	Winter	English
	Introduction to Perception (Einführung in die Wahrnehmung)	Irregularly	English
	The Neural Basis of Vision (seminar) (Die neuronalen Grundlagen des Sehens)	Irregularly	English
	Computational Cognitive Modeling (seminar) (Computergestützte kognitive Modellierung)	Irregularly	English
	Quantum Information and Computation	Winter	English

From the range of courses from the ICAMS (Interdisciplinary Centre for Advanced Materials Simulations):

Minor Subject:	Modules	Semester	Language	
Material Sciences	Elements of Microstructure	Winter	English	
(Materialwissenschaften)	(Elemente der Mikrostruktur)		211811011	
	Advanced Characterization Methods (Erweiterte	Summer	English	
	Charakterisierungsmethoden)		_	
	Materials Processing (Materialverarbeitung)	Winter	English	
	Atomistic Simulation Methods	Winter	English	
	(Atomistische Simulationsmethoden)	white	LIIGIISII	
	Advanced Atomistic Simulation Methods (Fort-	Winter	English	
	geschrittene atomistische Simulationsmethoden)	winter	Linglish	
	Interfaces and Surfaces	Summer	English	
	(Schnittstellen und Oberflächen)	Summer	Linghish	
	Application and Implementation of Electronic Struc-			
	ture Methods (Anwendung und Umsetzung von Me-	Winter	English	
	thoden der elektronischen Struktur)			
	Phase Field Theory and Application (Phasen-	Summer	English	
	feldtheorie und Anwendung)	(not in 25)	LIIGIIJII	
	Phase Field Theory II (Phasenfeldtheorie II)	Winter	English	
	Programming Concepts in Materials Science (Pro-	Winter	English	
	grammierkonzepte in der Materialwissenschaft)	whiter	English	
	Quantum Mechanics in Materials Science (Quanten-	Summor	English	
	mechanik in der Materialwissenschaft)	Summer	English	
	Microstructure and Mechanical Properties (Mikro-	Summer	English	
	struktur und mechanische Eigenschaften)	Summer	English	
	Continuum Methods in Materials Science (Kontinu-	Winter	English	
	ummethoden in der Materialwissenschaft)	whiter	English	
	The CALPHAD Method in Thermodynamics and Dif-			
	fusion	Summer	Facilian	
	(Die CALPHAD-Methode in Thermodynamik und Dif-	Summer	English	
	fusion)			
	Multiscale Mechanics of Materials	Winter	English	
	(Multiskalige Mechanik der Materialien)	white	LIIGIISII	
	Computational Fracture Mechanics (Computerge-	Winter	English	
	stützte Bruchmechanik)	whitei	Linghish	
	Lattice Boltzmann Modelling: From Simple Flows to			
	Interface Driven Phenomena			
	(Lattice-Boltzmann-Modellierung: Von einfachen	Winter	English	
	Strömungen zu grenzflächengetriebenen Phänome-			
	nen)			
	Computational Plasticity	Summer	English	
	(Plastische Berechnungen)	Summer	-16131	
	Solidification Processing (Verfestigungsverfahren)	Winter	English	
	Stochastic Processes (Stochastische Prozesse)	Irregularly	German	

Computatio	nal Physics	I			
Module 6a	Credits 4 CP	Workload 120 h	Semester from 1. Sem.	Cycle Winter	Duration 1 Semester
Courses a) Lecture Computational Physics I b) Exercises for Computational Physics I		Contact Hours a) 22 h b) 22 h	Self-Study 76 h	Group Size a) Unlimited b) 30	
Requirements formal None Formal None Content None Preparation Not	·	on		<u> </u>	
with phy are awa	ly completing basic understa ysical problem re of the poss	nding of funda ns ibilities of conc		on and verificat	ocedures for dealing ion
 Ordinar Linear s FFT Monte (y and partial c ystems of equ Carlo methods		ations		
Format of Teach	ning Lecture, E	Exercises			
tion (written exa	amination of 9	0 min, oral exa		n or an exercise	s the form of examina- certificate with weekly
Passing the writ	ten/oral exam s case, active p	nination or obta participation in	aining at least 50% the exercise is also	of the possible	form of examination: points in the weekly he form of examination
Use of the Mod	ule Key Comp	etences			
Importance of t	he Mark for t	he Final Grade	Weighted accordi	ng to Credit Poir	nts
Module Supervi	isor and Instru	uctor Prof. Dr. I	nnocenti		
Further Informa	tion				

4 CP 120 h Courses a) Lecture Computational Physics II b) Exercises for Computational Physics II Requirements for Participation Formal None Content Knowledge from Computational P Preparation None Learning Outcomes After successfully completing the module, • have a basic understanding of adva • are aware of the possibilities and li • re familiar with the basic concepts Monte Carlo methods • are familiar with the possibilities of Contents • Multiscale methods: FFT, Multigrid, Cell methods (Boris-Push). • Stochastic differential equations, Mi • Parallelisation: MPI, CUDA • Finite Volume, Discontinues Galerki	the students nced numerical met mitations of the use of multiscale methor parallelisation Wavelets, Barnes-Hu	hods and applica of numerical me ds, stochastic dif ut, Fast Multipole	ethods fferential equations, e Method, Particle in
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- Finite Volume, Discontinues Galerki Format of Teaching Lecture, Exercises			rithm, Ising model
Format of Teaching Lecture, Exercises			
-	1		
Format of Examination At the beginning o	the course, the lect	urer determines	the form of examina-
tion (written examination of 90 min, oral e			certificate with weekly
homework and active participation in the e	xercises) for the lect	ure.	
Requirements for the Attribution of Credi		•	
Passing the written/oral examination or ob	•	• •	
exercises. In this case, active participation		compulsory. Th	e form of examinatio
is determined at the beginning of the cours	e.		
Use of the Module Key Competences			
Importance of the Mark for the Final Grad	e Weighted accordir	ng to Credit Point	ts
Module Supervisor and Instructor Prof. Dr	Innocenti		
Further Information			

Presentatio					
Module 6c	Credits 2 CP	Workload 60 h	Semester from 1. Sem.	Cycle Summer	Duration 1 Semester
Courses a) Seminar "Presentation Skills"		kills"	Contact Hours a) 22 h	Self-Study 38 h	Group size a) 30
Requirements Formal None Content None Preparation N		tion			
have alearn lknow	ully completin basic unders now to engage the basic cone	•	o structure a prese during a presentation nguage		
were introduc	ed. This inclu	des preparing an	presentation, stude d practicing short ta other students and	alks outside of cl	e to use the tools that ass and presenting
Format of Tea	ching Lecture	, Seminar, Practi	ical Exercises		
other students	s. The grade w	· ·	e of the grades for s		giving feedback to the ns given in class (80%)
•			Points Presentation ed. Active participation	-	and participation in e seminar is manda-
Use of the Mo	dule Key Com	petences			
Importance of	the Mark for	the Final Grade	Weighted accordin	ng to Credit Point	ts
Module Super	visor and Inst	t ructor Prof. Dr.	Franckowiak		

Scientific En	Ť		Competer	Cuelo	Dungtion
Module 6d	Credits 5 CP	Workload 120 h	Semester from 1. Sem.	Cycle Winter & Summer	Duration 1 Semester
(from Level) b) Online-Exerc	my and Other B1/B2) cises	Subjects	Contact Hours a) 22 h	Self-Study 98 h	Group Size a) 30 b) Unlimited
Requirements Formal Proof o Content None Preparation No	f language apt		n entrance test (cf.	www.zfa.rub.de)	
 can present can extract They can us Students can knowledge can unders communication are able to answer que re able to explicit to ex	Ily completing t themselves, important inf se such extract an work out f competently tand both ess ate this clearly make a topic estions on it express and as guments and p	Formation from s ted quotations a the function an in self-produced sential and detai y, precisely, and c of interest acc	d their interests in specialised texts by and evidence to de d form of differen l texts iled information fro concisely to others essible to non-expo oints of view and o	a concise and compre- using specific reading fend their own point o t types of texts and om listening and read , both orally and in wi erts (laypersons) in a opinions, formulate an tages in a discussion o	g techniques. of view apply this ing texts and riting lecture and to guments and
times). The focu production, inte are taught and more, the speci course is accom fore consists of 1. face-to-face 2. moodle cour	us of the face- eraction and r applied, and s fic vocabulary panied by a s two parts: course. se in blended	to-face course i mediation, both students work w y in the field of p pecific e-learnin learning format	s on the communic in written and spol ith authentic audic physics and astrono og offer, which is an , in which, with the	online phase (freely c ative use of language (en form. Various read and visual texts on N my is trained. Blende integral part of the c help of the materials of individual feedbac	in reception, ding strategies loodle. Further- d Learning: The ourse. It there- provided
Format of Teac	hing Seminar,	, practical exerci	ises		
Format of Exan	nination Prese	entation, writter	n portfolio, Listenin	g-discussion test of c.	30 min
Requirements ing the examination		ution of Credit F	Points Active partic	ipation in the seminar	rs (>75%), pass-
Use of the Moo					
Importance of	the Mark for	the Final Grade	Weighted accordin	g to Credit Points	
Module Superv	visor and Instr	ructor Mariano			

List of Additional Key Competences

In justified exceptional cases, modules that are not in this module handbook may also be recognised. For this purpose, a justified request must be submitted to the study advisor (Dr. Ivonne Möller).

Note on Programming Languages:

All modules that deepen a programming language (C, C++, Python, Java, PHP or Modula) can be chosen from the RUB's offer (e.g. the module "Computer Science I (from winter semester 21/22: "Programming for ITS") on the programming language TScript). However, modules that only represent a basic introduction to the understanding of programming techniques cannot be credited in the M.Sc. in Physics.

Module	Credits	Semester	Frequency / Further Information	Duration	Language
Information Theory	5 CP	Summer	https://qi.rub.de/it_ss23	1 Semester	English
(VVZ-Nr.: 211007)			<u>https://qi.ruhr-uni-bo-</u>		
			<u>chum.de/it_ss23>)</u>		

From the catalogue of the Faculty of **Computer Science (Informatik):**

From the catalogue of **RUBION**:

Module	Workload/Credits	Semester	Frequency	Duration	Language
Basic Course in Radiation Protec- tion according S4.1 (Grundkurs im Strahlenschutz nach der Fachgruppe S4.1)	150 h/5 CP	Winter/ Summer	s. RUBION	Block Course	German

From the catalogue of the Academic Writing Centre (Schreibzentrum):

Module	Credits	Semester	Frequency	Duration	Language
Intensive Module Theses in Science and Engineering (Intensivmodul Ab- schlussarbeiten in den Naturwissen- schaften A oder B)		Winter/ Summer	s. SCHREIBZENTRUM	1 Semester	German

From the catalogue of the faculty of **Economic Sciences (Wirtschaftswissenschaften)**:

Module	Credits	Semester	Language
Fundamentals of Finance and Investment			
(Corporate Finance I: Finanzierung & Investition)	5 CP	Summer	German
Financial Risk Management			
(Corporate Finance II: Finanzielles Risikomanagment)	5 CP	Summer	German
Capital Market Theory			
(Corporate Finance III: Kapitalmarkttheorie)	5 CP	Winter	German
Basics of Starting a Business			
(Start-Up I: Grundlagen der Existenzgründung)	5 CP	Winter	German
Coaching-Workshop for Start-Ups			
(Start-Up II: Coaching-Workshop für Existenzgründer)	5 CP	Winter/Summer	German
Basics of Business Plan Preparation			
(Start-Up III: Grundlagen der Businessplanerstellung)	5 CP	Summer	German

Module 7	Credits	Workload	Semester	Cycle	Duration
	5 CP	150 h	from 1. Sem.	Summer	1 Semester
Courses		I	Contact Hours	Self-Study	Group Size
a) Seminar Pr	oject Manage	ment	a) 50 h	50 h	a) 30
b) Practical ex	kercises Projec	t Management	b) 50 h		b) 30
Requirements	s for Participat	tion			
Formal None					
Content None					
Preparation N	lone				
Learning Outo					
	<i>·</i> ·	g the module, the			
		e basics of project tanding of leading	•		
		-	e its implementati	on	
		and formal frame	•		
Contents	ar datas sonuo	on the one hand	to toach the basis	mathadalagical	skills for project and
 a) The seminative team manaproblems a supervisor. b) In the praction a group From the pmodule supervisor. 	agement. On the analysed. The f . Leadership pr tical exercises, of Bachelor st preparation of pport the SOW	he other hand, re focus is on the ex- rotocols and prog , the participants udents and to gui the exposés to th /AS students both	esults from the pra change of informa gress reports are p have the opportu ide them in the im le final poster presen professionally an	ctical exercises a tion and feedba repared. nity to apply the plementation of sentation, the pa	ck from the module e acquired knowledge f a SOWAS project. articipants of this
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	ıle 8	Credits	Workload	Semester	Cycle	Duration
		15 CP	450 h	from 3. Sem.	Winter & Summer	1 Semester
Cours	es			Contact Hours	Self-Study	Group Size
a) Pra	actical exe	rcises		a) 320 h	100 h	a) 30
b) Seminar				b) 30 h		b) 30
Requi	rements f	or Participat	ion			
				-	academic achievemen	-
			-		from experimental ph	
-					ion module (15-25 CP	
•	•		-		be written in the mir	for subject, at
	ent None	i the minor s	ubject must be	proven.		
	ration No	no				
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	ing Outco					
			g the module, th		ant theoretical mode	als and
•			m their subject a		ent, theoretical mode	
•	•		-		heir chosen field of s	pecialisation
•		•	-		nanagement and proj	
•			•	sis in terms of time		
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	ents	tical oversion	s the required s	concrete working m		rolograd
a) Ir	ents In the pract		· ·	-	ethods of the group a	
a) Ir A	ents n the pract	ensive famili	iarisation phase,	the students have	ethods of the group a the opportunity to pa	rticipate in
a) Ir A tl	ents In the pract Infter an int he concret	ensive famili	iarisation phase, eir topic for the	the students have Master's thesis. In a	ethods of the group a the opportunity to pa addition, a timetable f	rticipate in
a) Ir A tl m	ents In the pract ofter an int he concret mentation	ensive famili tisation of the of the Maste	iarisation phase, eir topic for the er's thesis is drav	the students have Master's thesis. In a vn up and its feasib	ethods of the group a the opportunity to pa addition, a timetable f ility is checked.	rticipate in for the imple-
a) Ir A tl n b) T	ents In the pract ofter an int he concret mentation the semina	ensive famili tisation of the of the Maste or serves to d	iarisation phase, eir topic for the r's thesis is drav levelop a concre	the students have Master's thesis. In a vn up and its feasib te topic for the Mas	ethods of the group a the opportunity to pa addition, a timetable f ility is checked. ster's thesis. At the be	rticipate in for the imple- ginning of
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Module 9	Credits	Workload	Semester	Cycle	Duration
	15 CP	450 h	3. & 4. Sem.	Winter & Summer	2 Semesters
Courses			Contact Hours	Self-Study	Group Size
a) Seminar A			a) 100 h	320 h	a) 30
b) Seminar B			b) 30 h		b) 30
Requirements Formal Proof o Content None Preparation No	f completion		Knowledge of Meth	ods and Planning a Pr	roject"
Learning Outco	omes Illy completin	g the module, th urrent status of		er's thesis" (on a weel	kly and monthly
can an ject stehave a	ep	-		rk out suggestions for ject content appropri	
-	•			eriod. Each student fir	•
 a) Seminar A tanta the results of ysis should l ported by gatent with th b) In seminar E presentation the end as a 	of the previou be the startin raphs or a pre e aim of desig 3, the project n can be given n "final report	is week and anal g point for furth esentation. The g gning the next w "Master's thesis n either in the m ". The individual	lyses the progress a er planning. The exp group discusses the rork steps as effectiv " is presented in the iddle of the Master	nd difficulties. The resolanations or argumen feasibility in terms of vely as possible. e respective working g 's thesis as an "interin vell as the time planni	sult of this anal nts can be sup- time and con- group. The n report" or at
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Module 10	Credits	Workload	Semester	Cycle	Duration
	30 CP	900 h	3. & 4. Sem.	Winter & Summer	2 Semester
Courses			Contact Hours	Self-Study	Group Size
Thesis			720 h	180 h	1
Requirements	•		Knowledge of Moth	ada and Dianning a D	eieet"
Content None		of the module	KIIOWIEuge OI WIEth	nods and Planning a Pi	oject
Preparation N					
Learning Outo	omes				
		ng the module, th			
	•	-	entific ways of think	ing and working d problems using scier	tific mothods
	a given perio		is and solve defined	a problems using scier	itine methous
			appropriate, writte	en presentation of der	manding and
	scientific resu				
				endent work organisa	
	ific practice	equate interature	e research, citation (of sources and the pri	nciples of good
Contents		f an averation ant		dal indanandant alar	
•		•		odel, independent plar of the results, optimis	-
	•	of the process ste			
The topic and	task must be f	formulated in su	ch a way that they o	can be completed wit	nin 9 months
with a workloa	ad of 30 CP.				
Format of Tea	ching				
Format of Exa	mination Wri [†]	ting a scientific p	baper		
Requirements	for the Attrik	oution of Credit	Points Passing the e	examination	
Use of the Mo	dule Mandato	ory Module			
Importance of	the Mark for	[•] the Final Grade	Weighted accordin	ng to Credit Points	
•			rs and private lectur ers may be admitte	rers of the Faculty of F d if necessary.	Physics and
Astronomy. U		aster's thesis mu	st be written in the	chosen physics specia	alisation in which
Further Inform					
Further Inform	ion module w		addition, it is possi	ible to write the thesi	s in a minor sub-