

# Faculty of Physics and Astronomy

## **Preliminary module manual**

Master of Science (M.Sc.) in Physics

### PO 2021

Ruhr-Universität Bochum

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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. Compulsory modules amounting to 60 CP cover the subject-specific and interdisciplinary preparation and execution of the final thesis. The compulsory elective area includes 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, plasma physics). In the area of key competences, further modules of up to 10 CP can be selected. A list of the approved modules can be found in this module handbook.

The division of the 120 CP to be completed into the modules in the physics degree programme is illustrated in the following table

#### 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:

Dr. Ivonne Möller (General Questions) NB 02/172	Dr. Andreas Kreyssig (for International Students NB 4/
Fon.: +49(0)234-32-29105	Fon.: +49(0)234-32
master-international@physik.rub.de	master-international@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, biophysics, 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 performances achieved are weighted with the CP in the module grade. One module from 1a to 1e (of choice) must be completed. A further module can be taken.
Modul 2.x 6 -12 CP Modul 3.x	One (or two) module(s) from "Statistical Physics", "Advanced Quantum Mechanics" and "General Theory of Relativity One (or two) elective module(s) from	1.+2.	Graded, via a module final examination or an oral examination. One module from 2a to 2c (at choice) must be completed. A further module can be taken. Graded, the partial performances achieved are weighted with the CP in the module grade. Graded, the partial
0-12 CP	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.	performances achieved are weighted with the CP in the module grade. One or two module(s) from 3a to 3c (at choice) can be completed.
Modul 4.x 15-25 CP	One compulsory elective module from one of the following subject areas: Astrophysics, Biophysics, Solid State Physics, Nuclear and Particle Physics or Plasma Physics. Courses from experimental and/or theoretical physics from the respective 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. mathematics, chemistry, geosciences, ICAMS, neuroscience, engineering science). A complete list of all modules can be found further on in the module handbook.	14.	Graded, via a final module examination, final oral module examination, seminar lecture, study-related exercises and active participation, protocols, practical exercises or homework.
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 examination, oral module final examination, seminar lecture, study-related exercises and active participation, protocols, practical exercises or term paper.
Modul 7 5 CP	Projektmanagement	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 expert 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 4e) 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 period.

#### 4. List of all modules:

#### Modul 1 (Wahlpflichtmodule aus der Experimentalphysik)

•	Modul 1a Einführung in die Astrophysik	6
	Modul 1b Einführung in die Biophysik	
	Modul 1c Einführung in die Festkörperphysik	
	Modul 1d Einführung in die Kern- und Teilchenphysik	
	Modul 1e Einführung in die Plasmaphysik	

#### Modul 2 (Wahlpflichtmodule aus der Theoretischen Physik)

•	Modul 2a Allgemeine Relativitätstheorie1	3
•	Modul 2b Quantenmechanik II1	4
•	Modul 2c Statistische Physik1	5

#### Modul 3 (Wahlmodule aus der Theoretischen Physik)

•	Modul 3a Einführung in die theoretische Astrophysik	.16
•	Modul 3b Einführung in die theoretische Festkörperphysik	.18
•	Modul 3c Einführung in die theoretische Plasmaphysik	.20

#### Modul 4 (Wahlpflichtmodule für den Schwerpunkt)

•	Modul 4a Astrophysik	21
	Modul 4b Biophysik	
	Modul 4c Festkörperphysik	
	Modul 4d Kern- und Teilchenphysik	
	Modul 4e Plasmaphysik	
		=0

#### Modul 5 (Wahlpflichtmodule für das Nebenfach)

•	Angebot aus der Fakultät für Chemie und Biochemie	29
	Angebot aus der Fakultät für Geowissenschaften	
•	Angebot aus der Fakultät für Elektrotechnik und Informationstechnik	30
•	Angebot aus der Fakultät für Maschinenbau	30
	Angebot aus der Fakultät für Mathematik	
	Angebot aus dem Institut für Neuroinformatik	
	Angebot aus dem ICAMS	

#### Modul 6 (Wahlmodule für den Bereich Schlüsselkompetenzen)

•	Modul 6a Computational Physics I	33
•	Modul 6b Computational Physics II	34
•	Modul 6c Scientific English	.35
•	Modul 6z Liste mit weiteren Modulen	36

#### Pflichtmodule

•	Modul 7 Projektleitung	38
•	Modul 8 Methodenkenntnis und Projektplanung (M.Sc.)	39
•	Modul 9 Projektseminar zur Masterarbeit	40
•	Modul 10 Masterarbeit	41

Module 1a	Credits	Workload	Semester	Cycle	Duration	
	9 CP	270 h	from 1. Sem.	Summer Term	1-2 Semesters	
Courses			Contact Hours	•	Group Size	
a) Lecture Inti			a) 44 h	183 h	Students	
Astrophysic			b) 22 h		a) unbegrenzt	
b) Exercises fo		i to	c) 21 h		b) 30	
Astrophysic c) Advanced		urses for			c) 2	
-	(Three experi					
•	cs/Astronomy)					
	. ,,					
Requirements	for Participat	ion				
Formal: none						
		dge of Physics I-	III (Bachelor) are h	nighly appreciated		
Preparation: r	ione					
Learning Outc						
		g this module, th				
		•	es and research fi	elds of modern m	nulti-wavelength and	
	messenger ast		plogical and mode	lling mothods of a	strophysics to simple	
<ul> <li>are ab examp</li> </ul>				aning methods of a		
•		e relevant scien	tific contents and	communicate the	m in a differentiated	
•	er, both orally					
	•		of physics and ast	ronomy for society	y and the importance	
of internationally cooperative research.						
Contents						
			-		onal phenomena and	
•					ught include, among	
					active galactic nuclei, ellar dynamics, state	
				-	disk physics, pulsars.	
		•			skills are acquired on	
the basis of co						
	·					
Format of Tea	ching Lecture,	Exercises, Pract	tical Exercises (Lab	oratory Course)		
Format of Exa	mination At th	e beginning of th	ne course, the lect	urer determines th	ne form of examinatio	
(written exam	ination of 90	min, oral exam	ination of 45 mir	n or an exercise c	ertificate with weekl	
homework and	d active partici	ipation in the ex	ercises) for the lea	cture. The advance	ed laboratory course	
examined via practical exercises and protocols.						
-			•		form of examination	
-			-		e points in the week	
exercises. In this case, active participation in the exercise is also compulsory. The form of examination						
	-	-			atory course must b	
successfully co	ompleted. Both	n grades go into	the module grade	with the CP-weig	nted.	
Utilisation of t	the Module Co	ompulsory-Elect	ive Module			
		<u> </u>	Weighed accordin	g to credit points		
-		ructor Prof. Dr. I				
Further Inforn						

introduction to Biophysics	Introduction to Biophysics						
Module 1b Credits Workle	oad Sen	nester	Cycle	Duration			
9 CP 270 h	froi	m 5. Sem.	Winter Term	1-2 Semesters			
Courses	Cor	ntact Hours	Self Study	Group Size			
a) Lecture Introduction to Biophysics		44 h	183 h	Studierende			
b) Exercises for Introduction to Bioph	ysics b)	22 h		a) unbegrenzt			
c) Advanced Laboratory Courses for	c)	21 h		b) 30			
Physicists (three experiments in				c) 2			
Biophysics)							
Requirements fro Participation							
Formal: none							
Content-Wise: Basic knowledge in Phy	vsics I-III (Bac	chelor) will b	pe highly appreciated	d			
Preparation: none							
Leaning Outcomes							
After successfully completing this mod							
have a basic understanding of m			-				
<ul> <li>can realise the relation between</li> </ul>		•	•				
and the examination of biologic reactions	al systems, a	nd they car	i use them to describ	e equilibriums and			
<ul> <li>are familiar with the basic physi</li> </ul>	cal mothods	for ovamini	ing malacular biologi	ical processos			
<ul> <li>are able to plan, execute, evaluation</li> </ul>							
the results in the scientific conte			biophysical experim				
<ul> <li>have received a first glance at cu</li> </ul>		ch topics of	molecular biophysics	s at Ruhr-University			
Bochum	in chief cocure						
• can acquire relevant scientific c	ontents. the	ories. and n	nethods, both guided	d and independent.			
and they can communicate thei							
		·					
Contents							
- Structure of biological Matter: from	n the atom to	o the protei	n				
- Spectroscopical methods		<i>t</i>					
- Methods for determining structure	-		tallography, NMR, el	ectron microscopy)			
<ul> <li>Fundamentals of reaction kinetics a</li> </ul>	ind electrocr	nemistry					
Format of Teaching Lecture, Exercises	. Practical Ex	ercises (Lab	oratory Course)				
Format of Examination At the beginnin			, .	form of examination			
(written examination of 90 min, oral	-						
homework and active participation in				•			
examined via practical exercises and p							
Requirements for the attribution of	Credit Points	s Dependin	g on the specified fo	orm of examination:			
Passing the written/oral examination	or obtaining	g at least 50	0% of the possible p	oints 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	e course. In	addition, th	ne advanced laborat	ory course must be			
successfully completed. Both grades g	successfully completed. Both grades go into the module grade with the CP-weighted.						
Utilisation of the Module Compulsory	-Elective Mo	dule					
Importance of the Mark for the Final	_						
Module Supervisor and Instructor Pro	of. Dr. Gerwe	rt, Prof. Dr.	Hofmann				
Further Information	Further Information						

Module 1c	Credits	Workload	Semester	Cycle	Duration
	9 CP	270 h	from 5. Sem.	Winter Term	1-2 Semesters
Courses a) Lecture Intro State Physics b) Exercises for State Physics c) Advanced La Physicists (th solid state pl	Introduction Introduction I boratory Cou aree experime	to Solid Irses for	Contact Hours a) 44 h b) 22 h c) 21 h	<b>Self Study</b> 183 h	Group Size Students a) unlimited b) 30 c) 2
Requirements f Formal: none Content-Wise: Preparation: no Learning Outco	Basic knowled		ll (Bachelor) will b	be highly apprecia	ated
<ul> <li>Have a macross</li> <li>Are away electron at least</li> <li>Know th</li> <li>Are away</li> <li>Can see</li> </ul>	basic unders copic and mic are of the po- nic properties a qualitive un the fundament are of scatter and apply re	croscopic charact ossibilities of th s of solid state m nderstanding of tal concepts of a ing phenomena	quantum mecha teristics of solid s e general concep natter from the b those concepts pplying quantum in the position an atomic and solid	tate matter ots to derive the asic methods of p mechanics to sol id momentum spa	
<ul> <li>(ideal crystal phenomena)</li> <li>Dynamics of</li> <li>(lattice oscil scattering ex</li> <li>Electrons in s</li> <li>(Classical fre conductors, i of band gaps and faults, p</li> <li>(klassisches Eigenschafte experimente</li> </ul>	s, misorder, r the crystallin lations, phon periments) solid state ma e electron ga metallic bonc s, semi-condu n-junction freies Elektr n von Leiter lle Bestimmu	e lattice ions, Bose-Einste atter as, Fermi-Dirac-I ling, charges in n ictors, thermal e onengas, Fermi n, metallische E ing der Bandlück	ein-distribution, f Distribution, elect nagnetic fields, ba xcitation of charg -Dirac-Verteilung Bindung, Ladungs	thermal propertie tric conductivity, and model, experi ges, effective mas , elektrische Leit sträger im Magn ermische Anregun	via diffraction, bonding es of non-conductors thermal properties of mental determination s, conducting by holes tfähigkeit, thermische etfeld, Bändermodell, g von Ladungsträgern,
		-	ical Exercises (Lab		
(written examir homework and	nation of 90 active partici	min, oral exami	nation of 45 mir ercises) for the lea	n or an exercise	he form of examinatio certificate with week ced laboratory course

**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.

Utilisation of the Module Compulsory-Elective Module

Importance of the Mark for the Final Mark Weighed according to credit points

Module Supervisor and Instructor Prof. Dr. Böhmer

		Workload	Semester	Cylce	Duration
	9 CP	270 h	from 5. Sem.	Winter Term	1-2 Semesters
Courses	roduction to N	uclear and	Contact Hours	-	Group Size
Particle Ph	roduction to N	uclear and	a) 44 h b) 22 h	183 h	Students a) unlimited
		to Nuclear	c) 21 h		b) 30
<ul><li>b) Exercises for Introduction to Nuclear and Particle Physics I</li><li>c) Advanced Laboratory Courses for</li></ul>		0, 2111		c) 2	
				<i>•, –</i>	
-	, three experime				
nuclear and particle physics)					
Requirements	for Participat	ion			
Formal: none		f Dhusies I III (De			
Preparation:		f Physics I-III (Ba	chelor) will be ex	pected	
-					
Learning Outo		g this module, th	na studants		
		-		natter and its int	eractions as well as
	oactivity	standing of the			
	•	ossible applicat	tions of nuclear	physical processe	es in technology and
	licine				
	المراجع والمراجع والمراجع		1 <b>1 1</b>		
<ul> <li>know</li> </ul>	the fundamen	tal concepts of e	electromagnetic, v	weak, and strong i	nteraction
		•	-	· · · · ·	
• are fai	miliar with gen	eral measureme	-	d methods and car	
<ul> <li>are fail and</li> </ul>	miliar with gen disadvantages	eral measureme of nuclear phys	ent techniques an ical and radioacti	d methods and car	n evaluate advantages
<ul> <li>are fail</li> <li>and</li> <li>see co</li> </ul>	miliar with gen disadvantages prrelations bety	eral measureme of nuclear phys ween processes	nt techniques an ical and radioacti in the universe ar	d methods and car ve processes nd in nuclear and p	n evaluate advantages
<ul> <li>are fail</li> <li>and</li> <li>see co</li> </ul>	miliar with gen disadvantages prrelations bety	eral measureme of nuclear phys ween processes	nt techniques an ical and radioacti in the universe ar	d methods and car ve processes nd in nuclear and p	n evaluate advantages particle physics
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<ul> <li>are fail and</li> <li>see co</li> <li>can ex</li> </ul>	miliar with gen disadvantages prrelations bety	eral measureme of nuclear phys ween processes	nt techniques an ical and radioacti in the universe ar	d methods and car ve processes nd in nuclear and p	n evaluate advantages particle physics
<ul> <li>are fail and</li> <li>see co</li> <li>can ex</li> </ul>	miliar with gen disadvantages prrelations betw valuate the play	eral measureme of nuclear phys ween processes ce into context t	ent techniques an ical and radioacti in the universe ar the results of nucl	d methods and car ve processes nd in nuclear and p lear physical and r	n evaluate advantages particle physics
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<ul> <li>are failed and</li> <li>see contents</li> <li>Contents</li> <li>Nuclear physice model of part interaction of</li> </ul>	miliar with gen disadvantages prrelations betw valuate the place cs processes in icle physics, st ponds with ma	eral measureme of nuclear phys ween processes ce into context t the universe, str cructure and des	ent techniques and ical and radioacti in the universe and the results of nucl ucture of matter scription of atom ors based on ther	d methods and car ve processes nd in nuclear and p lear physical and r from elementary p ic nuclei, relativis n, introduction to	n evaluate advantages particle physics adioactive processes particles - the standarc
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<ul> <li>are failers</li> <li>and</li> <li>see contents</li> <li>can experience</li> <li>can e</li></ul>	miliar with gen disadvantages orrelations betw valuate the place cs processes in icle physics, st ponds with ma the strong an opplications of osure, evaluations ching Lecture,	eral measureme of nuclear phys ween processes ce into context t the universe, str cructure and detect d electroweak nuclear and part on of experimen Exercises, Pract	ent techniques and ical and radioacti in the universe and the results of nucl ucture of matter scription of atom ors based on ther interaction, scatt ticle physics in tec ts.	d methods and car ve processes nd in nuclear and p lear physical and r from elementary p ic nuclei, relativis n, introduction to ering and decay hnology and medi	n evaluate advantages particle physics adioactive processes particles - the standard tic heavy ion physics quantum field theory experiments, particle cine, radioactivity and
<ul> <li>are fail and</li> <li>see contents</li> <li>can experimental contents</li> <li>Nuclear physice</li> <li>model of part</li> <li>interaction of</li> <li>processes of accelerators, a radiation exponental</li> <li>Format of Tean</li> <li>Format of Example</li> </ul>	miliar with gen disadvantages orrelations betw valuate the place is processes in icle physics, st ponds with ma the strong an opplications of osure, evaluation <b>ching</b> Lecture, <b>mination</b> At th	eral measureme of nuclear phys ween processes ce into context t the universe, str ructure and detect d electroweak nuclear and part on of experimen Exercises, Pract e beginning of th	ent techniques and ical and radioacti in the universe ar the results of nucl ucture of matter scription of atom ors based on ther interaction, scatt ticle physics in tec ts.	d methods and car ve processes nd in nuclear and p lear physical and r from elementary p ic nuclei, relativis n, introduction to ering and decay hnology and medi	n evaluate advantages particle physics adioactive processes particles - the standard tic heavy ion physics, quantum field theory experiments, particle cine, radioactivity and he form of examinatio
<ul> <li>are fail and</li> <li>see co</li> <li>can ex</li> </ul> Contents Nuclear physic model of part interaction of processes of accelerators, a radiation export Format of Teat (written examination export)	miliar with gen disadvantages orrelations betw valuate the place is processes in icle physics, st ponds with ma the strong an opplications of osure, evaluation <b>ching</b> Lecture, <b>mination</b> At th ination of 90	eral measureme of nuclear phys ween processes ce into context t the universe, str cructure and detected d electroweak nuclear and part on of experimen Exercises, Pract e beginning of th min, oral exam	ent techniques and ical and radioacti in the universe ar the results of nucl ucture of matter scription of atom ors based on ther interaction, scatt ticle physics in tec ts. ical Exercises (Lab ne course, the lect ination of 45 min	d methods and car ve processes nd in nuclear and p lear physical and r from elementary p ic nuclei, relativis n, introduction to ering and decay hnology and medi poratory Course) curer determines t n or an exercise o	n evaluate advantages particle physics adioactive processes particles - the standard tic heavy ion physics quantum field theory experiments, particle cine, radioactivity and he form of examinatic certificate with week
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Utilisation of the Module Compulsory-Elective Module

Importance of the Mark for the Final Mark Weighed according to credit points

Module Supervisor and Instructor Prof. Dr. Wiedner

Modul 1e	Credits	a Physics Workload	Semester	Cycle	Duration
Modul IC	9 CP	270 h	from 4. Sem.	Summer Term	1-2 Semesters
Courses			Contact Hours		Group Size
a) Lecture Introduction to Plasma Physics I		a) 44 h	183 h	Students	
b) Exercises for Introduction to Plasma		b) 22 h		a) unlimited	
Physics I			c) 21 h		b) 30
c) Advanced La	•				c) 2
•	nree experim	ents in plasma			
physics)					
Requirements	for Participat	tion			
Formal: none	•				
	-	of Physics I-III (Ba	chelor) will be ap	preciated	
Preparation: no	one				
Learning Outco					
		g this module, th			
		•	•	•	and of the forms of
	•	<b>e</b> 1	-	of the kinetic and t	heir locking concepts
			lasma equilibriun	•	nen locking concepts
		e dynamics of pla	•		
				asma properties a	nd can apply physica
		niques to known p			· · · · · · · · · · · · · · · · · · ·
Contonto					
Contents Basic concents	and plasm	a definition sin	gle narticles in	magnetic fields	collision interactions
Basic concepts	•			-	
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Basic concepts hydrodynamics controlled fusic Format of Teac Format of Exam	, magnetohy on, special for hing Lecture hination At th	drodynamics, kin rms of discharge. , Exercises, Practi ne beginning of th	etic theory, bour ical Exercises (Lab e course, the lect	ndary layers, waves poratory Course) urer determines th	collision interactions s in plasmas, basics o e form of examination ertificate with week
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General Rela	ativity				
Modul 2a	Credits	Workload	Semester	Cycle	Duration
	6 CP	180 h	from 6. Sem.	Not in the Summer Term 2023	1 Semester
Courses			Contact Hours	Self Study	Group Size
a) Lecture Gene	eral Relativity		a) 44 h	114 h	Students
b) Exercises Gei	neral Relativity	/	b) 22 h		a) unlimited b) 30
Requirements for Formal: none	or Participatio	on			
Content-Wise: r	none				
Preparation: no	ne				
Learning Outco					
After successful					
			y as curvature of s	•	
	•		erential-geometric		
			gravity and their a	• •	
Can see	connections t	between physic	cal ideas and can a	apply their mathemat	tic form
Contents					
Special relative	vity and flat sp	acetime: Lorei	ntz transformatior	ns; vectors and dual v	vectors (1-forms);
	• •			assical field theory.	ζ <i>μ</i>
Manifolds: G	ravity as a ge	ometric prope	rty; What is a ma	anifold; Vectors, ten	sors, metrics; An
expanding ur	niverse; Causa	lity; Tensor dei	nsities; Dif-ferenti	al forms; Integration	
Curvature: co	ovariant deriva	ative; parallel t	ransport and geod	desics; the Riemann o	curvature tensor;
symmetries a	and Killing vec	tors; maximally	/ symmetric space	es; geodesic divergen	ce
Gravitation:	physics in cu	urved spacetir	me; Einstein equ	ations; Lagrangian	formulation; the
-		ernative theori			
				off's theorem; singul	
			-	xtended Schwarzschi	
				/alker metric; the Fi	riedmann equation;
scale factor c	lynamics; reds	hift and distan	ces; Gravitational	lensing; inflation	
Format of Teach	ning Locture	vorcisos			
	-		e course the lect	urer determines the f	form of examination
			ination of 30 min)		onnorexamination
			Points Passing the		
Utilisation of th					
			Weighed accordin	g to Credit Points	
Module Supervi			-	0	
-				at the RUB in summ	er semester 23
Alternatively, th		•			

	Credits	/lechanics Workload	Semester	Cyclo	Duration
Modul 2b	6 CP	180 h	ab 5. Sem.	<b>Cycle</b> Winter Term	1 Semester
<u> </u>	0 CP	10011	Contact Hours		
a) Lecture Adv	vanced Quant	um	a) 44 h	<b>Self Study</b> 114 h	Group Size Students
Mechanics		um	b) 22 h	114 11	a) unlimited
	dvanced Quar	ntum Mechanics	0) 2211		b) 30
Requirements					0, 30
Formal: none					
	: knowledge o	f the contents of	"Introduction to	Quantum Mecha	nics and Statistics"
(Bachelor) will	-				
Preparation: r	•				
Learning Outc					
-		g this module, th	e students		
		-		uantum mechani	cs, enabling them to
		ysical phenomen			cs, enabiling them to
				summatrias in au	antum mechanics and
		ematical form of		symmetries in qu	
		•	• •		antum mechanics and
•			n-relativistic pher		
		cattering theory	and the quantu	im mechanical ti	reatment of identical
partic		dedee of volation			· · · · · · · · · · · · · · · · · · ·
Gaine	d basic know	ledge of relativ	istic field equati	ons and their qu	lantification
Contents					
	quantum me	echanics additio	n of angular mor	nentum selectio	n rules approximation
Symmetries in	•		-		
methods and	their applicat		-		n rules, approximatior les, field quantisation
Symmetries in methods and relativistic way	their applicat ve equations	ions, scattering	-		
Symmetries in methods and relativistic way Format of Tea	their applicat ve equations ching Lecture	ions, scattering , Exercises	theory, systems o	of identical partic	les, field quantisation
Symmetries in methods and relativistic way Format of Tea Format of Exa	their applicat ve equations ching Lecture, mination At th	ions, scattering , Exercises ne beginning of th	theory, systems of the course, the lect	of identical partic	les, field quantisation
Symmetries in methods and relativistic way Format of Tea Format of Exam (written exam	their applicat ve equations <b>ching</b> Lecture <b>mination</b> At th ination of 180	ions, scattering , Exercises ne beginning of th min or oral exan	theory, systems of ne course, the lect nination of 45 mir	of identical partic urer determines t n) for the module	les, field quantisation
Symmetries in methods and relativistic way Format of Tea Format of Exam (written exam Requirements	their applicat ve equations ching Lecture mination At th ination of 180 of or the attrib	ions, scattering , Exercises ne beginning of th min or oral exan ution of Credit P	theory, systems of ne course, the lect nination of 45 mir <b>Points</b> Passing the	of identical partic urer determines t n) for the module	les, field quantisation
Symmetries in methods and relativistic way Format of Tea Format of Exan (written exam Requirements Utilisation of t	their applicat ve equations ching Lecture, mination At th ination of 180 of or the attrib the Module Co	ions, scattering , Exercises ne beginning of th min or oral exan <b>ution of Credit P</b> ompulsory-Electi	theory, systems of ne course, the lect nination of 45 mir <b>Points</b> Passing the ve Module	of identical partic urer determines t n) for the module examination	les, field quantisation
Symmetries in methods and relativistic way Format of Tea Format of Exan (written exam Requirements Utilisation of t Importance of	their applicat ve equations ching Lecture, mination At the ination of 180 of or the attrib the Module Co f the Mark for	ions, scattering , Exercises ne beginning of th min or oral exan <b>ution of Credit P</b> ompulsory-Electi	theory, systems of the course, the lecture nination of 45 min <b>Points</b> Passing the ve Module Weighed accordin	of identical partic urer determines t n) for the module examination	les, field quantisation

Statistical	Physics				
Modul 2c	Credits	Workload	Semester	Cycle	Duration
	6 CP	180 h	from 6. Sem.	Summer Term	1 Semester
Courses			Contact Hours	Self Study	Group Size
a) Lecture Sta	tistical Physic	S	a) 44 h	114 h	Students
b) Exercises S	tatistical Physi	ics	b) 22 h		a) unlimited
					b) 30
Requirements	s for Participat	tion			
Formal: none					
<b>Content-Wise</b>	: knowledge o	f the contents o	f "Introduction to	Quantum Mechan	ics and Statistics"
(Bachelor) wil	l be expected				
Preparation:	none				
Learning Outo	omes				
After successf	ully completin	g this module, tl	he students		
Have	a basic unders	tanding of the c	oncepts of statistic	cal mechanics	
		-	, quantum statistics		
		•	•		nechanical statistical
physic					
		blems of non-ir	nteracting multi-pa	article nhysics	
• Call St	Sive typical pit			inticle physics	
Contents					
	istics and class	sical statistical n	nechanics. thermo	dynamics, applica	tions. Starting point is
			-		Afterwards quantum
statistics with		, , , , , , , , , , , , , , , , , , , ,	,		
Format of Tea		, Exercises			
Format of Exa	mination writ	ten examinatior	of 120 min		
Requirements	s for the attrib	ution of Credit	Points Passing the	examination	
Utilisation of	the Module C	ompulsory-Elect	ive Module		
Importance o	f the Mark for	the Final Mark	Weighed accordin	g to Credit Points	
			-		
Module Supe	rvisor and Inst	r <b>uctor</b> Prof. Dr.	Innocenti		

Introduction	to Theor	etical Astrop	hysics		
Modul 3a	Credits 6 CP	<b>Workload</b> 180 h	Semester From 5. Sem.	<b>Cycle</b> Summer Term	<b>Dauer</b> 1 Semester
<ul> <li>Courses</li> <li>a) Lecture Introduction to Theoretical Astrophysics</li> <li>b) Exercises Introduction to Theoretical Astrophysics</li> </ul>		Contact Hours a) 44 h b) 22 h	Self Study 114 h	<b>Group Size</b> Students a) unlimited b) 30	
Requirements f Formal: none Content-Wise: Preparation: no	Basic knowle		al physics (Bachel	or level) is highly a	ppreciated
<ul> <li>Have a</li> <li>Are awa</li> <li>Know th</li> <li>Are fam</li> <li>Can see</li> </ul>	basic unders are of the po ne fundamen niliar with dif e and succes	ssibilities of the un tal concepts for ferent theoretica sfully apply corre	etical astrophysics used mathematisa describing astrop I methods elations between	ation and modellin hysical environme	nts ective examples and
in connection of Astrophysics: do Stars: state var structure and in transfer; Stellar	with current efinition and iables, form iteraction wi	research results fundamentals (t ation, structure, ith the interstella eleration, structu	5. Focal points an he latter are pro evolution and fi ar medium; Stella	re selected from vided in short digr nal states; Stellar r atmospheres: St on with the interst	ystems and discussed the following topics ressions as required); winds: acceleration, ructure and radiative tellar medium; Milky
Format of Teac					
(written examin	nation of 90	min, oral exami		n or an exercise c	e form of examinatio ertificate with weekl
Passing the wri exercises. In thi	tten/oral exa s case, active	amination or obt	aining at least 50 the exercises is al	0 % of the possible	form of examination e points in the weekl e form of examinatio
		ompulsory-Electi			
Importance of			-	g to Credit Points	
Module Superv Further Inform		<b>ructor</b> PD Dr. Fic	htner		

Modul 3b	Credits	tical Solid St Workload	Semester	Cycle	Duration
	6 CP	180 h	from 5. Sem.	Winter Term	1 Semester
Courses	0.61	100 11	Contact Hours		Group Size
a) Lecture Intr	oduction to Th	eoretical Solid	a) 44 h	114 h	Students
State Physic			b) 22 h	11411	a) unlimited
b) Exercises In		heoretical	5) 2211		b) 30
Solid State I					5, 50
	,				
Requirements	for Particiption	า			L.
Formal: none					
<b>Content-Wise:</b>	knowledge of	theoretical phys	ics, including the	e contents of "Intro	duction to Quantum
	-	chelor), will be e	expected		
Preparation: n	one				
Learning Outco					
	, , ,	the module, the			
		al concepts of sc	•		
		-			rds to structure, th
• •		•	tronic properties	s and their influend	ce on the macroscopi
	our of the solid			<b>6</b> 11 1 1 1 1	
			•		cond quantification,
				entary excitation)	
	ive and interpre	et typical exercis	ses of solid state	theory	
	structure of th	e solid			
			crystal structu	re determination h	y diffraction, bondin
ratios)			, crystar stracta		y annaction, sonan;
	of the crystal la	ittice			
•			n distribution, tl	hermal properties	of the non-conducto
scattering e	xperiments)				
Electrons i	n the solid stat	e			
(classical f	ree electron ga	is, Fermi-Dirac d	listribution, elect	trical conductivity,	thermal properties of
conductors,	metallic bond	ling, charge car	riers in the ma	gnetic field, band	model, experimenta
determinati	on of band ga	aps, semicondu	ctors, thermal e	excitation of charge	ge carriers, scatterin
experiment					
- excitation o	f charge carrie	rs, effective mas	s, hole conductio	on, impurity condu	ction, pn junction).
Format of Tea	<b>ching</b> Lecture, E	Exercises			
Format of Exar	<b>ninarion</b> At the	beginning of the	e course, the lect	urer determines th	e form of examinatio
(written exami	nation of 90 n	nin, oral examir	nation of 45 mir	n or an exercise co	ertificate with weekl
homework and	active particip	ation in the exe	rcises) for the le	cture.	
-				-	orm of examination:
-			-		points in the week
exercises. In th	is case, active	participation in t	the exercise is al	so compulsory. The	e form of examinatio
is determined a	at the beginnin	g of the course.			
Jtilisation of th	e Module Com	pulsory-Elective	Module		

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

Module Supervisor and Instructor Prof. Dr. Eremin

Modul 3c	Credits	Workload	Semester	Cycle	Duration
	6 CP	180 h	from 5. Sem.	Winter Term	1 Semester
Courses a) Lecture Introduction to Theoretical Plasma Physics b) Exercises Introduction to Theoretical Plasma Physics		Contact Hours a) 44 h b) 22 h	Self Study 114 h	Group Size Students a) unlimited b) 30	
Requirements f Formal: none Content-Wise: highly appreciat Preparation: no	Basic knowled ted		l physics, especia	Illy electrodynamics	(Bachelor level), is
<ul> <li>many-p</li> <li>are fam and are</li> <li>know the develop</li> <li>are fam context found t</li> <li>have gat</li> </ul>	article system illiar with the o able to assess he basic math bed in the moo hiliar with resp of astrophys here hined initial ex of the pra	descriptions of pl s the possibilities ematical technic dule pective plasma-p ics and space pl perience in the r	lasmas on the ba s and limitations ques for working hysical applicatio hysics and have numerical modell	heoretical model bu sis of kinetic and flui of such models within the framew ons of the theories a an insight into the ling of plasma-physi carried out corres	id dynamic theories ork of the theories and methods in the parameter regimes cal processes in the
magnetohydroc physical contex Format of Teac Format of Exam	dynamics, equ t, numerical m hing Lecture, hination At the nation of 90 r	librium theory, nodelling of plasm Exercises, numer beginning of the nin, oral examin	waves and instat mas. rical computer sin e course, the lect nation of 45 mir	urer determines the or an exercise cer	in astro- and space- form of examinatio
(written examir homework and	active particip				
homework and Requirements for Passing the write	or the Attribu ten/oral exam case, active p	<b>tion of Credit Po</b> ination or obtair articipation in th	ints Depending on hing at least 50%	on the specified form of the possible poin compulsory. The fo	ts in the weekly
homework and Requirements for Passing the write exercises. In this s determined at Utilisation of th	or the Attribu ten/oral exam case, active p the beginning the Module Co	tion of Credit Po ination or obtair articipation in th of the course. mpulsory-Electiv	ints Depending hing at least 50% he exercise is also he Module	on the specified forr of the possible poin compulsory. The fo	ts in the weekly
homework and Requirements for Passing the write exercises. In this a determined at Utilisation of the Importance of the	or the Attribu ten/oral exam case, active p the beginning the Module Co the Mark for t	tion of Credit Po ination or obtair articipation in th of the course. mpulsory-Electiv	ints Depending hing at least 50% he exercise is also e Module /eighed accordin	on the specified forr of the possible poin	ts in the weekly

	Credits	Workload	Semester	Cycle	Duration
	15-25 CP	450-750 h	12. Sem.	Winter & Summer	2 Semesters
				Term	
Courses			<b>Contact Hours</b>	Self Study	Group Size
a) Lecture			Each at least.	mind. 309 h	Students
b) Exercises			a) 44 h		a) unlimited
c) Seminar (at	least 2 CP)		b) 44 h		b) 30
d) Advanced L CP)	aboratory Cou	irses (at least 5	c) 22 h d) 35 h		c) 30 d) 2
A complete ov	erview of the d	courses can be			
found in the cu	irrent course d	atalogue. The CP			
of the individu	al courses resu	ult from the			
semester hour	s per week (1	hour per			
semester week					
Requirements	for Participat	ion			
Formal: none			<i>.</i> .		
		dge of astronomy	/astrophysics wi	ill be expected	
Preparation: n	one				
• are ab	le to read, und le to write the	current astrophys lerstand and class ir Master's thesis	sify astrophysica	l literature xperimental or theol	etical astronomy
of research'. T working group provided. Extra	his is done wi s in experimer agalactic astro punt of space.	th special empha Ital and theoretica Inomy, up to (obs Interactions of di	sis on the resea al astrophysics/a servational) cosr ifferent compon	he students are take arch foci of the parti- astronomy, but a bro mology and astropar ants (such as phases a) are of particular in	cipating chairs and ad overview is also ticle physics, take s of the interstella
medium, galac processes in o components o also on solar-te	our own Milky f the Milky Wa errestrial relat	ay and the format	ited in detail. H ion of stars and the physics of th	lere, the focus is on - linked to this - plar he solar wind. Close	the gas and dus

**Requirements for the Attribution of Credit Points** Passing the oral examination. The specialisation module must include: advanced laboratory courses (5 CP), 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. **Utilisation of the Module** Compulsory-Elective Module

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

Module Supervisor Prof. Dr. Bomans

**Examiners** Prof. Dr. Bomans, Prof. Dr. Dettmar, Prof. Dr. Franckowiak, Prof. Dr. Hildebrandt, Prof. Dr. Tjus, PD Dr. Fichtner

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

#### Winter Semester

160611 Cosmology (Lecture) Hildebrandt, Hendrik Lecture 160612 Cosmology (Exercises) Hildebrandt, Hendrik Exercises 160623 Astrophysical Fluids, Plasmas and Shocks Scherer. Klaus *Lecture* 160613 Radio Astronomy Adebahr, Björn Lecture 160608 Stars, Winds, Nebulae Weis, Kerstin Lecture 160602 The Milky Way and External Galaxies Bomans, Dominik J. Lecture 160621 Selected Topics of Astronomy Bomans, Dominik J.; Dettmar, Ralf-Jürgen; Franckowiak, Anna; Hildebrandt, Hendrik Seminar 160656 Selected Topics on High Energy Particle Astrophysics Tius, Julia Seminar 160624 Advanced Laboratory: Observational Astronomy Dettmar, Ralf-Jürgen; Bomans, Dominik J.; Franckowiak, Anna Laboratory 160615 Fluid Dynamics in Astrophysics Scherer, Klaus Lecture 160616 Theoretical Neutrino Astrophysics Lecture Tjus, Julia 160617 Theoretical Neutrino Astrophysics (Exercises) Tjus, Julia; Merten, Lukas Exercises 160618 Introduction to Space Physics Fichtner, Horst Lecture 160619 Introduction to Space Physics (Exercises) Fichtner, Horst Exercises 160609 **Theoretical Heliophysics** Fichtner, Horst; Kleimann, Jens Seminar 160663 Research Topics in Heliophysics Fichtner, Horst Seminar 160610 Methods in Theoretical Astroparticle Physics Tjus, Julia Seminar 160661 Observational Cosmology Hildebrandt, Hendrik Seminar 160665 Crossing the Desert Rhode, Wolfgang Seminar 160666 Multi-Wavelength Astrophysics Franckowiak, Anna Seminar 160250 Advanced Laboratory Course for Physics Students Krebs, Hermann; Reicherz, Gerhard Laboratory 160651 Extragalactic Astronomy Dettmar, Ralf-Jürgen Seminar Summer Semester: 160601 Interstellar Medium Astrophysics Bomans, Dominik J. Lecture 160614 Astroparticle Physics Franckowiak, Anna Lecture 160615 Astroparticle Physics (Exercises) Franckowiak, Anna Exercises 160660 Variabilities and Instabilities in Stars Weis, Kerstin Lecture 160613 Introduction to Statistics for Astronomers and Physicists Wright, Angus 160610 X-ray Astronomy Bomans, Dominik J. Lecture 160511 Modeling of Atomic Populations in the Spectroscopy of Laboratory and **Astrophysical Plasmas II** Marchuk, Oleksandr Lecture 160512 Modeling of Atomic Populations in the Spectroscopy of Laboratory and Astrophysical Plasmas II (Exercises) Marchuk, Oleksandr Exercises 160616 Modelling Transport and Interactions of Cosmic Rays Tjus, Julia; Merten, LukasLecture

160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced		actions of Cosmic Rays Tjus, Julia; Merten, L Exerc
Hildebrandt, Hendrik; Dettmar, Ralf-Jürgen; Bomans, Dominik J.; Franckowiak, Anna 160662 Multi-Wavelength Astrophysics (Seminar) Franckowiak, Anna 160650 Observational Cosmology (Seminar) Hildebrandt, Hendrik Seminar 160661 Crossing the Desert Hildebrandt, Hendrik Seminar 160623 Methods in Theoretical Astroparticle Physics (Seminar) Tjus, Julia (not in SoSe 2023) Seminar 160624 Theoretical Heliophysics (Seminar) Fichtner, Horst; Kleimann, Jens 160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational ast Bomans, Dominik J.; Dettmar, Ralf-Jürgen Laboratory 160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	.60605 Fluid Dynamics in Astrophysics	Scherer, Klaus Lecture
160662 Multi-Wavelength Astrophysics (Seminar)Franckowiak, Anna160650 Observational Cosmology (Seminar)Hildebrandt, HendrikSeminar160661 Crossing the DesertHildebrandt, HendrikSeminar160623 Methods in Theoretical Astroparticle Physics (Seminar)Tjus, Julia(not in SoSe 2023)Seminar160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	.60620 Selected Topics of Astronomy II	l (Seminar)
160650 Observational Cosmology (Seminar) Hildebrandt, HendrikSeminar160661 Crossing the DesertHildebrandt, HendrikSeminar160623 Methods in Theoretical Astroparticle Physics (Seminar)Tjus, Julia(not in SoSe 2023)Seminar160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	lildebrandt, Hendrik; Dettmar, Ralf-Jürg	gen; Bomans, Dominik J.; Franckowiak, Anna
160661 Crossing the DesertHildebrandt, HendrikSeminar160623 Methods in Theoretical Astroparticle Physics (Seminar)Tjus, Julia(not in SoSe 2023)Seminar160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	.60662 Multi-Wavelength Astrophysics	<b>s (Seminar)</b> Franckowiak, Anna
160623 Methods in Theoretical Astroparticle Physics (Seminar)Tjus, Julia(not in SoSe 2023)Seminar160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	.60650 Observational Cosmology (Semi	inar) Hildebrandt, Hendrik Seminar
160623 Methods in Theoretical Astroparticle Physics (Seminar)Tjus, Julia(not in SoSe 2023)Seminar160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced		-
(not in SoSe 2023)Seminar160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	-	
160624 Theoretical Heliophysics (Seminar)Fichtner, Horst; Kleimann, Jens160626 Astronomisches Beobachtungs-Praktikum / Laboratory: Observational astBomans, Dominik J.; Dettmar, Ralf-JürgenLaboratory160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	•	
Bomans, Dominik J.; Dettmar, Ralf-Jürgen Laboratory 160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	-	nar) Fichtner, Horst; Kleimann, Jens
160250 Fortgeschrittenen-Praktikum für Physikerinnen und Physiker / Advanced	.60626 Astronomisches Beobachtungs-	-Praktikum / Laboratory: Observational astrc
	Bomans, Dominik J.; Dettmar, Ralf-Jürge	en Laboratory
	60250 Fortgeschrittenen-Praktikum fü	ir Physikerinnen und Physiker / Advanced La
, , , ,		-

	<b>Credits</b> 4 CP	<b>Workload</b> 120 h	Semester 1. Sem.	<b>Turnus</b> WiSe	<b>DURATION</b> 1 Semester
<b>Courses</b> a) Lecture "Cosm	ology (Lecture	e)"	Kontaktzeit a) 33 h	Selbststudium a) 76 h	<b>Group size</b> Students
b) Exercise "Cosm	nology (Exerci	ces)"	b) 11 h		a) Unlimited b) 30
Participation requ Formal: none Content: Introduc Preparation: Prior	tion to Astror		astronomy introd	uctory lecture	
<ul> <li>are award</li> <li>know the</li> <li>are familevolution</li> <li>are ready</li> </ul> Content Content course	ompletion of t understanding e of the physic physical cond liar with basi , v to work on a	g of the propertie cs of the thermal cepts of cosmic s cs of the inflation master thesis wind description of the	s of a homogeneo history of the Uni tructure formation onary universe, re ith a cosmological e physics of homog	n and the cosmic micro eionisation, gravitatic topic. geneous, isotropic univ	owave background, nal lensing, and galax verses, a.k.a. Friedmani
constrain such m covered, connecti isotropic world m fluctuations all the is introduced and	odels are dison ng insights fro odels. Next, way to the st understood b	cussed. Starting om particle physi structure format cructures we see i based on these co	from the hot big ics, thermodynam ion and evolution n the Universe too incepts. Cosmic in	bang, the thermal hi ics, and the above mo are discussed, starti day. The Cosmic Micro	bservational avenues story of the Universe entioned homogeneou ng from tiny primordi wave Background (CMI ravitational lensing, ar with observations.
Teaching forms le	cture, exercis	e class			
Forms of examina	i <b>tion</b> oral exar	m			
<b>Requirements for</b> Active participatio		-	ful completion of 1	the oral exam.	
Use of the module	<b>e</b> Courses in P	Physics Major			
Importance of the	e grade for the	<b>e final grade</b> grad	led, but does not o	contribute to the weig	hted average final grad
	tor/full-time	<b>lecturer</b> Prof. Dr.	Hendrik Hildebrai	ndt	
Module coordinat					

	Credits	Workload	Semester	Turnus	DURATION
	2 CP	60 h	3. / 4. Sem.	WiSe / SoSe	1 Semester
Courses	·		Kontaktzeit	Selbststudium	Group size
a) Se	minar "Extragala	ctic Astronomy"	a) 22 h	a) 38 h	Students
					a) Unlimite
<u> </u>	·				d
•	on requirements				
•	vate inquiry				
Content: no		aturas in astrona	my and actrant	vier	
		ectures in astrono	my and astrophy	/SICS	
Learning ou	ssful completion	of the modul			
			of current recea	ch projects at the	bair of actronomy
		-		rch projects at the c	
		•		ield of extragalactic	•
				eduction technique	
		•	ne impact of a p	ublication and judge	e the importance
	their own resea	rch project			
Content					
-				ed in the context of	
		tronomy. The imp	ortance of pape	rs is discussed with	regards to the
ongoing pro	-				
	orms Seminar				
Teaching fo	• • •				
Forms of ex	kamination Pres				
Forms of ex Requireme	nts for the awar	d of credit points	Active participa	tion and presentation	on
Forms of ex Requireme Use of the	nts for the awar module Courses	d of credit points in Physics Major		·	
Forms of ex Requireme Use of the Importance	nts for the awar module Courses e of the grade fo	d of credit points in Physics Major		tion and presentation not contribute to the	
Forms of ex Requireme Use of the Importance average fin	nts for the awar module Courses e of the grade fo al grade	d of credit points in Physics Major r the final grade g	graded, but does	not contribute to t	
Forms of ex Requireme Use of the Importance average fin	nts for the awar module Courses e of the grade fo al grade ordinator/full-tin	d of credit points in Physics Major	graded, but does	not contribute to t	

	Credits	Workload	Semester	Turnus	DURATION
	3 CP	90 h	5. / 7. Sem.	WiSe	1 Semester
Courses	-		Kontaktzeit	Selbststudium	Group size
a) Lectur	e <i>"</i> The Milky	Way and	a) 33 h	a) 57 h	Students
Extern	al Galaxies"				a) Unlimite
					d
Participation re	equirements				
Formal: none					
Content: none					
Preparation: So	olid knowled	ge of the foundat	ions of Astronom	iy is necessary, as it	is presented in the
	-		ous attendance o	f the lecture "Introd	uction to
Astrphysics" is l		not required.			
Learning outco	mes				
After the succe	ssful comple <sup>-</sup>	tion of the course	e students will ha	ve gained a deeper	understanding of
structure, kiner	matics, and e	volution of our N	Ailky Way galaxy.	Using these concep	ots, in the second
part of the lect	ure the prop	erties and evolut	ion of external ga	laxies will explored	and a coherent
picture for evol	ution of gala	xies inside the ev	olving universe v	vill be derived.	
Content					
	cicts of tha ty	vo maior narts <sup>,</sup> t	he exploration of	the physical proper	tion of our Millor
		• •			•
Galaxy and the	extension to	the various type	s of external gala	xies, both the unde	rlining goal to
Galaxy and the derive a consist	extension to ent picture f	the various type or the evolution	s of external gala of galaxies from t	xies, both the unde he early universe to	rlining goal to today. Methods
Galaxy and the derive a consist and results for t	extension to ent picture f the structure	the various type or the evolution , kinematics, sta	s of external gala of galaxies from t rformation histor	xies, both the unde the early universe to y, and chemical evo	rlining goal to today. Methods lution will be
Galaxy and the derive a consist and results for the presented and	extension to ent picture f the structure	the various type or the evolution , kinematics, sta	s of external gala of galaxies from t rformation histor	xies, both the unde he early universe to	rlining goal to today. Methods lution will be
Galaxy and the derive a consist and results for presented and types derived.	extension to cent picture f the structure applied to th	the various type or the evolution , kinematics, sta	s of external gala of galaxies from t rformation histor	xies, both the unde the early universe to y, and chemical evo	rlining goal to today. Methods lution will be
Galaxy and the derive a consist and results for presented and types derived. Teaching forms	extension to ent picture f the structure applied to th s lecture	the various type or the evolution , kinematics, star e different galax	s of external gala of galaxies from f rformation histor y types and concl	xies, both the unde the early universe to y, and chemical evo usions for the evolu	rlining goal to today. Methods lution will be tion of the galaxy
Galaxy and the derive a consist and results for t presented and types derived. Teaching forms Forms of exam	extension to ent picture f the structure applied to th lecture ination usua	the various type or the evolution , kinematics, star e different galax Ily a short oral pr	s of external gala of galaxies from f rformation histor y types and concl	xies, both the unde the early universe to y, and chemical evo	rlining goal to today. Methods lution will be tion of the galaxy
Galaxy and the derive a consist and results for presented and types derived. Teaching forms Forms of exam written essay o	extension to ent picture f the structure applied to th lecture ination usua r an oral exa	the various type or the evolution , kinematics, star e different galax lly a short oral pr m	s of external gala of galaxies from t rformation histor y types and concl esentation, alter	xies, both the unde the early universe to y, and chemical evo usions for the evolu	rlining goal to today. Methods lution will be tion of the galaxy
derive a consist and results for presented and types derived. Teaching forms Forms of exam written essay o Requirements	extension to ent picture f the structure applied to th lecture ination usua r an oral exa for the awar	the various type or the evolution , kinematics, star e different galax Ily a short oral pr m d of credit points	s of external gala of galaxies from t rformation histor y types and concl essentation, alter	xies, both the unde the early universe to y, and chemical evo usions for the evolu	rlining goal to today. Methods lution will be tion of the galaxy
Galaxy and the derive a consist and results for f presented and types derived. Teaching forms Forms of exam written essay o Requirements	extension to ent picture f the structure applied to th lecture ination usua r an oral exa for the awar	the various type or the evolution , kinematics, star e different galax lly a short oral pr m	s of external gala of galaxies from t rformation histor y types and concl essentation, alter	xies, both the unde the early universe to y, and chemical evo usions for the evolu	rlining goal to today. Methods lution will be tion of the galaxy
Galaxy and the derive a consist and results for presented and types derived. Teaching forms Forms of exam written essay o Requirements active participa	extension to ent picture f the structure applied to th lecture ination usua r an oral exa for the awar tion and a su	the various type or the evolution , kinematics, star e different galax Ily a short oral pr m d of credit points	s of external gala of galaxies from t rformation histor y types and concl essentation, alter	xies, both the unde the early universe to y, and chemical evo usions for the evolu	rlining goal to today. Methods lution will be tion of the galaxy
Galaxy and the derive a consist and results for presented and types derived. Teaching forms Forms of exam written essay o Requirements active participa	extension to ent picture f the structure applied to th lecture ination usua r an oral exa for the awar tion and a su	the various type or the evolution , kinematics, star e different galax Ily a short oral pr m d of credit points in Physics Major	s of external gala of galaxies from t rformation histor y types and concl resentation, alter ation	xies, both the unde the early universe to y, and chemical evo usions for the evolu	rlining goal to today. Methods lution will be tion of the galaxy onditions apply) a
Galaxy and the derive a consist and results for a presented and types derived. Teaching forms Forms of exam written essay o Requirements active participa Use of the mod Importance of	extension to ent picture f the structure applied to th s lecture ination usua r an oral exa for the awar tion and a su lule Courses the grade fo	the various type or the evolution , kinematics, star e different galax Ily a short oral pr m d of credit points in Physics Major	s of external gala of galaxies from t rformation histor y types and concl resentation, alter ation	xies, both the unde the early universe to y, and chemical evo usions for the evolu natively (if special co	rlining goal to today. Methods lution will be tion of the galaxy onditions apply) a
Galaxy and the derive a consist and results for presented and types derived. Teaching forms Forms of exam written essay o Requirements active participa Use of the mod Importance of average final gr	extension to ent picture f the structure applied to th ination usua r an oral exa for the awar tion and a su lule Courses the grade for ade	the various type or the evolution , kinematics, star e different galax Ily a short oral pr m d of credit points accessful examination in Physics Major r the final grade	s of external gala of galaxies from t rformation histor y types and concl resentation, alter ation	xies, both the unde the early universe to y, and chemical evo usions for the evolu natively (if special co not contribute to th	rlining goal to today. Methods lution will be tion of the galaxy onditions apply) a

2 CP Courses b) Seminar "Multi-Way Astrophysics" Participation requirements Formal: Work on a bachelor Content: Lecture "Basics of A Preparation: Final exam of th Learning outcomes After successful completion of have a broad overvie know how to presen learn to participate i have acquired the sk Content This weekly seminar brings to covers topics of neutrino ast modeling of multi-wavelengt the group regularly present to collaborations, have opportu- to the group. Teaching forms Seminar Forms of examination Regul students' work, discussions w Requirements for the award At this stage, i.e. after the sta	/ master thesis Astronomy", "As he module astro of the module s ew of state-of-th t their work to a n the discussion cillset to comple ogether the me ronomy, gamma	stroparticle Physic onomy (master) tudents ne-art topics in m an international g among internation te their bachelor mbers of the mul- a-ray astronomy,	ulti-messenger astro roup of experts onal experts / master theses ti-wavelength astro optical astronomy a s concerning the top	ophysics ohysics group. It nd numerical
<ul> <li>b) Seminar "Multi-Way Astrophysics"</li> <li>Participation requirements</li> <li>Formal: Work on a bachelor</li> <li>Content: Lecture "Basics of A Preparation: Final exam of the Learning outcomes</li> <li>After successful completion of have a broad overviet have a broad overviet have a broad overviet have a broad overviet have a courred the ske</li> <li>Content</li> <li>This weekly seminar brings to covers topics of neutrino ast modeling of multi-wavelengt the group regularly present to collaborations, have opportu- to the group.</li> <li>Teaching forms Seminar</li> <li>Forms of examination Regul students' work, discussions were requirements for the award</li> </ul>	/ master thesis Astronomy", "As he module astro of the module s ew of state-of-th t their work to a n the discussion cillset to comple ogether the me ronomy, gamma	b) 22 h in the multi-wave stroparticle Physic onomy (master) tudents ne-art topics in m an international g among international te their bachelor mbers of the multa-ray astronomy,	b) 38 h elength astronomy g cs" is recommended ulti-messenger astro roup of experts onal experts / master theses ti-wavelength astrop optical astronomy a s concerning the top	Students b) Unlimite d roup ophysics
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covers topics of neutrino ast modeling of multi-wavelengt the group regularly present t collaborations, have opportu- to the group. <b>Teaching forms</b> Seminar <b>Forms of examination</b> Regul students' work, discussions w <b>Requirements for the award</b>	ronomy, gamma	a-ray astronomy,	optical astronomy a s concerning the top	nd numerical
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collaborations, have opportu to the group. <b>Teaching forms</b> Seminar <b>Forms of examination</b> Regul students' work, discussions v <b>Requirements for the award</b>				
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Forms of examination Regul students' work, discussions v Requirements for the award				
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Requirements for the award	•		•	ions of the
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additional credit points. How		-		•
participation as detailed abo	•		in necessary for leg	
Use of the module Courses i				
Importance of the grade for			not contribute to th	ne weighted
average final grade	the margrade	Brauca, but utes		ie weignieu
Module coordinator/full-tim				
Other information	<b>1e lecturer</b> Prof	Dr. Anna Franck	owiak	

	Credits 2 CP	<b>Workload</b> 60 h	<b>Semester</b> 3. / 4. Sem.	<b>Turnus</b> WiSe / SoSe	<b>DURATION</b> 1 Semester	
<b>Courses</b> a) Semi	inar "Observati	onal Cosmology"	onal Cosmology" a) 22 h		<b>Group size</b> Students a) Unlimited	
Formal: Wor Content: Lec Astronomy"	ture "Cosmolog (bachelor)	r/master thesis in	/ also "Astrostat	al cosmology group istics" (master); lec		
have can c	learned to pre conduct scientif	e interactions in a sent their work to fic discussions, res	their peers in a		id take on	
• have Content This weekly r progress, pro the team, ge	meeting brings oblems, and cur t input from the	killset to complete together all member rent topics. It is e eir peers, and imp	bers of the obse xpected that stu rove their work	rvational cosmolog Idents present their through new ideas	weekly progress to , productive criticism	
<ul> <li>have</li> <li>Content</li> <li>This weekly r progress, pro the team, ge and discussic giving the stu</li> </ul>	e acquired the s meeting brings oblems, and cur t input from the ons. The work o udents first insig	killset to complete together all member rent topics. It is e eir peers, and imp f the group member ghts into the inne	bers of the obse xpected that stu rove their work pers in several ir r workings of su	rvational cosmolog Idents present their through new ideas	weekly progress to productive criticism, th teams is discussed otentially with	
<ul> <li>have</li> <li>Content</li> <li>This weekly r</li> <li>progress, protocol</li> <li>the team, ge</li> <li>and discussion</li> <li>giving the studies</li> <li>opportunities</li> <li>Teaching for</li> <li>Forms of examples</li> </ul>	acquired the s meeting brings oblems, and cur t input from the ons. The work o udents first insig s to interact wi <b>ms</b> Seminar	killset to complete together all member rent topics. It is e eir peers, and imp f the group member ghts into the inne th international co	bers of the obse xpected that stu rove their work pers in several ir r workings of su plleagues and pr ation in the forr	rvational cosmolog idents present their through new ideas iternational researc ch collaborations, p resent their work to n of short presentat	weekly progress to productive criticism, th teams is discussed otentially with	
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<ul> <li>have</li> <li>Content</li> <li>This weekly r</li> <li>progress, protection</li> <li>the team, ge</li> <li>and discussion</li> <li>giving the studies</li> <li>opportunities</li> <li>Teaching for</li> <li>Forms of example</li> <li>work, discussion</li> <li>Requirement</li> <li>At this stage,</li> <li>additional craphotic</li> </ul>	e acquired the s meeting brings oblems, and cur t input from the ons. The work o udents first insig s to interact wir <b>ms</b> Seminar <b>mination</b> Regu sions with mem <b>ts for the awar</b> , i.e. after the si edit points. How	killset to complete together all member rent topics. It is e eir peers, and imp f the group member ghts into the inne th international co lar active particip obers of the group <b>d of credit points</b> tart of the bachelo wever, points can	bers of the obse xpected that stu rove their work pers in several ir r workings of su plleagues and pr ation in the forr ation in the forr	rvational cosmolog idents present their through new ideas iternational researc ch collaborations, p resent their work to n of short presentan nt follow-up.	weekly progress to , productive criticism, th teams is discussed otentially with a wider audience. tions of the students' do not require	
<ul> <li>have</li> <li>Content</li> <li>This weekly r</li> <li>progress, protection</li> <li>the team, ge</li> <li>and discussion</li> <li>giving the study</li> <li>opportunities</li> <li>Teaching for</li> <li>Forms of example</li> <li>At this stage,</li> <li>additional craphotic participation</li> <li>Use of the m</li> </ul>	acquired the s meeting brings oblems, and cur t input from the ons. The work o udents first insig s to interact wir <b>ms</b> Seminar <b>mination</b> Regu sions with mem <b>ts for the awar</b> , i.e. after the st edit points. How as detailed abo	killset to complete together all member rent topics. It is e eir peers, and imp f the group member ghts into the inne th international co llar active particip obers of the group <b>d of credit points</b> tart of the bachelo wever, points can ove.	bers of the obse xpected that stu prove their work pers in several ir r workings of su plleagues and pr ation in the form ation in the form ation subsequen pr/master thesis still be awarded	rvational cosmolog idents present their through new ideas nternational researc ch collaborations, p resent their work to n of short presentat nt follow-up.	weekly progress to , productive criticism th teams is discussed otentially with a wider audience. tions of the students' do not require	

Radio AstronomyCreditsWorkloadSemesterTurnusDURATION2 CP60 h1. / 2. Sem.WiSe1 Semester
2 CP 60 h 1. / 2. Sem. WiSe 1 Semester
Courses Kontaktzeit Selbststudium Group size
a) Lecture "Radio Astronomy" a) 22 h a) 38 h Students
a) Unlimited
Participation requirements
Formal: none
Content: none
<b>Preparation:</b> Introduction to Astrophyiscs and a good understanding of Fourier Transforms
<ul> <li>After successful completion of the module         <ul> <li>students have a basic understanding of radio astronomical imaging techniques</li> <li>Students are aware of the capabilities of modern radio telescopes and receivers</li> <li>students know the basic concepts of emission and absorption mechanisms of astronomi bodies radiating in the radio regime</li> <li>are familiar with radio astronomical polarisation measurements</li> <li>students are able to recognize connections between plasma physics, high energy parti physics and radio astronomy</li> <li>students are able to perform their Master Thesis within the area of radio astronomy</li> </ul> </li> <li>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.</li> <li>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.</li> <li>Teaching forms Lecture</li> <li>Forms of examination oral exam 45 min</li> <li>Requirements for the award of credit points         <ul> <li>Passing the oral exam</li> <li>Use of the module Courses in Physics Major</li> <li>Importance of the grade for the final grade graded, but does not contribute to the weighted average final grade</li> </ul> </li> </ul>
Other information

Research To	pics in He	liophysics			
	Credits	Workload	Semester	Turnus	DURATION
	2 CP	60 h	from 6th	WiSe & SoSe	1 Semester
			Sem.		
Courses			Kontaktzeit	Selbststudium	Group size
-	ar "Research hysics"	Topics in	a) 22 h ?	a) 38 h	Students a) Unlimite d
Participation re	equirements				
Formal: none					
Content: none					
Preparation: no	one				
Learning outco	mes				
After successfu	l completion	of the module			
<ul> <li>student</li> </ul>	ts will have a	n overview of th	e research topics	currently being inv	estigated in the
helioph	iysics group				
<ul> <li>student</li> </ul>	ts will have p	resented their o	wn ongoing work	(resulting in a B.Sc.	., M.Sc., or Ph.D.
thesis)	to the other	group members			
<ul> <li>student</li> </ul>	ts will have le	earned to make a	an oral presentati	on of their current	work to a
speciali	ized audience	9			
<ul> <li>studen</li> </ul>	ts are able to	summarize, to c	omprehensively	present, and to criti	ically discuss the
motiva	tion, method	ology and result	s of their work		
Content					
In a series of ta	lks by B.Sc., I	M.Sc., or Ph.D: st	udents they pres	ent the motivations	s, methods and
results of their	thesis-relate	d work on helio-	and astrophysica	l topics. Thereby fo	cused scientific
discussions are	triggered that	at help the prese	nter to improve l	ner/his work and giv	ve the specialized
audience an ov	erview over o	other heliophysic	cal and related as	trophysical topics.	
Teaching forms	s Seminar				
Forms of exam	ination oral	oresentation			
Requirements	for the awar	d of credit point	s oral presentation	on	
Use of the mod	lule Courses	in Physics Major			
Importance of	the grade fo	r the final grade	graded, but does	not contribute to t	he weighted
average final gr	ade	-			
		<b>ne lecturer</b> PD D	r. Horst Fichtner		
Other informat	tion				

	<i>Credits</i> 2 CP	<i>Workload</i> 60 h	<b>Semester</b> 5.,6.,7. Sem	<b>Turnus</b> WiSe /SoSe	DURATION 1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
a) Seminar "S	Selected Topics	s of Astronomy"	a) 22 h	a) 38 h	Students
					a) Unlimited
Participation	requirements				
Formal: yes					
Content: yes					
Preparation:	Solid knowled	ge of the foundat	ions of Astronor	ny is needed, as pre	sented in
	-			the lecture "Introdu	
			attendance of m	ore specialized Astr	onomy/Astrophysic
lecture is reco	ommended, bu	it not required.			
Learning outo	omes				
The seminar i	s intended to a	tive the students	exposure to cut	ting edge Astronom	ical/Astrophysical
		-	•		
		-	•	ne presentation of so	
science topics	s, train the und	lerstanding of res	earch papers, tł		cience results at the
science topics knowledge le	s, train the und vel of their fell	lerstanding of res	earch papers, th discuss them fo	ne presentation of so blowing each of the	cience results at the
science topics knowledge le requires the p	s, train the und vel of their fell	lerstanding of res ow students, and	earch papers, th discuss them fo	ne presentation of so blowing each of the	cience results at the
science topics knowledge le requires the <u>p</u> Content In the semina	s, train the unc vel of their fell participation in r the students	lerstanding of res ow students, and at least most of f select from a list	earch papers, th discuss them for the seminar dat of topical paper	ne presentation of so ollowing each of the es.) rs the one to present	cience results at the presentations. (Th t. The topics are
science topics knowledge le requires the p <b>Content</b> In the semina selected by th	s, train the und vel of their fell participation in r the students ne full-time lec	lerstanding of res ow students, and at least most of select from a list turers and theref	earch papers, th discuss them fo the seminar dat of topical paper ore reflect most	ne presentation of so ollowing each of the es.) The one to present ly the work topics a	cience results at the presentations. (Th t. The topics are ctively persued at
science topics knowledge le <u>requires the p</u> <b>Content</b> In the semina selected by th the Astronom	s, train the und vel of their fell participation in r the students ne full-time lec nical Institute.	lerstanding of res ow students, and <u>at least most of</u> select from a list turers and theref With help of the	earch papers, th discuss them for the seminar dat of topical paper ore reflect most respective advis	ne presentation of so ollowing each of the es.) To the one to presen ly the work topics a ors the students pre	cience results at the presentations. (Th t. The topics are ctively persued at epare the topics to
science topics knowledge le requires the p Content In the semina selected by th the Astronom be presented	s, train the und vel of their fell participation in or the students ne full-time lec nical Institute. in their semin	lerstanding of res ow students, and at least most of select from a list turers and theref With help of the ar talk and are pr	earch papers, the discuss them for the seminar dat of topical paper ore reflect most respective advis ovided with help	ne presentation of so ollowing each of the es.) To the one to present by the work topics and ors the students pre- p for the actual pres	t. The topics are ctively persued at epare the topics to entation. Result of
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	Credits	Physics Workload	Semester	Turnus	DURATION
	3 CP	90 h	from 5th	WiSe	1 Semester
			Sem.		
Courses		·	Kontaktzeit	Selbststudium	Group size
a) Lecture "Int	roduction to	Space Physics	a) 22 h	a) 57 h	Students
(Lecture)"					a) Unlimited
<ul><li>b) Exercise "In (Exercices)"</li></ul>	troduction to	Space Physics	b) 11 h		b) 30
Participation re Formal: none	quirements				
	knowledge of	Theoretical Phys	ics		
Preparation: no	-	medicularinys			
-					
Learning outcor After successful		f the module			
	-	understanding c	of Snace Physics	-	
		-	• •		atization and of the
modelli				csponding mathem	
	-	sic concents for	the quantitativ	e description of space	ce physical processes
		apply them succ	-		
•			•	en snace nhysics a	nd astrophysics and
	physics				
Content					
Methods and re	esults of space	nhysics will be r	recented for co		
		physics will be p	nesented for se	elected space physic	al systems and will
				will be selected from	al systems and will not the following
be discussed in	the context of	f current researc	h. Focus areas		n the following
be discussed in topics: the Sun,	the context of the quiet and	f current researc disturbed solar	h. Focus areas wind and its in	will be selected from	n the following errestrial
be discussed in topics: the Sun, environment (n	the context of the quiet and nagnetosphere	f current researc disturbed solar	h. Focus areas v wind and its in nterstellar med	will be selected from teraction with the t ium (heliosphere), v	n the following errestrial
be discussed in topics: the Sun, environment (n	the context of the quiet and nagnetosphere ne solar wind,	f current researc disturbed solar e as well as the ir transport of ene	h. Focus areas v wind and its in nterstellar med	will be selected from teraction with the t ium (heliosphere), v	n the following errestrial
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be discussed in topics: the Sun, environment (n turbulence in th Teaching forms Forms of exami exam of 45 min during the lectu Requirements f Je nach festgele	the context of the quiet and nagnetosphere the solar wind, clectures and ination At the duration, oral ure period). for the award egter Prüfungs	f current researc disturbed solar e as well as the ir transport of ene exercises beginning of the l exam of 30 min of credit points form:	h. Focus areas y wind and its in nterstellar med rgetic particles, e course the doc duration, or se	will be selected from teraction with the tr ium (heliosphere), v space weather ent defiines the type of veral shorter (multi	n the following errestrial vaves and exam (e.g., written ple choice) tests
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	Credits	Workload	Semester	Turnus	DURATION
	2 CP	60 h	4./6. Sem.	SoSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
a) Lecture "S	tars, Wind Neb	ulae"	a) 22 h	a) 38 h	Students
					a) Unlimited
Participation	requirements				
Formal: none	2				
Content: non	е				
Preparation:	basic know how	v in astronomy (	e.g. Introduction	to Astronomy cour	se) neccessary
Learning outo					
	-			consequences of ma	•
	onal perspective	e but also theore	tical concepts ar	e introduced and di	scussed.
Content					
<b>TI</b>					
				asses. A focus is give	
parameters tl	hat influence th	e evolution – in	particular the sto	ellar mass loss and i	ts consequences.
parameters tl The lecture a	hat influence th ddresses the to	e evolution – in pic from an obse	particular the store store the store store structure str	ellar mass loss and i of view but also the	ts consequences. pretical models
parameters tl The lecture ad presented. Be	hat influence th ddresses the to eside the observ	e evolution – in pic from an obse vational characte	particular the store rvational point corrections also the n	ellar mass loss and i of view but also theo nechanism of stella	ts consequences. pretical models r winds are
parameters tl The lecture ad presented. Be addressed. Th	hat influence th ddresses the to eside the obser- ne formation of	e evolution – in pic from an obse vational characte circumstellar ne	particular the sto rvational point o eristics also the n bula from stellar	ellar mass loss and i of view but also theo nechanism of stellar r winds and possible	ts consequences. pretical models winds are shell ejections is
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parameters tl The lecture ac presented. Be addressed. Th another topic properties of Teaching form Forms of exa	hat influence th ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar <b>ms</b> lecture <b>mination</b> possil	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium.	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly cam, a short oral	ellar mass loss and i of view but also theo nechanism of stellar r winds and possible	ts consequences. pretical models winds are shell ejections is neepts and
parameters tl The lecture a presented. Be addressed. Th another topic properties of Teaching forr Forms of exa Requirement	hat influence th ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar <b>ms</b> lecture <b>mination</b> possil <b>is for the award</b>	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium. ble are an oral ex	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly am, a short oral	ellar mass loss and i of view but also theo nechanism of stellar winds and possible tackles several cor	ts consequences. pretical models winds are shell ejections is neepts and
parameters tl The lecture a presented. Be addressed. Th another topic properties of Teaching forr Forms of exa Requirement active particij	hat influence the ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar ms lecture mination possil s for the award pation and a sur	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium.	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly am, a short oral	ellar mass loss and i of view but also theo nechanism of stellar winds and possible tackles several cor	ts consequences. pretical models winds are shell ejections is neepts and
parameters tl The lecture ac presented. Be addressed. Th another topic properties of Teaching forr Forms of exa Requirement active particip Use of the mo	hat influence the ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar <b>ms</b> lecture <b>mination</b> possil <b>is for the award</b> pation and a sur <b>odule</b>	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium. ble are an oral ex d of credit points ccessfull examina	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly <u>kam, a short oral</u> ation	ellar mass loss and i of view but also theo nechanism of stellar winds and possible tackles several cor presentation or wr	ts consequences. pretical models winds are shell ejections is prepts and
parameters the The lecture ac presented. Be addressed. The another topic properties of Teaching forr Forms of exal Requirement active particing Use of the me Importance of	hat influence the ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar ms lecture mination possil s for the award pation and a sur- odule of the grade for	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium. ble are an oral ex d of credit points ccessfull examina	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly <u>kam, a short oral</u> ation	ellar mass loss and i of view but also theo nechanism of stellar winds and possible tackles several cor	ts consequences. pretical models winds are shell ejections is prepts and
parameters the The lecture are presented. Be addressed. The another topic properties of Teaching form Forms of exa Requirement active particing Use of the me Importance of average final	hat influence the ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar ms lecture mination possil s for the award pation and a sur- odule of the grade for grade	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium. ble are an oral ex d of credit points ccessfull examination the final grade	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly cam, a short oral ation graded, but does	ellar mass loss and i of view but also theo nechanism of stellar winds and possible tackles several cor presentation or wr	ts consequences. pretical models winds are shell ejections is prepts and
parameters the The lecture are presented. Be addressed. The another topic properties of Teaching form Forms of exa Requirement active particing Use of the me average final	hat influence the ddresses the to eside the observ- ne formation of c of the lecture. the Interstellar ms lecture mination possil c for the award pation and a sur- odule of the grade for grade dinator/full-tin	e evolution – in pic from an obse vational characte circumstellar ne In this context t medium. ble are an oral ex d of credit points ccessfull examina	particular the sto rvational point o eristics also the n bula from stellar he lecture briefly cam, a short oral ation graded, but does	ellar mass loss and i of view but also theo nechanism of stellar winds and possible tackles several cor presentation or wr	ts consequences. pretical models winds are shell ejections is pepts and itten essay

Theoretical	Heliophys	sics			
	Credits	Workload	from 5th	Turnus	DURATION
	2 CP	60 h	Sem.	WiSe & SoSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
a) Seminar " Th	neoretical He	liophysics"	a) 22 h	a) 38 h	Students
					a) Unlimited
Participation re	quirements				
Formal: none					
Content: none					
Preparation: no	one				
Learning outco	mes				
After successfu	l completion	of the module			
<ul> <li>studen</li> </ul>	ts will have a	basic insight into	o selected topics	of contemporary he	eliophysical research
			selves with one	topic in more detai	I on the basis of one
	e research ρι				
			an oral presentat	tion of a chosen scie	entific problem to an
	ted audience				
		o extract, to sun	nmarize, and to	critically discuss the	e essence of a given
	ch paper				
Content					
	•			arious heliophysical	
					tical heliophysics is
•	•			t research activititie	
		onveyed now a so	cientific presenta	ation should be strue	ctured and made.
Teaching forms		ral procentation	lor in overation	nal cases, the term p	apar) will be
evaluated.	ination the c	oral presentation	(or, in exception	iai cases, the term p	aper) will be
	for the awar	d of credit points	5		
Je nach festgele		•	-		
-			der Erlangen vor	n mindestens 50 % d	ler möglichen
		-	-		aktive Beteiligung in
				er Veranstaltung fest	
-	-	-	-	de Noten gehen mit	
in die Modulno		C C		Ū	C C
Use of the mod	dule Courses	in Physics Major			
		· · · · · · · · · · · · · · · · · · ·		s not contribute to t	he weighted
average final gi	rade	_			
Module coordi	nator/full-tir	ne lecturer PD D	r. Horst Fichtner	, Dr. Jens Kleimann	
Other informat	tion				

	Nebulae		Somostor	Turpuc	DUDATION
	Credits	Workload	Semester	Turnus	DURATION
-	2 CP	60 h	5./7. Sem.	WiSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
a) Lecture "Va	riability and	Instability in	a) 22 h	a) 38 h	Students
Stars"					a) Unlimited
Participation re	quirements				
Formal: none					
Content: none					
		in astronomy (e	.g. Introduction	to Astronomy cours	se) neccessary
Learning outcor					
-				stellar varibility and	-
•		• •		l concepts of are int	roduced and
discussed to cor	nnect the varia	bilty to instabili	ty processe.		
Content					
				isses. In this context	•
		•		A focus is given on th	•
•				the stability of a sta	r. The lecture
addresses all su	hiacts from an				
	•	•		t also theoretical mo	odels are presented
and necessary t	o explain and o	describe instabil	ities.		
and necessary t With a possible	o explain and o origin of varial	describe instabil pility being trans	ities. sits, stellar bina	ries and even exopla	nets are topics in
and necessary t With a possible	o explain and o origin of varial	describe instabil pility being trans	ities. sits, stellar bina		•
and necessary t With a possible	o explain and o origin of varial	describe instabil pility being trans	ities. sits, stellar bina	ries and even exopla	nets are topics in
and necessary t With a possible this lecture. Ste	o explain and o origin of varial llar winds and	describe instabil pility being trans	ities. sits, stellar bina	ries and even exopla	nets are topics in
and necessary t With a possible this lecture. Ste Teaching forms	o explain and o origin of varial llar winds and lecture	describe instabil pility being trans mass transfer be	ities. sits, stellar bina etween stars ar	ries and even exopla e further issues in th	inets are topics in is context.
and necessary t With a possible this lecture. Ste Teaching forms Forms of exami	o explain and o origin of varial llar winds and lecture <b>nation</b> possibl	describe instabil pility being trans mass transfer be e are an oral exa	ities. sits, stellar bina etween stars ar	ries and even exopla	inets are topics in is context.
and necessary t With a possible this lecture. Ste Teaching forms Forms of exami Requirements f	o explain and o origin of varial llar winds and lecture nation possibl or the award o	describe instabil bility being trans mass transfer be e are an oral exa of credit points	ities. sits, stellar bina etween stars ar am, a short oral	ries and even exopla e further issues in th	inets are topics in is context.
and necessary t With a possible this lecture. Ste Teaching forms Forms of exami	o explain and o origin of varial llar winds and lecture nation possibl or the award o tion and a succ	describe instabil bility being trans mass transfer be e are an oral exa of credit points	ities. sits, stellar bina etween stars ar am, a short oral	ries and even exopla e further issues in th	inets are topics in is context.
and necessary t With a possible this lecture. Ste Teaching forms Forms of exami Requirements f active participat Use of the mod	o explain and o origin of varial llar winds and lecture nation possibl or the award o tion and a succ ule	describe instabil pility being trans mass transfer be e are an oral exa of credit points ressfull examinat	ities. sits, stellar bina etween stars an am, a short oral tion	ries and even exopla e further issues in th	inets are topics in is context. tten essay
and necessary t With a possible this lecture. Ste Teaching forms Forms of exami Requirements f active participat Use of the mod	o explain and o origin of varial llar winds and lecture nation possibl or the award o tion and a succ ule he grade for t	describe instabil pility being trans mass transfer be e are an oral exa of credit points ressfull examinat	ities. sits, stellar bina etween stars an am, a short oral tion	ries and even exopla e further issues in th presentation or writ	inets are topics in is context. tten essay
and necessary t With a possible this lecture. Ste Teaching forms Forms of exami Requirements f active participat Use of the mod Importance of t	o explain and o origin of varial llar winds and lecture nation possibl or the award o tion and a succ ule the grade for t ade	describe instabil pility being trans mass transfer be e are an oral exa of credit points ressfull examinat he final grade g	ities. sits, stellar bina etween stars ar am, a short oral tion raded, but does	ries and even exopla e further issues in th presentation or writ not contribute to th	inets are topics in is context. tten essay

	Credits	Workload	Semester	Turnus	Duration
	3 CP	90 h	8.	SoSe	1 Semester
Courses			Contact	Self Study	Group size
a) Lecture "Mo	odelling Trar	nsport and	Hours	a) 57 h	a) 20
Interactions	of Cosmic F	Rays"	a) 22 h		b) 20
b) Exercise "M	odelling Tra	nsport and	b) 11 h		
Interactions	of Cosmic F	Rays"			
Requirements	for			- 1	I
Participation					
Formal: none					
Content-Wise:	Knowledge	in one or mor	e of the followi	ng programming	languages Python, c++
and Fortran is	useful and r	ecommended			
Preparation: k	eine				
Learning Outco					
During this cou	•				_
<ul> <li>get farr</li> </ul>	iliar with di	fferent metho	ds to model the	e transport and ir	nteraction of cosmic
rays					
		ages and disa	dvantages of dif	fferent modeling	concepts based on th
	problems				
-	•	-			nodel CR transport
		•	uts into physica	•	
<ul> <li>gain ba</li> </ul>	sic knowled	ge to optimize	e the simulation	models based or	n measurements of C
observa	ables				
Contents					
		•	ingle particle p	ropagation and e	efficient nuclei-photo
	tion modelir	0			
			-	•	+ turbulent), ensemb
-	•	t (grid based	and stochasti	c differential eq	uations), nuclei-nucl
interac					The latest to the second of
			e evolution of	energy spectra,	tabulated interaction
•	natrix metho		luce. De maiek		
		o physics va	liues: Re-weigr	iting, normalizat	tion, comparison wit
observa					
Format of Tea			<u> </u>	<u> </u>	
					(90 min written exan
	am or week	ly nomework	including active	e participation) a	at the beginning of th
course.	(). All.				
•			edit Points Depe	ending	
on the kind of			a at least EO %	ftha nassihla na	vinta in the (hi )weekh
-			-		pints in the (bi-)weekly he exercise group is
	-			d at the beginnin	
Utilisation of t				u at the beginnin	
				t does not contrib	bute to the weighted
verage final gra			iain graueu, bu		
		ctructor Dr. L	ukac Morton Dr	of. Dr. Julia Tjus	
		50 UK IVI 1/1 1		vi. n. und hus	

Biophysics	I			_ <b>.</b>	
Modul 4b	Credits 15-25 CP	<b>Workload</b> 450-750 h	Semester 12. Sem.	<b>Cycle</b> Winter & Summer Term	Duration 2 Semesters
Courses e) Lecture f) Exercises g) Seminar (at least 2 CP) h) Advanced Laboratory Courses (at least 5 CP)			Contact Hours Each at least. e) 44 h f) 44 h g) 22 h h) 35 h	Self Study mind. 309 h	Group Size Students e) unlimited f) 30 g) 30 h) 2
of the individua semester hours semester week	rrent course c I courses resu per week (1 I = 1 CP).	atalogue. The CP Ilt from the nour per			
Requirements f Formal: none Content-Wise: Preparation: no	Knowledge fro	<b>on</b> om "Introduction	to Biophysics" v	vill be expected	
Univers <ul> <li>are abl</li> <li>commution</li> <li>can ind</li> </ul>	ity Bochum le to work o nicate them o ependently fir	out scientific cor confidently orally nd and use inforn	ntents, theories and in writing nation in the rele	in molecular bioph and methods inde evant databases nd structure with sui	pendently and to
Force fields, m spectroscopy a	olecular dyna oplied to curre		QM/MM simulation of the simulation of the second se	efinement, modelling ation, FTIR and Ram /ork	
	-	examination of 45			
The specialisati Including the fir after the final n	on module m nal oral modul nodule examir	nust include: adv le examination (2 nation no longer o	anced laborator CP), 15-25 CP ca count towards th	e oral examination. y courses (5 CP), a an be achieved. Achie ne module.	
		mpulsory-Electiv			
-		<b>the Final Mark</b> W Gerwert, Prof. Dr	-	g to Credit Points	
				ig, PD Dr. Kötting	
				es, please contact the	e module
supervisor. Plea					
Winter Semest					

160821 Laboratory Biophysics: Molecular Biology of Proteins for Physics Students

mann, Eckhard <b>ar Biophysics for Ph</b> mann, Eckhard	Laboratory ysics Students
	ysics Students
mann Eckhard	
	Laboratory
Kötting, Carsten	Seminar
ny (Literature Semir	nar)
	Lecture
Krebs, Hermann; Re	icherz, Gerhard
Labora	itory
fmann, Eckhard	Lecture
fmann, Eckhard	Exercises
mann, Eckhard	Seminar
Hofmann, Eckhard	Seminar
tics Hofmann, Eckha	ard
Rudack, Till	Seminar
	Seminar
oteincrystallograph	
lofmann, Eckhard	Seminar
ben, Mathias	Seminar
ben, Mathias; Köttir	ng Carsten;
(	Colloquium
	Laboratory
d Physiker / Advand	,
	Laboratory
	y (Literature Semin Krebs, Hermann; Re <i>Labora</i> mann, Eckhard mann, Eckhard Hofmann, Eckhard Hofmann, Eckhard ntics Hofmann,Eckhard Rudack, Till roteincrystallograph Hofmann, Eckhard ben, Mathias ben, Mathias; Köttir

	Credits	Workload	Semester	Turnus	Duration
	2 CP	60 h	1. Sem.	WiSe u. SoSe	1 Semester
Course			Contact	Self study	Group size
c) Seminar			Hour	c) 38 h	Students
			c) 22 h		c) unlimited
Participation re	equirements				
Formal: none	-				
Content: none					
Preparation: no	one				
Learning outco	omes:				
After successfu	I completion	of the module, s	students will hav	/e	
<ul> <li>gained</li> </ul>	an overview	of current metho	odological develo	opments and their a	pplications in the fiel
of theo	pretical bioph	ysics and structu	ural bioinformati	irs	
				10.5.	
<ul> <li>a basic</li> </ul>	understandi				e.
		ng of how to crit	ically evaluate a	nd present literatur	е.
acquire			ically evaluate a	nd present literatur	e.
acquire Content:	ed the basic c	ng of how to crit oncepts for a go	ically evaluate a od literature pre	nd present literatur esentation.	
<ul> <li>acquire</li> <li>Content:</li> <li>During the sem</li> </ul>	ed the basic c ninar, literatu	ng of how to crit oncepts for a go re on current ap	ically evaluate a od literature pre plications and m	nd present literatur esentation. nethodological deve	lopments in the field
acquire     Content:     During the sem     of theoretical b	ed the basic c ninar, literatu piophysics and	ng of how to crit oncepts for a go re on current ap	ically evaluate a od literature pre plications and m	nd present literatur esentation.	lopments in the field
acquire     content:     During the sem     of theoretical b     Teaching forms	ed the basic c ninar, literatu piophysics and s: Seminar	ng of how to crit oncepts for a go re on current ap d structural bioir	ically evaluate a od literature pre plications and m	nd present literatur esentation. nethodological deve	lopments in the field
acquire     Content:     During the sem     of theoretical b     Teaching forms     Forms of exam	ed the basic c ninar, literatu piophysics and s: Seminar nination: Sen	ng of how to crit oncepts for a go re on current ap d structural bioir ninar.	ically evaluate a od literature pre plications and m nformatics will b	nd present literatur esentation. nethodological deve	lopments in the field cussed.
acquire     content:     During the sem     of theoretical b     Teaching forms     Forms of exam     Requirements	ed the basic c ninar, literatu piophysics and s: Seminar nination: Sem for the Attrik	ng of how to crit oncepts for a go re on current ap d structural bioir ninar.	ically evaluate a od literature pre plications and m nformatics will b	nd present literatur esentation. nethodological deve ne presented and dis	lopments in the field cussed.
acquire     content:     During the sem     of theoretical b     Teaching forms     Forms of exam     Requirements     (>75%) and an	ed the basic c ninar, literatu piophysics and s: Seminar nination: Sen for the Attrik own literatur	ng of how to crit oncepts for a go re on current ap d structural bioir ninar. Dution of Credit re presentation.	ically evaluate a od literature pre plications and m nformatics will b	nd present literatur esentation. nethodological deve ne presented and dis	lopments in the field cussed.
<ul> <li>acquire</li> <li>Content:</li> <li>During the sem</li> <li>of theoretical b</li> <li>Teaching forms</li> <li>Forms of exam</li> <li>Requirements</li> <li>(&gt;75%) and an</li> <li>Use of the mode</li> </ul>	ed the basic c ninar, literatu piophysics and s: Seminar nination: Sem for the Attrik own literatur dule: Elective	ng of how to crit oncepts for a go re on current ap d structural bioir ninar. Dution of Credit e presentation. Module	ically evaluate a od literature pre plications and m nformatics will b <b>Points</b> : Active p	nd present literatur esentation. nethodological deve ne presented and dis	lopments in the field cussed. eminar events
acquire     content:     During the sem     of theoretical b     Teaching forms     Forms of exam     Requirements     (>75%) and an     Use of the mod	ed the basic c ninar, literatu piophysics and s: Seminar ination: Sen for the Attrik own literatur dule: Elective the grade for	ng of how to crit oncepts for a go re on current ap d structural bioir ninar. Dution of Credit e presentation. Module	ically evaluate a od literature pre plications and m nformatics will b <b>Points</b> : Active p	nd present literatur esentation. nethodological deve ne presented and dis participation in the s	lopments in the field cussed. eminar events
acquire     acquire     Content:     During the sem     of theoretical b     Teaching forms     Forms of exam     Requirements     (>75%) and an     Use of the moo     Importance of     average final gr	ed the basic c ninar, literatu piophysics and s: Seminar nination: Sen for the Attrik own literatur dule: Elective the grade for rade	ng of how to crit oncepts for a go re on current ap d structural bioir ninar. <b>Dution of Credit</b> e presentation. Module r <b>the final grade</b>	ically evaluate a od literature pre plications and m nformatics will b Points : Active p : graded, but do	nd present literatur esentation. nethodological deve ne presented and dis participation in the s	lopments in the field cussed. eminar events the weighted

	Credits 15-25 CP	<b>Workload</b> 450-750 h	Semester 12. Sem.	<b>Cycle</b> Winter & Summer	Duration 2 Semesters
Courses i) Lecture j) Exercises k) Seminar (at least 2 CP) l) 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			Contact Hours Each at least. i) 44 h j) 44 h k) 22 h l) 35 h	Term Self Study mind. 309 h	Group Size Students i) unlimited j) 30 k) 30 l) 2
semester week Requirements f	= 1 CP).	•			
<ul> <li>have a electric.</li> <li>are awa theoret</li> <li>know th</li> <li>are fam</li> <li>re able</li> </ul>	ly completing basic underst al, magnetic, i are of the pe ical and exper he basic conce iliar with basi to recognise o	mechanical and cossibilities within imental solid states of the theore correlations betw	operties of the s optical properties in the different ite physics etical description rocedures for mo veen the microso	solid state, its atomics research areas and of the solid state easuring solid state p copic structure of the echnological usability	specialisations of properties e solid body and its
superconducting places the main of special lectu Semiconductor Physics, Physic	g properties. areas of solid res are offere Physics and s of Thin Fil	Theoretical solid state physics on ed for in-depth s Semiconductor	l state physics de a solid quantum i study: Surface P Devices, Phase uring and Spint	ysics, especially opt eals with the many- mechanical basis. In a hysics, Magnetism, S Transitions, Metal F tronics, and other	body problem and addition, a number Superconductivity, Physics, Scattering
Deepening of k superconducting places the main of special lectu Semiconductor Physics, Physic experimental ar Format of Teacl	g properties. areas of solid res are offere Physics and s of Thin Fil nd theoretical hing Lecture,	Theoretical solid state physics on ed for in-depth s Semiconductor Ims, Nanostruct solid state physi Exercises, Semin	state physics de a solid quantum i study: Surface P Devices, Phase uring and Spint cs. ar, Laboratory W	eals with the many- mechanical basis. In a hysics, Magnetism, 1 Transitions, Metal F tronics, and other	body problem and addition, a number Superconductivity, Physics, Scattering
Deepening of k superconducting places the main of special lectu Semiconductor Physics, Physic experimental ar Format of Teacl	g properties. areas of solid res are offere Physics and s of Thin Fil nd theoretical hing Lecture,	Theoretical solid state physics on ed for in-depth s Semiconductor lms, Nanostruct solid state physi	state physics de a solid quantum i study: Surface P Devices, Phase uring and Spint cs. ar, Laboratory W	eals with the many- mechanical basis. In a hysics, Magnetism, 1 Transitions, Metal F tronics, and other	body problem and addition, a number Superconductivity, Physics, Scattering

Utilisation of the Module Compulsory-Elective Module

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

Module Supervisor Prof. Dr. HägeleExaminers Prof. Dr. Böhmer, Prof. Dr. Drautz, Prof. Dr. Eremin, Prof. Dr. Hägele, Prof. Dr. SchProf. Dr. Sulpizi, Prof. Dr. Wieck PD Dr. JukamFurther Information For advice and coordination of the courses, please contact the module	
Prof. Dr. Sulpizi, Prof. Dr. Wieck PD Dr. Jukam	
	erer,
<b>Further Information</b> For advice and coordination of the courses. please contact the module	
supervisor. Please see the <u>course list</u> below.	
Winter Semester	
160301 Scientific Methods of Semiconductor Physics Wieck, Andreas Lecture	
160302 Scientific Methods of Semiconductor Physics (Exercises) Wieck, Andreas	
Exercises	
160303 Semiconductor Physics I Ludwig, Arne Lecture	
160304 Semiconductor Physics I (Exercises) Ludwig, Arne Exercises	
160311 Physics of Quantum Cascade Lasers Jukam, Nathan Lecture	
160312 Physics of Quantum CascadeLasers (Discussion) Jukam, Nathan Seminar / Exercise.	5
160322 Selected Topics of Applied Solid State Physics Wieck, Andreas; Ludwig, Arne	
Seminar	
160324 Journal Club: Applied Solid State Physics Ludwig, Arne Seminar / Tex	atlektüre
160323 Spintronics and Ultrafast Spectroscopy Hägele, Daniel Seminar	
160350 Quantum Materials Böhmer, Anna Seminar	
160325 Solid State Physics Theory Eremin, Ilya Seminar	
160327 Selected Topics of Solid State Physics Theory Scherer, Michael Seminar	
160305 Compact Course: Practical Exercises in Semiconductor Technology Ludwig, Arne	
Compact Laboratory	
160351 Semiconductor Band Structures Ludwig, Arne Seminar / Led	ture
160250 Advanced Laboratory Course for Physics Students Krebs, Hermann; Reicherz, Ge	rhard
Laboratory	
Summer Semester	
160303 Introduction to Solid State Physics II Böhmer, Anna Lecture	
160304 Introduction to Solid State Physics II (Exercises) Böhmer, Anna; Kreyßig, Andre	eas
Exercises	
160306 Scientific Methods of Semiconductor Physics Wieck, Andreas Lecture	
160307 Scientific Methods of Semiconductor Physics (Exercises) Wieck, Andreas	
Exercises	
160309 Semiconductor Physics II: Experiments with Semiconductor Quantum Devices Ludw	ig, Arne
Lecture	
160310 Semiconductor Physics II (Exercises)Ludwig, ArneExercises	
160317 <b>Quantum Materials</b> Böhmer, Anna; Kreyßig, Andreas	
Lecture	
160318 Quantum Materials (Exercises)Böhmer, Anna; Kreyßig, Andreas	
160318 Quantum Materials (Exercises)Böhmer, Anna; Kreyßig, AndreasExercisesExercises	
Exercises160311 Advanced Solid State TheoryScherer, MichaelLecture	
Exercises160311 Advanced Solid State TheoryScherer, Michael160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercisesScherer, Michael	
Exercises160311 Advanced Solid State TheoryScherer, MichaelLecture160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercises160319 Physics of Complex Phase Transitions in SolidsScherer, Michael; Grünebohm, Anna	
Exercises160311 Advanced Solid State TheoryScherer, MichaelLecture160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercises160319 Physics of Complex Phase Transitions in SolidsScherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture	
Exercises160311 Advanced Solid State TheoryScherer, MichaelLecture160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercises160319 Physics of Complex Phase Transitions in SolidsScherer, Michael; Grünebohm, Anna	-
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Exercises160311 Advanced Solid State TheoryScherer, MichaelLecture160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercises160319 Physics of Complex Phase Transitions in SolidsScherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture160320 Physics of Complex Phase Transitions in Solids (Exercises)Scherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture160320 Physics of Complex Phase Transitions in Solids (Exercises)Scherer, Michael; Grünebo(not in SoSe 2023)Exercises(not in SoSe 2023)Exercises	-
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ExercisesExercises160311 Advanced Solid State TheoryScherer, MichaelLecture160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercises160319 Physics of Complex Phase Transitions in SolidsScherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture160320 Physics of Complex Phase Transitions in Solids (Exercises)Scherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture160315 Introduction to X-ray and Neutron ScatteringHolland-Moritz, DirkLecture160510 Surface Physics and ChemistryLinsmeier, ChristianLecture	ises
ExercisesExercises160311 Advanced Solid State TheoryScherer, MichaelLecture160312 Advanced Solid State Theory (Exercises)Scherer, MichaelExercises160319 Physics of Complex Phase Transitions in SolidsScherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture160320 Physics of Complex Phase Transitions in Solids (Exercises)Scherer, Michael; Grünebohm, Anna(not in SoSe 2023)Lecture160315 Introduction to X-ray and Neutron ScatteringHolland-Moritz, DirkLecture160510 Surface Physics and ChemistryLinsmeier, ChristianLecture160613 Introduction to Statistics for Astronomers and PhysicistsWright, Angu	ises

160330 Physical Principles of Quantum Information	Fistul, Mikhail	Lecture
160331 Physical Principles of Quantum Information (Ex	<b>(ercises)</b> Fistul, Mikha	ail Exercises
160332 Computer Simulations in Statistical Physics	Sulpizi, Marialore; Sett	anni, Giovanni
		Lecture
160333 Computer Simulations in Statistical Physics (Ex	ercises) Sulpizi, Marialo	re; Settanni, Giovanni
		Exercises
160322 Journal Club: Applied solid state physics	Wieck, Andreas; Ludwig	g, Arne
		Seminar
160323 Solid State Theory (Seminar)	Scherer, Michael	Seminar
160327 Superconductivity (Seminar)	Böhmer, Anna	Seminar
160358 Spintronics and Ultrafast Spectroscopy (Semin	ar) Hägele, Daniel	Seminar
(not in SoSe 2023)		
160326 Seminar on Quantum Materials (Seminar)	Böhmer, Anna	Seminar
(not in SoSe 2023)		
160353 Selected Topics of Applied Solid State Physics	Seminar) Wieck,	Andreas; Ludwig, Arne
		Seminar
160354 Selected Topics of Solid State Theory (Seminar	Eremin, Ilya	Seminar
160321 Semiconductor Band Structures	Ludwig, Arne	Seminar
160250 Fortgeschrittenen-Laboratory für Physikerinne	n und Physiker / Advan	ced Laboratory Course
for Physics Students Reicherz, Gerhard; Krebs, Herm	ann	Laboratory

	Credits	Workload	Semester	Turnus	DURATION
	4 CP	120 h	5./6. Sem.	WiSe / SoSe	1 week (plus
					preparation and
					a presentation o
					the results
Courses			Contact	Self Study	Group size
d) Labco	urses: Practic	al Exercises in	Hours	d) 80 h	Students
Semic	onductor Tec	hnology	d) 40 h		d) 3-5
Participation re	equirements				
Formal: prepar	ation of cont	ent			
Content: will b	•				
-	-			pplied Solid State	Physics" is
recommended	" Preparation	n of the content	will be checked i	n advance.	
Learning outco					
After successfu	•				
		-		nductor devices are	made from
semico	nductor chip	s. And how these	e functions are te	ested.	
		of the capabilitie	es of photo-litho	graphy, device test	ing setups, focused
ion imp	plantation.				
<ul> <li>studen</li> </ul>	ts know the k	pasic concepts of	semiconductor	devices	
<ul> <li>are fan</li> </ul>	hiliar with pho	oto lithography			
Content					
In the practical	course, stud	ents independen	tly produce a sir	nple field-effect tra	insistor. Basic
techniques of s learned.	emiconducto	or processing, suc	ch as photolithoរ្	graphy and wet che	emical etching, are
Furthermore, s	tudents will ι	use focused ion in	mplantation to n	nodify the electrica	l properties of
semiconductor			•	,	
The electrical c	haracterizati	on of the fabricat	ted devices is an	other focus of the	lab. Here, modern,
				acterization. Each p	
		•		, basics for the work	•
explained.					,
Tooching form		and locture			
Teaching form			ent and plan ho	w to measure the d	levice (mid term
		ion after the pra	•		
-		d of credit point			
Successful oral		•	3		
			sk in Courses in [	Physics Major	
		d lab course bloc the final grade			the weighted
importance of	the grade for	i the final grade	graueu, but doe	es not contribute to	ine weighted
-	ado				
average final g		<b>ne lecturer</b> Dr. A			

	Credits	Workload	Semester	Turnus	DURATION
	1 CP	30 h	410. Sem.	WiSe / SoSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
e) Semiı	nar		e) 11 h	e) 19 h	Students
					e) Unlimite
					d
Participation I	equirements				
Formal: none					
Content: none					
•		nd Participation	in module "Specia	al Problems in Appli	ed Solid State
Physics" is rec					
Learning outco					
	•	of the module			
				ind understand a sc	ientific article,
•	•	•	a compact and co	•	
<ul> <li>Studer</li> </ul>	nts are aware	of the capabilitie	es to access journ	al articles behind a	paywall from the
univer	sity bibliograp	ohic system			
		pasic concepts of	f scientific presen	tation of content, a	sk basic and
	fic questions				
<ul> <li>are fai</li> </ul>	niliar with lite	erature research	methods		
Content					
•	-	•		nt research publishe	
	•	•	•	he chosen paper the	
				ing questions, disc	•
•		•		vriting style, and bri	ng a healthy
	· · · · · · · · · · · · · · · · · · ·	aise) to the resul	ts.		
Teaching form					
Forms of exan					
•		d of credit point			
		sentation of a pa	•		
		in Physics Major			
Importance of	•	r the final grade	graded, but does	not contribute to t	he weighted
	rada				
average final g Module coord Other informa	inator/full-tir	<b>ne lecturer</b> Dr. A	Arne Ludwig		

Physic	cs of Q	uantum Ca	scade Lasers	<u> </u>				-
		Credits	Workload	Semes	ter	Turnus		DURATION
		3 CP	90 h	1./2.9	Sem.	WiSe / SoSe	è	1 Semester
Courses	5			Kontak	tzeit	Selbststudi	um	Group size
f)	Lecture	e "Physics of C	Quantum	f)	22 h	f) 57	h	Students
	Cascad	le Lasers"						f) Unlimite
g)	Discuss	sion "Physics c	of Quantum	g)	11 h			d
	Cascad	le Lasers"						
Particip	ation re	quirements						
Formal	: none							
Conten	<b>t:</b> none							
-		-	e of quantum me	chanics	is highly	recommend	ed	
	g outco							
After su		completion o						
•	Student	ts have a basic	understanding	of the ph	iysics ne	ecessary for la	asing	
•	Student	ts are aware o	f the capabilities	and app	lication	s of quantum	n cascad	le lasers
٠	Student	ts know the ba	asic concepts of s	solid-stat	te physi	cs, optical an	d laser p	physics that are
	necessa	ary for the des	ign of quantum (	cascade	asers.			
•	Student	ts are familiar	with different qu	uantum d	cascade	laser designs	5	
Conten	t							
This cou	urse will	cover the phy	sics necessary to	o underst	and qu	antum cascad	de lasers	s. Quantum
cascade	e lasers a	are a new class	s of semiconduct	tor lasers	s that ar	e based on ir	ntersubb	and transitions.
They er	nit radia	tion at mid-in	frared and far-in	frared w	aveleng	ths. This con	trasts w	ith conventional
ماممام			بالمحججا حبيح واحتوار					

They emit radiation at mid-infrared and far-infrared wavelengths. This contrasts with conventional diode semiconductor lasers which are based on interband transitions and emit radiation at visible and near-infrared wavelengths. The active region of a quantum cascade laser consists of repeating series (cascades) of quantum wells and barriers that are grown in Molecular Beam Epitaxy (MBE) or Metal Organic Vapor Deposition (MOCVD) machines. To achieve lasing, wavefunctions and levels should be designed to maximize/(minimize) the lifetime of the upper/(lower) laser level, reduce parasitic scattering, maximize injection into the upper laser level, and minimize losses. This requires a thorough 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

Teaching forms Lecture and exercise/discussion session

**Forms 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 award 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 Elective

**Importance of the final examination for the grade** The grade will be determined by the final examination.

Module coordinator/full-time lecturer Dr. Nathan Jukam (email: Nathan.Jukam@rub.de)

Other information

Scientif	fic Me	ethods of S	emiconducto	or Physics		
		Credits	Workload	Semester	Turnus	DURATION
		3 CP	90 h	3 6. Sem.	WiSe / SoSe	1 Semester
Courses				Kontaktzeit	Selbststudium	Group size
h) I	Lecture	, Scientific M	lethods of	h) 22 h	g) 57 h	Students
9	Semico	nductor Physi	cs (Lecture)"			g) Unlimite
i) I	Exercise	e "Scientific M	lethods of	i) 11 h		d
9	Semico	nductor Physi	cs (Exercices)"			h) 30
Participa	tion re	quirements				
Formal: r	none					
Content:	none					
Preparati	ion: no	ne				
Learning	outcon	nes				
After suce	cessful	completion of	f the module			
• s <sup>+</sup>	tudents	s have a basic	understanding of	of preparation, v	vork principles and a	nalytics of
S	emicon	ductor device	S			
• S	tudent	s are aware of	the capabilities	of semiconduct	ors in transport and	optics
• st	tudents	s know the bas	sic concepts of t	hermodynamics	concerning evapora	tion rates, electric
С	harge c	arrier densitie	es and excitation	ns in solids		
• a	ire fami	liar with elect	ron and hole dy	namics in semic	onductors	
• s <sup>+</sup>	tudents	s are able to re	ecognize connec	ctions between t	he materials and bar	idgaps, doping,
n	nobility	and electrical	l conductivity ar	nd apply this kno	wledge to all semico	nductors
Content						
Material	compo	sition of semio	conductors from	the periodic tal	ole, bandgaps, pn-jur	ction, Shockley-
equation,	, bipola	r transistor, h	istorical point-co	ontact Schottky-	transistor, field-effect	ct transistor,
current-v	oltage	(IV) measuren	nents, temperat	ure dependence	e of the electric carrie	er density, simple
basic circ	uits wit	h diodes and	transistors, nega	ative and positiv	e feedback, operatio	nal amplifiers,
linearizat	ion of r	non-linear acti	ve devices, nois	e, oscilloscope,	spectrum analyzer, lo	ock-in amplifier,
typical an	nd popu	ılar semicondı	uctor devices wi	th hints for thei	r applications in labor	ratory life,
checking	of indiv	idual or conn	ected devices, t	ypical failures in	electronics, electroly	tic capacitors and
their prob	blems, s	sustainability	aspects and plar	nned obsolescer	ce including strategi	es how to react,
repair str	ategies	of electronic	equipment.			
Teaching	forms	Vorlesung, Üb	oungsgruppe			
Forms of	exami	nation: In the	last part of the	semester, each	student performs a t	alk of 45 min.
about a s	elf-def	ined subject i	n the vicinity of	the lecture's co	ntents in front of the	e whole
auditoriu	ım and	the professor	. If this is not po	ossible for admi	nistrative reasons (e	.g. not enough
dates ava	ailable)	, an individua	l oral examinati	ion of 45 min. w	ill be performed.	
Requirem	nents fo	or the award o	of credit points			
Successfu	ul talk /	examination				
Use of th	e modu	<b>ule</b> Courses in	Physics Major			
Importan	nce of t	he grade for t	he final grade g	raded, but does	not contribute to the	e weighted
average f	final gra	de				
Module o	coordin	ator/full-time	<b>e lecturer</b> Prof. [	Dr. Andreas Wie	ck	
Other inf	formati	on				

<ul> <li>j) Seminar "Semiconductor Band j) 11 h h) 19 h Students i) Unlimited</li> <li>Participation requirements</li> <li>Formal: none</li> <li>Content: none</li> <li>Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.</li> <li>Learning outcomes</li> <li>After successful completion of the module</li> <li>students have a basic understanding of semiconductor band structure calculations</li> <li>Students are aware of the capabilities of software packages to perform complex device simulations</li> <li>students know the basic concepts of heterostructure devices</li> <li>are familiar with creating device concepts based on band structure and functionalities</li> </ul>	Semiconduc	tor Band S	tructures			
1 CP       30 h       1. / 2. Sem.       WiSe / SoSe       1 Semester         Courses       Semiconductor       Band       j) 11 h       h) 19 h       Students         Structures"       Semiconductor       Band       j) 11 h       h) 19 h       Students         Participation requirements       Formal: none       Formal: none       Formal: none       Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.         Learning outcomes       After successful completion of the module       semiconductor band structure calculations         • students have a basic understanding of semiconductor band structure calculations       • students have a basic concepts of heterostructure devices         • are familiar with creating device concepts based on band structure and functionalities       Content         The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the electrostaic potential and (quantized) energy states of carriers. In the seminar we will calculate the quantized states and the band structures. The structures devloped in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source Leviton devices.         The ability tr		Credits	Workload	Semester	Turnus	DURATION
Courses i) Seminar "Semiconductor Band ii) 11 h       Selbststudium h) 19 h       Group size Students Students ii) Unlimited         Participation requirements Formal: none Content: none Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended. Learning outcomes After successful completion of the module students have a basic understanding of semiconductor band structure calculations Students are aware of the capabilities of software packages to perform complex device simulations students know the basic concepts of heterostructure devices are familiar with creating device concepts based on band structure and functionalities Content The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the crystal matrix elements and dopants resulting in the band structure, the spatial arrangement of the crystal matrix elements and dopants resulting in the band structure, the spatial arrangement of the close relation to structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source. Leviton devices. Teaching forms Seminar, practicals Forms of examination active participation and presentation of an own simulation project Requirements for the award of credit points active participation and presentation				1. / 2. Sem.	WiSe / SoSe	
j) Seminar       Semiconductor       Band       j)       11 h       h)       19 h       Students         Structures"       Participation requirements         Formal: none       Content: none         Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.       Image: Content: None         Learning outcomes       After successful completion of the module       students have a basic understanding of semiconductor band structure calculations         •       Students have a basic understanding of semiconductor band structure calculations       students have a basic concepts of heterostructure devices         •       students know the basic concepts of heterostructure devices       are familiar with creating device concepts based on band structure and functionalities         Content       The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the crystal matrix elements and dopants resulting in the band structure, the spatial arrangement of the quantized states and the band structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electrons ource Leviton devices.         Teaching forms Seminar, practicials       Formon dive participa	Courses			Kontaktzeit	Selbststudium	
Structures"       i)       Unlimited         Participation requirements       Formal: none       Content: none         Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.       Image: Content: none         Learning outcomes       After successful completion of the module       Image: Content: none         •       students have a basic understanding of semiconductor band structure calculations         •       Students are aware of the capabilities of software packages to perform complex device simulations         •       students know the basic concepts of heterostructure devices         •       are familiar with creating device concepts based on band structure and functionalities         Content       The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the crystal matrix elements and dopants resulting in the band structure, the spatial arrangement of the electrostatic potential and (quantized) energy states of carriers. In the seminar we will calculate the quantized states and the band structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source Leviton devices.         Teaching forms Seminar, practicals       Forms of examinat	i) Seminar	"Semicondu	ictor Band			•
<ul> <li>Formal: none</li> <li>Content: none</li> <li>Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.</li> <li>Learning outcomes</li> <li>After successful completion of the module <ul> <li>students have a basic understanding of semiconductor band structure calculations</li> <li>Students are aware of the capabilities of software packages to perform complex device simulations</li> <li>students know the basic concepts of heterostructure devices</li> <li>are familiar with creating device concepts based on band structure and functionalities</li> </ul> </li> <li>Content The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the electrostatic potential and (quantized) energy states of carriers. In the seminar we will calculate the quantized states and the band structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source Leviton devices. Teaching forms Seminar, practicals Forms of examination active participation and presentation of an own simulation project Requirements for the award of credit points active participation and presentation of an own simulation project Requirements of the grade for the final grade graded, but does not contribute to the weighted average final grade Module coordinator/full-time lecturer Dr. Arne Ludwig</li></ul>	••				,	i) Unlimited
<ul> <li>Formal: none</li> <li>Content: none</li> <li>Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.</li> <li>Learning outcomes</li> <li>After successful completion of the module <ul> <li>students have a basic understanding of semiconductor band structure calculations</li> <li>Students are aware of the capabilities of software packages to perform complex device simulations</li> <li>students know the basic concepts of heterostructure devices</li> <li>are familiar with creating device concepts based on band structure and functionalities</li> </ul> </li> <li>Content The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the electrostatic potential and (quantized) energy states of carriers. In the seminar we will calculate the quantized states and the band structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source Leviton devices. Teaching forms Seminar, practicals Forms of examination active participation and presentation of an own simulation project Requirements for the award of credit points active participation and presentation of an own simulation project Requirements of the grade for the final grade graded, but does not contribute to the weighted average final grade Module coordinator/full-time lecturer Dr. Arne Ludwig</li></ul>	Participation red	quirements				
<ul> <li>Preparation: Participation in module "Special Problems in Applied Solid State Physics" is recommended.</li> <li>Learning outcomes</li> <li>After successful completion of the module         <ul> <li>students have a basic understanding of semiconductor band structure calculations</li> <li>Students are aware of the capabilities of software packages to perform complex device simulations</li> <li>students know the basic concepts of heterostructure devices</li> <li>are familiar with creating device concepts based on band structure and functionalities</li> </ul> </li> <li>Content</li> <li>The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the electrostatic potential and (quantized) energy states of carriers. In the seminar we will calculate the quantized states and the band structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source Leviton devices.</li> <li>Teaching forms Seminar, practicals</li> <li>Forms of examination active participation and presentation of an own simulation project</li> <li>Requirements for the award of credit points active participation and presentation of an own simulation project average final grade</li> <li>Module coordinator/full-time lecturer Dr. Arne Ludwig</li> </ul>	Formal: none					
<ul> <li>recommended.</li> <li>Learning outcomes</li> <li>After successful completion of the module         <ul> <li>students have a basic understanding of semiconductor band structure calculations</li> <li>Students are aware of the capabilities of software packages to perform complex device simulations</li> <li>students know the basic concepts of heterostructure devices</li> <li>are familiar with creating device concepts based on band structure and functionalities</li> </ul> </li> <li>Content</li> <li>The ability to create semiconductor heterostructures by combining different constituents from the periodic table of elements in perfect crystalline arrangements is a huge technological leap. It enabled the creation of highly efficient and miniaturized optoelectronic devices like laser light sources and ultrafast electronic components. Key to this is the control of the arrangement of the electrostatic potential and (quantized) energy states of carriers. In the seminar we will calculate the quantized states and the band structure of different devices like quantum wells, high electron mobility transistor and diode structures. The structures developed in practical exercises will be in close relation to structures used for quantum experiments with e.g. qubit, single photon source, and single electron source Leviton devices.</li> <li>Teaching forms Seminar, practicals</li> <li>Forms of examination active participation and presentation of an own simulation project</li> <li>Requirements for the award of credit points</li> <li>active participation and presentation</li> <li>Use of the module Courses in Physics Major</li> <li>Importance of the grade for the final grade graded, but does not contribute to the weighted average final grade</li> <li>Module coordinator/full-time lecturer Dr. Arne Ludwig</li> </ul>	Content: none					
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Module coordinator/full-time lecturer Dr. Arne Ludwig	•	-				
			e lecturer Dr. Ar	ne Ludwig		
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	Credits	Workload	Semester	Turnus	DURATION
	4 CP	120 h	59. Sem.	WiSe / SoSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
k) Lectu	re "Semicond	uctor Physics I	k) 33 h	i) 76 h	Students
(Lectu	ıre)"				j) Unlimite
l) Exerci	se "Semicond	luctor Physics I	l) 11h		d
(Exerc	cises)"				k) 30
Participation r	equirements				
Formal: none					
Content: none					
Preparation: n	one				
Learning outco					
After successfu	I completion	of the module			
		•		ng, electronic transp	oort, band
		s in semiconduct			
<ul> <li>Studer</li> </ul>	nts are aware	of the capabilities	s of different mo	dels applied to dese	cribe semiconducto
physic	S				
		basic concepts of	selected semicor	nductor devices	
<ul> <li>are far</li> </ul>	niliar with sen	niconductors			
Content					
•			• •	tics in semiconduct	
		•	•	escribe and methor	•
		ced. The physics	and operation p	rinciples of selected	semiconductor
devices are pre					
Teaching form					
		examination at th		ture	
•		d of credit points			
		aining class and p	bass the oral exa	m	
Use of the mo		in Physics Major			
	the grade for	the final grade a	graded, but does	not contribute to t	he weighted
•	-				
average final g	rade		-		
average final g	rade	ne lecturer Dr. Ar	rne Ludwig		

	Physics Th	Workload	Semester	Turnus	DURATION
	8 CP	240 h	1. / 2. Sem.	WiSe / SoSe	1 Semester
Courses	0.61	21011	Kontaktzeit	Selbststudium	Group size
m) Lecture C Theory n) Exercise fo		ced Solid State lid State Theory sics Theory"	m) 44 n) 22 o) 22 h	j) 152 h	l) Unlimited m) 25 n) 25
Formal: none	ic knowledge o	f solid state theor	y, statistical me	chanics and quantu	m mechanics is
Learning outo	comes ful completion				
<ul> <li>physi</li> <li>Stude secor</li> <li>stude phase</li> <li>stude formation</li> <li>stude</li> </ul>	cs including que ents are able to ad quantization ents know the e transitions in ents are familian alism for variou ents are able t	antum field theor o derive an effect and to compute of basic concepts of solid state system with Feynman di s model systems o employ simple	y methods and tive Hamiltonia elementary exci f functional intens agrams at zero e numerical alg	n methods of the the many-body theory n of the given solid tations and thermo- egral description of and finite temperat corithms to obtain Monte-Carlo or sin	state systems usin dynamic observable the thermodynam ures and can use th the thermodynam
<ul> <li>Green funct self-e</li> <li>Finite Funct</li> <li>Fluct</li> <li>Kubo</li> <li>Phase critic</li> <li>Cohe</li> </ul>	ions); Zero Ter energy, respons e Temperature tion and Wick's uation Dissipati Formula, e Transitions ar ality, rent states and	nteraction repres nperature Feynm e functions, the R Many Body Phy theorem, Examp on Theorem and nd broken symme path integrals, Eff	an Diagrams, F PA (Large-N) el- ysics, Imagina ples of the applic Linear Response etry, Ginzburg La fective action ar	en's Functions: Ma Feynman rules in m ectron gas; ary Time Green Fu cation of the Matsu e Theory, Electron t andau theory, Thern and Hubbard Stratono and the Kondo effect.	nomentum space, th unctions, Generatin bara Technique , ransport Theory, Th mal Fluctuations an pyich transformation
-		ersize, Seminar			1
examination. homework ar	(written exam nd active partic	of 90 min, oral ex ipation in the exe	am of 45 min o rcises) for the le	ecturer determines r an exercise certific ecture. The seminar the modern researc	cate with weekly is examined via a
-	•	d of credit points			
Passing the w	ritten/oral exa	orm of examination mination or obtai e participation in t	ning at least 50	% of the possible po	•

completed successfully. Both grades go into the module grade with the CP weighted

Use of the module Courses in Physics Major

**Importance of the grade for the final grade** graded, but does not contribute to the weighted average final grade

Module coordinator/full-time lecturer Prof. Dr. Ilya Eremin

Other information

	Credits	Workload	Semester	Turnus	DURATION
	2 CP	60 h	5 10. Sem.	WiSe / SoSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
-	ar "Spintroni roscopy"	cs and Ultrafast	p) 22 h	k) 38 h	Students o) Unlimite d
Participation re Formal: Lecture	•				
Content: none	, ,				
Preparation: P	hysik Illa/b				
linear o		-		asurement outcom	spectroscopy, non- nes, and spintronic
devices • Content Time-resolved	pptics, higher s. pump-probe	order coherence	h 100 fs – tempo	easurement outcom	linear optics. Spin
devices • Content Time-resolved noise spectroso	pptics, higher s. pump-probe copy. Second	order coherence spectroscopy wit order frequency	h 100 fs – tempo resolved spectra	easurement outcom pral resolution. Non Higher order polys	linear optics. Spin
devices • Content Time-resolved noise spectroso measurement.	pptics, higher s. pump-probe copy. Second Quantum Po	order coherence spectroscopy wit order frequency lyspectra. Optica	h 100 fs – tempo resolved spectra l spin injection. S	easurement outcom pral resolution. Non Higher order polys	linear optics. Spin
devices • Content Time-resolved noise spectroso measurement. Teaching forms	pptics, higher s. pump-probe copy. Second Quantum Po s Seminar tall	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an	h 100 fs – tempo resolved spectra l spin injection. S d instructors	easurement outcom oral resolution. Non . Higher order polys pin-transport.	-linear optics. Spin spectra and their
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam	pptics, higher s. pump-probe copy. Second Quantum Po s Seminar tall ination The s	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an	h 100 fs – tempo resolved spectra l spin injection. S d instructors	easurement outcom pral resolution. Non Higher order polys	-linear optics. Spin
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam is prepared for	pptics, higher s. pump-probe copy. Second Quantum Po s Seminar tall ination The s a subsequen	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an student prepares t discussion.	h 100 fs – tempo resolved spectra l spin injection. S d instructors and delivers a ta	easurement outcom oral resolution. Non . Higher order polys pin-transport.	-linear optics. Spin
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam is prepared for Requirements	pptics, higher s. pump-probe copy. Second Quantum Po s Seminar tall ination The s a subsequen for the awar	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an student prepares t discussion. d of credit points	h 100 fs – tempo resolved spectra l spin injection. S d instructors and delivers a ta	easurement outcom oral resolution. Non . Higher order polys pin-transport.	-linear optics. Spin spectra and their
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam is prepared for Requirements Successful exar	pptics, higher s. pump-probe copy. Second Quantum Po s Seminar tall ination The s a subsequen for the awar mination. Atto	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an student prepares t discussion. d of credit points	h 100 fs – tempo resolved spectra l spin injection. S d instructors and delivers a ta eminar and oral o	easurement outcom oral resolution. Non . Higher order polys pin-transport. lk at the seminar (3	-linear optics. Spin spectra and their
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam is prepared for Requirements Successful exar Use of the mod	pump-probe copy. Second Quantum Po s Seminar tall ination The s a subsequen for the award mination. Atto	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an student prepares t discussion. d of credit points endance of the se s in Physics Major	h 100 fs – tempo resolved spectra l spin injection. S d instructors and delivers a ta eminar and oral o	easurement outcom oral resolution. Non . Higher order polys pin-transport. lk at the seminar (3	-linear optics. Spin spectra and their 5-45 Minutes) and
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam is prepared for Requirements Successful exar Use of the mod Importance of	pump-probe copy. Second Quantum Po s Seminar tall ination The s a subsequen for the awar nination. Atto dule Courses the grade for	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an student prepares t discussion. d of credit points endance of the se s in Physics Major	h 100 fs – tempo resolved spectra l spin injection. S d instructors and delivers a ta eminar and oral o	easurement outcom oral resolution. Non . Higher order polys pin-transport. Ik at the seminar (3 contributions to disc	-linear optics. Spin spectra and their 5-45 Minutes) and
devices • Content Time-resolved noise spectroso measurement. Teaching forms Forms of exam is prepared for Requirements Successful exar Use of the moo Importance of average final g	pump-probe copy. Second Quantum Po s Seminar tall ination The s a subsequen for the awar mination. Atto dule Courses the grade for rade	order coherence spectroscopy wit order frequency lyspectra. Optica ks by students an student prepares t discussion. d of credit points endance of the se s in Physics Major	h 100 fs – tempo resolved spectra l spin injection. S d instructors and delivers a ta eminar and oral o graded, but does	easurement outcom oral resolution. Non I. Higher order polys pin-transport. Ik at the seminar (3 contributions to disc s not contribute to t	-linear optics. Spin spectra and their 5-45 Minutes) and

Solid State P Courses q) Seminar Theory"	Credits 2 CP	Workload	_	1	
q) Seminar	2 CP		Semester	Turnus	DURATION
q) Seminar		60 h	1. Sem.	WiSe	1 Semester
		I	Kontaktzeit	Selbststudium	Group size
	r "Solid State	e Physics	q) 22 h	l) 38 h	p) 25
		,	17	,	.,
Participation rec	uirements				
Formal: none					
	nowledge of	f solid state theo	orv. statistical me	chanics and quantu	m mechanics is
desirable			,,		
Preparation: nor	ne				
Learning outcom					
After successful of		of the module			
	-		lerstanding of th	e modern topics of	the solid state
theory			0		
•	are able to	work independe	ently with the mo	odern literature on t	heoretical and
		•	•	presentations on a g	
				y and can use them	-
		scientific article		,	
·					
Content					
Brief description	of the subje	ect content:			
- topologi	cal band the	ory and its appli	ication to the nov	vel quantum materi	als
- basics of	the quantu	m information a	nd qubits realiza	tion	
- concepts	s of Phase Tr	ransitions and br	oken symmetry		
- Coheren	t states and	path integrals,			
- Supercor	nductivity ar	nd BCS theory,			
To a chine former (	C i				
Teaching forms		ominar is avami	ad via a procent	ation by the studen	t on the colorted
			ied via a present	ation by the studen	t on the selected
topic, related to			-		
Requirements fo		•			
JDepending on the series				% of the nessible ne	vints in the weekly
-			-	% of the possible po	•
				, the F practical cou	form of examination
				e with the CP weigh	
sompleted succe	.ssiully. DUll	i Braues go into	the moune grau	c with the Cr weigh	
Use of the modu	Ile Courses i	n Physics Major			
				not contribute to t	he weighted
average final gra	-		Bradea, bat abes		
Module coordina		ne lecturer Prof	Dr. Ilva Fremin		
Other information					

	Credits	Workload	Semester	Turnus	DURATION
	2 CP	60 h	3 10. Sem.	WiSe / SoSe	1 Semester
Courses			Kontaktzeit	Selbststudium	Group size
r) Semi	nar "Selected	Topics of	r) 22 h	m) 38 h ?	Students
Appli	ed Solid State	Physics"	?		q) Unlimite
					d
Participation	requirements				
Formal: none					
Content: none					
Preparation:	None or "Parti	cipation in solid	state physics mod	dule is recommende	ed."
Learning outc					
	•	of the module			
			of applied solid		
		•		tors in transport an	•
		pasic concepts of	molecular beam	epitaxy and focuse	d ion beam
techn					
				emiconductor resea	
		recognize conne	ections between s	semiconductor mat	erials and their
	ations				
Content					
				search. In particula	
				ration of semicond	
				portant issue is the	
-			•	quently discussed s	•
systems in ger	-	photon sources,	quantum dots ar	nd low-dimensional	electrical carrier
· · ·		lks, discussions			
-			s a talk of 45 min	. plus discussion wi	thin the research
group		·			
Requirements	for the awar	d of credit point	s: Successful talk	with valid discussio	n
Use of the mo	dule: Courses	in Physics Majo	r		
Importance o	f the grade for	r the final grade:	graded, but does	s not contribute to	the weighted
average final g	grade				
Module coord	linator/full-tir	<b>ne lecturer:</b> Dr. /	<u>Arne Ludwig, P</u> rol	f. Dr. Andreas Wiec	K

	Credits	Workload	Semester	Turnus	Duration
	4 CP	120 h	ab 6. Sem.	SoSe	1 Semester
Course			Contact	Self Study	Group size
a) Lecture "Ph	nysical Princ	iples of	Hour	a) 76 h	Students
Quantum Ir	nformation"	1	a) 22 h		a) unlimited
b) Exercise "P	hysical Prine	ciples of	b) 22 h		b) unlimited
Quantum Ir	nformation"	1			
Participation	requiremen	ts			
Formal: none					
Content: Know	wledge of lir	near algebra, qu	iantum mecha	nics	
Preparation:	none				
Learning outc					
		• •	of quantum inf	formation and qu	antum engineering
with quantum	supercond	ucting circuits.			
and algorithn	ns, quantur	m computing,	adiabatic qua	ntum computin	n, i.e., quantum logio g, quantum games d. The second part o
In the first par and algorithn quantum mac the course wi	ns, quantur hine learnin II be devote	m computing, ng, quantum sim ed to a particula	adiabatic qua nulations etc.,	ntum computing will be addressed	g, quantum games d. The second part o
In the first par and algorithn quantum mac the course wi superconducti	ns, quantur hine learnin II be devote ing qubits ci	m computing, ng, quantum sim ed to a particula rcuits.	adiabatic qua nulations etc.,	ntum computing will be addressed	· · · •
In the first par and algorithn quantum mac the course wi superconducti Recommende	ns, quantur hine learnin II be devote ing qubits ci d literature:	m computing, ng, quantum sim ed to a particula rcuits.	adiabatic qua nulations etc., ar realization o	ntum computin will be addressed of quantum infor	g, quantum games d. The second part o mation devices, i.e.
In the first par and algorithn quantum mac the course wi superconducti Recommende • M. A. N	ns, quantur hine learnin II be devote ing qubits ci d literature: Nielsen, I. Cl	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu	adiabatic qua nulations etc., ar realization o m computatio	ntum computing will be addressed	g, quantum games d. The second part o mation devices, i.e. nformation"
In the first par and algorithm quantum mac the course wi superconduction Recommende • M. A. M • D. Heis	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Cl ss, "Fundam	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu	adiabatic qua nulations etc., ar realization o m computatio um informatio	ntum computin will be addressed of quantum infor n and quantum in	g, quantum games d. The second part o mation devices, i.e. nformation"
In the first par and algorithn quantum mac the course wi superconduction Recommende M. A. M D. Heis comm	ns, quantur hine learnin II be devote ing qubits ci d literature: Nielsen, I. Ch ss, "Fundam unication, d	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and	adiabatic qua nulations etc., ar realization o m computatio um informatio d all that"	ntum computin will be addressed of quantum infor n and quantum in	g, quantum games d. The second part o mation devices, i.e. nformation" putation,
In the first par and algorithm quantum mac the course wi superconduction Recommende • M. A. M • D. Heis commende • M. Kja	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Cl ss, "Fundam unication, d ergaard et a	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and il. "Superconduc	adiabatic qua nulations etc., ar realization o m computatio um informatio d all that"	ntum computin will be addressed of quantum infor n and quantum in n: quantum com	g, quantum games d. The second part o mation devices, i.e. nformation" putation,
In the first par and algorithn quantum mac the course wi superconducti Recommende • M. A. N • D. Heis comm • M. Kja Teaching form	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Ch ss, "Fundam unication, d ergaard et a <b>ns:</b> Lecture,	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and il. "Superconduc	adiabatic qua nulations etc., ar realization o m computatio um informatio d all that" cting qubits: Cu	ntum computin will be addressed of quantum infor n and quantum in n: quantum com	g, quantum games d. The second part o mation devices, i.e. nformation" putation,
In the first par and algorithn quantum mac the course wi superconducti Recommende • M. A. N • D. Heis comm • M. Kja Teaching form Forms of exar	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Cl ss, "Fundam unication, d ergaard et a ns: Lecture, nination: O	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and il. "Superconduc Exercises	adiabatic qua nulations etc., ar realization o m computatio um informatio d all that" cting qubits: Cu	ntum computin will be addressed of quantum infor n and quantum in n: quantum com urrent state of pl	g, quantum games d. The second part o mation devices, i.e. nformation" putation,
In the first par and algorithn quantum mac the course wi superconducti Recommende • M. A. N • D. Heis comm • M. Kja Teaching form Forms of exar Requirements	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Cl ss, "Fundam unication, d ergaard et a ns: Lecture, nination: O s for the aw odule: Electi	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and il. "Superconduc <u>Exercises</u> ral Exam 30 Mir <b>ard of credit po</b> ve Module	adiabatic qua nulations etc., ar realization o um informatio d all that" cting qubits: Cu ns. bints: Successf	ntum computin will be addressed of quantum infor n and quantum in n: quantum com urrent state of pl ul oral exam.	g, quantum games d. The second part o mation devices, i.e. nformation" putation, ay."
In the first par and algorithn quantum mac the course wi superconducti Recommende • M. A. N • D. Heis comm • M. Kja Teaching form Forms of exar Requirements	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Cl ss, "Fundam unication, d ergaard et a ns: Lecture, nination: O s for the aw odule: Electi	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and il. "Superconduc <u>Exercises</u> ral Exam 30 Mir <b>ard of credit po</b> ve Module	adiabatic qua nulations etc., ar realization o um informatio d all that" cting qubits: Cu ns. bints: Successf	ntum computin will be addressed of quantum infor n and quantum in n: quantum com urrent state of pl ul oral exam.	g, quantum games d. The second part o mation devices, i.e. nformation" putation, ay."
In the first par and algorithn quantum mac the course wi superconduction Recommende • M. A. N • D. Heis comme • M. Kja Teaching form Forms of exar Requirements Use of the moo Importance o	ns, quantur hine learnin Il be devote ing qubits ci d literature: Nielsen, I. Ch ss, "Fundam unication, d ergaard et a ns: Lecture, nination: O for the aw odule: Electi f the grade	m computing, ng, quantum sim ed to a particula rcuits. nuang, "Quantu entals of quant ecoherence and il. "Superconduc <u>Exercises</u> ral Exam 30 Mir <b>ard of credit po</b> ve Module	adiabatic qua nulations etc., ar realization o m computatio um informatio d all that" cting qubits: Cu ns. <b>Dints:</b> Successf	ntum computin will be addressed of quantum infor n and quantum in n: quantum com urrent state of pl ul oral exam.	g, quantum games d. The second part o mation devices, i.e. nformation" putation,

	Credits	Workload	Semester	Turnus	Duration
	4 CP	120 h	ab 5. Sem.	SoSe	1 Semester
Course			Contact	Self study	Group size
a) Lecture "Co	mputer Sim	ulations in	hour	a) 76 h	Students
Statistical P	hysics"		a) 22 h		a) unlmited
b) Exercise "Co		nulations in	b) 22 h		b) 30
Statistical P					
Participation r	equirement	ts			
Formal: none	•				
Content: none	. Recomme	nded: Basic cor	ncepts of classion	cal and statistica	l mechanics
Preparation: n	one		-		
Learning outco	omes:				
After successf	ully passing	the exam:			
• The stu	idents will h	nave an unders	tanding of the	algorithms used	I to perform state-of
the-art molecu	ılar dynamio	cs and Monte C	arlo simulatior	ns in Statistical Pl	nysics
• they w	vill be able	e to make co	mputer progra	ams to perform	and analyze thos
simulations					
• they w	ill have a ba	asic understand	ding of how to	optimize the pr	ograms for improve
efficiency • the	y will have	the knowledge	to use and un	derstand availat	ole program package
from the litera	ture to perf	orm the simula	itions.		
Content:					
Short introduc	tion to basio	c concepts of th	nermodynamic	s, statistical mec	hanics and
introduction to	error analy	ysis.			
Classical mole	ecular dyna	mics (MD): ir	ntegration algo	orithms, accura	cy, thermostats an
barostats, Ewa	ld summati	on.			
Monte Carlo a	and kinetic	Monte Carlo:	importance sa	impling, canonic	al ensemble, maste
equation.					
		ns and free end	• ·		
		roaches and de	•	-	
	•		he Lennard-Jor	ies fluid, MD sim	ulations of
biomolecules,	-				
Teaching form					
		ral Exam 30 Mi			
Requirements	for the awa	ard of credit po	oints: Successf	ul oral	
exam.					
Use of the mo					_
Importance of	the grade f	or the final gra	<b>U</b> ,		ibute to the weighte
			average fir		
Module coord	inator/full-	time lecturer:	Marialore Sulp	izi / Giovanni Set	ttanni
Further Inform			•		

	Credits	Workload	Semester	Cycle	Duration
	15-25 CP	450-750 h	12. Sem.	Winter & Summer	2 Semesters
				Term	
Courses			<b>Contact Hours</b>	Self Study	Group Size
m) Lecture			Each at least.	mind. 309 h	Students
n) Exercises			m) 44 h		m) unlimited
o) Seminar (at	least 2 CP)		n) 44 h		n) 30
b) Advanced La	aboratory Cou	rses (at least 5	o) 22 h		o) 30
CP)			p) 35 h		p) 2
A complete ove					
		atalogue. The CP			
of the individua					
semester hours	• •	nour per			
semester week	,				
Requirements : Formal: none	for Participat	on			
	Knowlades	om "Introduction	to Nuclear and	Darticla Dhusics"	he evented
Content-Wise: Preparation: no	-	om introduction	to inuclear and	Particle Physics" will	ne expected
earning Outco					
<ul> <li>are fam</li> </ul>	niliar with and	can internret No	bel Prize experir	ments in nuclear and	particle physics
<ul> <li>possess particle</li> </ul>	s a knowledge e physics	connection betw of open question	veen symmetries and current re	and experimental o search topics in the f and the development	field of nuclear an
<ul> <li>possess particle</li> <li>can exp</li> </ul> Contents Dirac equation strangeness, gr resonances, co parton model, states, Higgs m theories, solito	s a knowledge physics plain the conn oup the conn lours in QCD, deep inelasti nechanism of ns. In additio	connection betw of open question ection between p articles, conserva ad symmetry, Cle charm, confiner c scattering and mass production n, special events	veen symmetries as and current re particle physics a ation laws, Fey bsch-Gordon co nent, Global an scale behaviour , physics beyon are offered in	and experimental o esearch topics in the f	Field of nuclear and of the universe kawa interaction, nets, Breit-Wigner hadron structure, veak WW, mixing lel, quantum field and seminars on

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), 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.

Module Supervisor Prof. Dr. Wiedner, Prof. Dr. Epelba		
Examiner Prof. Dr. Epelbaum Prof. Dr. Fritsch, Prof. Dr	r. Heinsius, Prof. Dr. Tju	s, Prof. Dr. Wiedner, PD
Dr. Krebs,		
Further Information For advice and coordination of the	ne courses, please conta	ict the module
supervisor. Please see the <u>course list</u> below.		
Winter Semester		
60406 Symbolic Computation in Mathematica	Krebs, Hermann	Lecture
60412 Detectors and Algorithms for Charged Track R	econstruction Ritma	n, James
ntograted Evereises		Lecture with
ntegrated Exercises .60616 Theoretical Neutrino Astrophysics	Tjus, Julia	Lecture
.60617 Theoretical Neutrino Astrophysics (Exercises)	•	
	rjus, Julia, Mertell, Lu	Exercises
60420 Experimental Methods in Nuclear and Particle	Physics Wiedner Ulric	
	Thysics wreater, only	Seminar
60421 Detectors for Particle Physics	Wiedner, Ulrich; Heins	
	theatery enterly rien.	Seminar
60418 Seminar on Hadron Physics	Fritsch, Miriam	Seminar
.60422 Selected Topics of Hadron Physics I	Epelbaum, Evgeny; Kr	
······································	_p =,8e,,	Seminar
.60429 Current Topics in the Standard Model and bey	ond Epelbaum, Ev	geny
		Seminar
60250 Advanced Laboratory Course for Physics Stude	ents Krebs, Herma	nn; Reicherz, Gerhard
		Laboratory
Summer Semester		
60401 Introduction to Nuclear and Particle Physics II	Wiedner, Ulrich	
60402 Introduction to Nuclear and Particle Physics II		Lecture
and churchen to muchear and rather rigsits if	(Exercices) Wied	Lecture ner, Ulrich Exercises
<sup>60412</sup> Particle Detectors for Hadron Physics Experime	ents Ritman, James	ner, Ulrich Exercises s <i>Lecture</i>
<sup>60412</sup> Particle Detectors for Hadron Physics Experime	ents Ritman, James	ner, Ulrich Exercises s <i>Lecture</i>
.60412 Particle Detectors for Hadron Physics Experime .60413 Particle Detectors for Hadron Physics Experim	ents Ritman, James ents (Excercises) Ritma	ner, Ulrich Exercises s <i>Lecture</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experim 160409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev	ents Ritman, James eents (Excercises) <sub>Ritma</sub> re geny Exercise	ner, Ulrich Exercises s <i>Lecture</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 160409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I	ents Ritman, James nents (Excercises) <sub>Ritma</sub> re	ner, Ulrich Exercises s <i>Lecture</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023)	ents Ritman, James nents (Excercises) <sub>Ritma</sub> re geny Exercise Krebs, Hermann	ner, Ulrich Exercises 5 <i>Lecture</i> 1, James <i>Exercises</i> <i>Lecture</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises)	ents Ritman, James eents (Excercises) <sub>Ritma</sub> re geny Exercise	ner, Ulrich Exercises s <i>Lecture</i> n, James <i>Exercises</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises) not in SoSe 2023)	ents Ritman, James eents (Excercises) <sub>Ritma</sub> re geny Exercise Krebs, Hermann Krebs, Hermann	ner, Ulrich Exercises s <i>Lecture</i> n, James <i>Exercises</i> <i>Lecture</i> <i>Exercises</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises) not in SoSe 2023) 60405 Quantum Field Theory II	ents Ritman, James eents (Excercises) <sub>Ritma</sub> re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann	ner, Ulrich Exercises s <i>Lecture</i> n, James <i>Exercises</i> <i>Lecture</i> <i>Exercises</i> Lecture
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises) not in SoSe 2023) 60405 Quantum Field Theory II 60406 Quantum Field Theory II (Exercise)	ents Ritman, James nents (Excercises) <sub>Ritma</sub> re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann	ner, Ulrich Exercises s <i>Lecture</i> n, James <i>Exercises</i> <i>Lecture</i> <i>Exercises</i> Lecture Exercises
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises) not in SoSe 2023) 60405 Quantum Field Theory II 60406 Quantum Field Theory II 60411 Symbolic Computation in Mathematica	ents Ritman, James eents (Excercises) <sub>Ritma</sub> re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann	ner, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> Lecture Exercises Lecture Exercise <i>Lecture</i> <i>Exercise</i> <i>Lecture</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises) not in SoSe 2023) 60405 Quantum Field Theory II 60406 Quantum Field Theory II 60411 Symbolic Computation in Mathematica	ents Ritman, James eents (Excercises) <sub>Ritma</sub> re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann	ner, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> Lecture Exercises Lecture Exercise <i>Lecture</i> <i>Lecture</i> <i>Exercise</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i> <i>Lecture</i>
60412 Particle Detectors for Hadron Physics Experime 60413 Particle Detectors for Hadron Physics Experime 60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 60410 Theoretical Hadron Physics Epelbaum, Ev 60403 Quantum Field Theory I not in SoSe 2023) 60404 Quantum Field Theory I (Exercises) not in SoSe 2023) 60405 Quantum Field Theory II 60406 Quantum Field Theory II 60411 Symbolic Computation in Mathematica 60613 Introduction to Statistics for Astronomers and	ents Ritman, James nents (Excercises) Ritma re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Physicists Wrigh	ner, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> Lecture Exercises Lecture Exercise <i>Lecture</i> t, Angus <i>Lecture</i>
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160412 Particle Detectors for Hadron Physics Experime 160413 Particle Detectors for Hadron Physics Experime 160409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 160410 Theoretical Hadron Physics Epelbaum, Ev 160403 Quantum Field Theory I 1001 in SoSe 2023) 160404 Quantum Field Theory I (Exercises) 160405 Quantum Field Theory II 160406 Quantum Field Theory II 160406 Quantum Field Theory II (Exercise) 160411 Symbolic Computation in Mathematica 160613 Introduction to Statistics for Astronomers and 160419 Seminar on Hadron Physics (Seminar) 160420 Experimental Methods in Nuclear and Particle	ents Ritman, James ents (Excercises) Ritma re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Fritsch, Miriam Physics (Seminar)	ner, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> Lecture Exercise <i>Lecture</i> <i>Exercise</i> <i>Lecture</i> <i>t</i> , Angus <i>Lecture</i> <i>Seminar</i> Wiedner, Ulrich <i>Seminar</i>
160412 Particle Detectors for Hadron Physics Experime 160413 Particle Detectors for Hadron Physics Experime 160409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu 160410 Theoretical Hadron Physics Epelbaum, Ev 160403 Quantum Field Theory I 1001 in SoSe 2023) 160404 Quantum Field Theory I (Exercises) 160405 Quantum Field Theory II 160406 Quantum Field Theory II 160406 Quantum Field Theory II (Exercise) 160411 Symbolic Computation in Mathematica 160613 Introduction to Statistics for Astronomers and 160419 Seminar on Hadron Physics (Seminar) 160420 Experimental Methods in Nuclear and Particle	ents Ritman, James nents (Excercises) Ritma re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Fritsch, Miriam	her, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> <i>Lecture</i> <i>Exercises</i> <i>Lecture</i> <i>Exercise</i> <i>Lecture</i> <i>t</i> , Angus <i>Lecture</i> <i>seminar</i> Wiedner, Ulrich <i>Seminar</i> sius, Fritz-Herbert
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<ul> <li>60412 Particle Detectors for Hadron Physics Experime</li> <li>60413 Particle Detectors for Hadron Physics Experime</li> <li>60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu</li> <li>60410 Theoretical Hadron Physics Epelbaum, Ev</li> <li>60403 Quantum Field Theory I</li> <li>not in SoSe 2023)</li> <li>60404 Quantum Field Theory I (Exercises)</li> <li>not in SoSe 2023)</li> <li>60405 Quantum Field Theory II</li> <li>60406 Quantum Field Theory II (Exercise)</li> <li>60411 Symbolic Computation in Mathematica</li> <li>60613 Introduction to Statistics for Astronomers and</li> <li>60419 Seminar on Hadron Physics (Seminar)</li> <li>60421 Particle Physics Detectors (Seminar)</li> </ul>	ents Ritman, James ents (Excercises) Ritma re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Fritsch, Miriam Physicists Wrigh Fritsch, Miriam Wiedner, Ulrich; Heins	her, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> <i>Lecture</i> <i>Exercises</i> <i>Lecture</i> <i>Exercise</i> <i>Lecture</i> <i>t</i> , Angus <i>Lecture</i> <i>seminar</i> Wiedner, Ulrich <i>Seminar</i> sius, Fritz-Herbert <i>Seminar</i> ebs, Hermann
<ul> <li>60412 Particle Detectors for Hadron Physics Experime</li> <li>60413 Particle Detectors for Hadron Physics Experime</li> <li>60409 Theoretical Hadron Physics Epelbaum, Evgeny Lectu</li> <li>60410 Theoretical Hadron Physics Epelbaum, Evgeny Lectu</li> <li>60403 Quantum Field Theory I</li> <li>not in SoSe 2023)</li> <li>60404 Quantum Field Theory I (Exercises)</li> <li>not in SoSe 2023)</li> <li>60405 Quantum Field Theory II</li> <li>60406 Quantum Field Theory II (Exercise)</li> <li>60411 Symbolic Computation in Mathematica</li> <li>60613 Introduction to Statistics for Astronomers and</li> <li>60420 Experimental Methods in Nuclear and Particle</li> <li>60421 Particle Physics Detectors (Seminar)</li> <li>60426 Selected Topics of Hadron Physics II (Seminar)</li> </ul>	ents Ritman, James nents (Excercises) Ritma re geny Exercise Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Krebs, Hermann Physicists Wrigh Fritsch, Miriam Physics (Seminar) Wiedner, Ulrich; Heins Epelbaum, Evgeny; Kr	her, Ulrich Exercises <i>Lecture</i> <i>Lecture</i> <i>Exercises</i> <i>Lecture</i> <i>Exercises</i> <i>Lecture</i> <i>Exercise</i> <i>Lecture</i> <i>t</i> , Angus <i>Lecture</i> <i>seminar</i> Wiedner, Ulrich <i>Seminar</i> Sius, Fritz-Herbert <i>Seminar</i> ebs, Hermann <i>Seminar</i>
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Current Top		Standard Mod	-	r	Durati
	Credits	Workload	Semester	Cycle	Duration
_	2 CP	60 h	1. Sem.	Winter Term	1 Semester
Courses			Contact	Self-Study	Group Size
-	ar "Current To	•	Hours	n) 38 h	Students
	rd Model and	1	s) 22 h		r) 30
Requirements f	or Participati	on:			
Formal: none					
	•	•			anics and Quantum
•	-	ction to Theoreti	cal Hadron Phys	ics will be advanta	ageous.
Preparation: no					
Learning Outco					
		the module, the			
				particle physics, it	s successes and
	-	as current resea			
<ul> <li>Student</li> </ul>	ts have a deep	per understandin	g of the scientifi	c issues in the cho	osen focus area.
<ul> <li>student</li> </ul>	s have experi	ence in preparing	g and giving a sc	ientific presentation	on.
Contents					
				•	cs such as quantum
chromodynamic	cs, theory of t	he electroweak i	nteraction, anor	nalies, QCD metho	ods, precision tests o
the Standard M	odel, neutrine	o physics, physics	s beyond the Sta	ndard Model, etc.	
The seminar ser	rves the elabo	pration of a concr	ete topic. At the	beginning of the	seminar, different
•	•	•	•	ssed. Within the se	eminar series,
· · · · · · · · · · · · · · · · · · ·		ed and presented	J.		
Format of Teac	hing Seminar				
Format of Exam	nination Prese	entation			
<b>Requirements f</b>	or the Attrib	ution of Credit Po	oints		
Active participa	tion in the se	ssions, presentat	ion		
Utilisation of th	e Module Ele	ective Course			
Importance of t	the Mark for	the Final Mark gr	aded, but does not	contribute to the we	ighted average final grad
Module Superv	isor and Instr	uctor Prof. Dr. E	vgeny Epelbaum	n, Priv Doz. Dr. Hei	rmann Krebs
Further Informa	ation				

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	1. Sem.	Winter/Summer	1 Semester
				Term	
Courses			Contact	Self-Study	Group Size
	ar "Detector	s for Particle	Hours	o) 38 h	Students
Physic			t) 22 h		s) 30
Requirements	for Participa	tion			
Formal: none					
Content-Wise:					
Preparation: n					
Learning Outco	omes				
Students will	and to the second second	alata ata 11 Contra	hatania (control		
•			batomic particles		
			•	from subdetectors	
		tations of detect	tors		
			nics and data acc		
				uisition systems tailored experiment:	S.
Unders					s.
Unders     Contents	stand the inte	erplay between p	hysics goals and t	tailored experiment	
Unders     Contents     Detectors for c	stand the intended the harged and n	erplay between p eutral particles v	hysics goals and the second	tailored experiments	. The relevance of
Unders     Contents     Detectors for c     electronics and	harged and n data acquisi	erplay between p eutral particles v tion systems for	hysics goals and the second se	tailored experiments ages and drawbacks for systems. The inte	. The relevance of erplay between the
Unders     Contents     Detectors for c     electronics and     source of suba	harged and n data acquisi tomic particle	erplay between p eutral particles v tion systems for es and the desigr	with their advanta composed detect	tailored experiments ages and drawbacks for systems. The inte etector system tailor	. The relevance of erplay between the red to very specific
Unders     Contents     Detectors for c     electronics and     source of suba     physics goals. I	harged and n harged and n data acquisi tomic particle Multipurpose	erplay between p eutral particles v tion systems for es and the desigr	with their advanta composed detect of a complete de s at accelerators	tailored experiments ages and drawbacks for systems. The inte	. The relevance of erplay between the red to very specific
Unders     Contents     Detectors for c     electronics and     source of suba     physics goals. I     Format of Teac	harged and n harged and n d data acquisi tomic particle Multipurpose <b>ching</b> Semina	erplay between p eutral particles v tion systems for es and the desigr detector system r talks by the stu	with their advanta composed detect of a complete de is at accelerators dents.	tailored experiments ages and drawbacks for systems. The inte etector system tailor	. The relevance of erplay between the red to very specific ents.
Unders     Contents     Detectors for c     electronics and     source of suba     physics goals. I     Format of Teac	harged and n harged and n d data acquisi tomic particle Multipurpose <b>ching</b> Semina	erplay between p eutral particles v tion systems for es and the desigr detector system r talks by the stu	with their advanta composed detect of a complete de is at accelerators dents.	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achieveme	. The relevance of erplay between the red to very specific ents.
Unders     Contents     Detectors for c     electronics anc     source of subar     physics goals. I     Format of Teae     Format of Example     group.	harged and n harged and n data acquisi tomic particle <u>Multipurpose</u> ching Semina mination Prep	erplay between p eutral particles v tion systems for es and the desigr detector system r talks by the stu	with their advanta composed detect of a complete de s at accelerators dents. sequent presenta	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achieveme	. The relevance of erplay between the red to very specific ents.
Unders     Contents     Detectors for c     electronics and     source of suba     physics goals. I     Format of Teac     group.     Requirements	harged and n d data acquisi tomic particle <u>Multipurpose</u> ching Semina mination Pre for the Attril	erplay between p eeutral particles w tion systems for es and the desigr detector system r talks by the stu paration and sub	with their advanta composed detect of a complete de as at accelerators dents. sequent presenta	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achieveme ation of a seminar ta	. The relevance of erplay between the red to very specific ents.
Unders     Contents     Detectors for c     electronics anc     source of suba     physics goals. I     Format of Teae     Format of Example     group.     Requirements     Independent p	harged and n d data acquisi tomic particle <u>Multipurpose</u> <u>ching Semina</u> <b>mination</b> Prep <b>for the Attril</b> reparation of	erplay between p neutral particles w tion systems for es and the design detector system r talks by the stu paration and sub pution of Credit	with their advanta composed detect of a complete de as at accelerators dents. sequent presenta	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achievement ation of a seminar ta ectors and their phy	. The relevance of erplay between the red to very specific ents. Ik to the whole
Unders     Contents     Detectors for c     electronics and     source of suba     physics goals. I     Format of Tead     group.     Requirements     Independent p     comprehensive     Utilisation of t	harged and n d data acquisi tomic particle Multipurpose ching Semina mination Pre for the Attril reparation of e presentation he Module E	erplay between p neutral particles w tion systems for es and the design detector system r talks by the stu paration and sub <b>oution of Credit</b> a seminar talk a n of the material lective Course	with their advanta composed detect of a complete de s at accelerators dents. sequent presenta <b>Points</b> bout particle detect to the seminar p	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achieveme ation of a seminar ta ectors and their phy articipants.	. The relevance of erplay between the red to very specific ents. Ik to the whole sics goals. Clear and
Unders     Contents     Detectors for c     electronics and     source of suba     physics goals. I     Format of Tead     group.     Requirements     Independent p     comprehensive     Utilisation of t	harged and n d data acquisi tomic particle Multipurpose ching Semina mination Pre for the Attril reparation of e presentation he Module E	erplay between p neutral particles w tion systems for es and the design detector system r talks by the stu paration and sub <b>oution of Credit</b> a seminar talk a n of the material lective Course	with their advanta composed detect of a complete de s at accelerators dents. sequent presenta <b>Points</b> bout particle detect to the seminar p	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achieveme ation of a seminar ta ectors and their phy articipants.	. The relevance of erplay between the red to very specific ents. Ik to the whole
Unders     Contents     Detectors for c     electronics and     source of subar     physics goals. I     Format of Teae     Format of Exam     group.     Requirements     Independent p     comprehensive     Utilisation of t Importance of	harged and n d data acquisi tomic particle Multipurpose ching Semina mination Prep for the Attril reparation of e presentation he Module E the Mark for	erplay between p eeutral particles w tion systems for es and the design detector system r talks by the stu paration and sub <b>oution of Credit</b> a seminar talk a n of the material lective Course <b>the Final Mark</b>	with their advanta composed detect of a complete de s at accelerators dents. sequent presenta <b>Points</b> bout particle dete to the seminar p	tailored experiments ages and drawbacks for systems. The inte etector system tailor and their achieveme ation of a seminar ta ectors and their phy articipants.	. The relevance of erplay between the red to very specific ents. Ik to the whole sics goals. Clear and weighted average final g

	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	2. Sem.	Summer Term	1 Semester
Courses			Contact	Self-Study	Group Size
u) Semi	nar "Effective	Field Theories"	Hours	p) 38 h	Students
			u) 22 h		t) 30
Requirements	for Participat	ion:			
Formal: none					
<b>Content-Wise</b>	: Successful pa	irticipation in the	course Advanc	ed Quantum Mecha	inics; participation i
the lectures Q	uantum Field	Theory I and/or I	ntroduction to 7	Theoretical Hadron I	Physics will be
advantageous					
Preparation:	none				
Learning Outo					
		g the module, the			
<ul> <li>are fa</li> </ul>	miliar with the	basics of effective	ve field theories	and their application	ons in nuclear and
partic	le physics.				
<ul> <li>Stude</li> </ul>	nts have a dee	per understandir	ng of the scienti	fic issues in the cho	sen focus area.
<ul> <li>stude</li> </ul>	nts have exper	ience in preparin	ig and giving a s	cientific presentatio	n.
Contents					
				ogy of effective field	• •
	••			pics include the inte	•
	••		-	tion and renormalisa	• •
equation, EFT	for the treatm	ent of halo nucle	ei, EFT for BSM µ	ohysics, EFT of gravit	ty, etc.
The consider it			tonia Atthe	a sina in a af tha annu	and different texts
	-	•	•	eginning of the semi	•
are developed	• •		aiscussea. wit	hin the seminar seri	es, individual topics
Format of Tea					
Format of Exa	-				
		oution of Credit P	Points		
•		essions, presenta			
	the Module El				
			radad but daes no	t contributo to the weig	htod avorago final grad
	t tha Miark tor	the individing	i aueu, but uues no	it contribute to the welg	nieu average illiai glaue
Importance o			Evgony Englagy	m Priv Doz Dr Hor	mann Krohs
Importance o			Evgeny Epelbau	m, Priv Doz. Dr. Her	mann Krebs,

Experimenta	al Method	s in Nuclear a	nd Particle F	Physics	
•	Credits	Workload	Semester	, Cycle	Duration
	2 CP	60 h	1. Sem.	Winter/Summer	1 Semester
				Term	
Courses			Contact	Self-Study	Group Size
v) Semina	ar "Experime	ntal Methods in	Hours	q) 38 h	Students
Nuclea	r and Particle	e Physics"	v) 22 h		u) 30
<b>Requirements f</b>	or Participat	ion			
Formal: none					
Content-Wise:	none				
Preparation: no	one				
Learning Outco	mes				
Students will					
•			•	and particle physics	
<ul> <li>Present</li> </ul>	the underlyi	ng theoretical co	ncepts		
<ul> <li>Learn th</li> </ul>	ne interpreta	tion of experimer	ntal data		
Have a	basic knowle	dge of nuclear an	d particle physic	CS	
Be awai	re of the pred	cision of measure	ments and the c	uestion of statistics	
Contents					
Strong and wea	k interaction	s. Heavy ion and	neutrino physics	. Quantum field the	ory as underlying
theoretical cond	ept. Statistic	al interpretation	of data.		
Format of Teac	hing Seminar	r talks by the stud	ents.		
Format of Exam	<b>ination</b> Prep	paration and subs	equent presenta	ation of a seminar ta	lk to the whole
group.					
<b>Requirements</b> f	or the Attrib	ution of Credit P	oints		
	•		•	ectors and their phy	sics goals. Clear and
comprehensive	presentatior	n of the material t	o the seminar p	articipants.	
Utilisation of th	e Module El	ective Course			
Importance of t	he Mark for	the Final Mark gr	aded, but does not	contribute to the weight	ed average final grade
Module Superv	isor and Inst	<b>ructor</b> Prof. Dr. L	Jlrich Wiedner		
<b>Further Informa</b>	ation				

	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	7. Sem.	Summer Term	1 Semester
Courses			Contact	Self-Study	Group Size
w) Lecture	e "Introductio	on to Nuclear	Hours	r) 38 h	Students
and Pa	rticle Physics	· II"	w) 22 h	s) 38 h	v) Unlimite
x) Exercis	es "Introduct	tion to Nuclear	x) 22 h		d
and Pa	rticle Physics	II (Exercises)"			w) 30
Requirements f	or Participat	ion			
Formal: none					
		dge of nuclear ph	iysics.		
Preparation: no					
Learning Outco					
	•	n of the module			
		over the Standard		•	
		be the most impo	•		
	•	•		ods and techniques	
		-		etectors for subator	nic particles.
<ul> <li>Is the co</li> </ul>	onnection be	tween theory and	d experiment cle	ear.	
observation in a consequences for	historical co or the develo	ontext discussed.	Important expe	resented and their or rimental discoveries e course including in	experimental s and their mportant
observation in a consequences fo breakthroughs I included is a loo goals. Format of Teacl	historical co or the develo ike the disco k into the fu <b>hing</b> Lectures	ontext discussed. opment of the fiel very of the Higgs ture to address o s, exercises and sh	Important expe Id are part of the boson or the ok pen questions a hort presentatio	rimental discoveries e course including ir pservation of neutrin and the planned exp ons of the students	s and their nportant no oscillations. Also eriments and their
observation in a consequences fo breakthroughs l included is a loo goals. Format of Teach Format of Exam	historical co or the develo ike the disco k into the fu hing Lectures hination Succ	ontext discussed. opment of the fiel very of the Higgs ture to address o s, exercises and sh cessful and regula	Important expe d are part of the boson or the ob pen questions a hort presentation r participation i	rimental discoveries e course including in oservation of neutrin and the planned exp ons of the students n the exercise classe	experimental s and their mportant no oscillations. Also eriments and their es. In the homewor
observation in a consequences fo breakthroughs l included is a loo goals. Format of Teach Format of Exam section at least	historical co or the develo ike the disco ik into the fur hing Lectures hination Succ 50% of all po	ontext discussed. opment of the fiel very of the Higgs ture to address o s, exercises and sh cessful and regula ssible points. Stu	Important expe d are part of the boson or the ob pen questions a hort presentation r participation i dents are asked	rimental discoveries e course including in oservation of neutrin and the planned exp ons of the students n the exercise classe to present solution	experimental s and their mportant no oscillations. Also eriments and their es. In the homewor s to the problems a
observation in a consequences for breakthroughs l included is a loo goals. Format of Teach Format of Exam section at least least twice durin	historical co or the develo ike the disco k into the fur hing Lectures hination Succ 50% of all po ng the semes	ontext discussed. opment of the fiel very of the Higgs ture to address o s, exercises and sh cessful and regula ssible points. Stu	Important expe d are part of the boson or the ob pen questions a hort presentation r participation i dents are asked	rimental discoveries e course including in oservation of neutrin and the planned exp ons of the students n the exercise classe	experimental s and their mportant no oscillations. Also eriments and their es. In the homewor s to the problems a
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observation in a consequences for breakthroughs l included is a loo goals. Format of Teach Format of Exam section at least least twice durin previous lecture Requirements f Je nach festgele	historical co or the develo ike the disco ik into the fur ning Lectures ination Succ 50% of all po ng the semes twice. or the Attrib gter Prüfung	ontext discussed. opment of the fiel very of the Higgs ture to address o <u>s</u> , <u>exercises and sh</u> essful and regula ssible points. Stu ter to the group a <b>ution of Credit Po</b> sform:	Important expe d are part of the boson or the ob pen questions a hort presentation r participation i dents are asked and are asked to oints	rimental discoveries e course including ir oservation of neutrin and the planned exp ons of the students n the exercise classe to present solution o present a short su	experimental s and their mportant no oscillations. Also eriments and their es. In the homewor s to the problems a mmary of the
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observation in a consequences for breakthroughs l included is a loo goals. Format of Teach Format of Exam section at least least twice durin previous lecture Requirements f Je nach festgele The students ne and participate	historical co or the develo ike the disco ik into the fur hing Lectures ination Succ 50% of all po ng the semes twice. or the Attrib gter Prüfung eed to obtain actively in th	ontext discussed. opment of the fiel very of the Higgs ture to address o <u>s</u> , exercises and sh essible points. Stu- eter to the group a <b>ution of Credit Po-</b> sform: at least 50% of the e discussion of the	Important expe d are part of the boson or the ob pen questions a hort presentation r participation i dents are asked and are asked to oints he possible poin he exercises. Als	rimental discoveries e course including in pservation of neutrin and the planned exp ons of the students n the exercise classe to present solution o present a short su	experimental s and their mportant no oscillations. Also eriments and their es. In the homewor s to the problems a mmary of the octice assignments mmary of the
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observation in a consequences for breakthroughs l included is a loo goals. Format of Teach Format of Teach Format of Exam section at least least twice durin previous lecture Requirements f Je nach festgele The students ne and participate previous lecture Praktikum) are r grade of the mo Utilisation of th	historical co or the develo ike the disco ik into the fur ning Lectures ination Succ 50% of all po og the semes twice. or the Attrib gter Prüfung ed to obtain actively in the will be prese required. The dule. e Module Elector	ontext discussed. opment of the fiel very of the Higgs ture to address o <u>5, exercises and sl</u> essful and regula ssible points. Stu ter to the group a <b>ution of Credit P</b> sform: at least 50% of the ented in class. In e grades from the ective Course	Important expe d are part of the boson or the ob pen questions a hort presentation r participation i dents are asked and are asked to oints he possible poin he exercises. Als addition, the ad lectures/exerci	rimental discoveries e course including in oservation of neutrin and the planned exp ons of the students n the exercise classe to present solution o present a short sum that in the weekly pra- o, twice a short sum lvanced practical ex ses and the lab cour	experimental s and their mportant no oscillations. Also eriments and their es. In the homewor s to the problems a mmary of the ectice assignments mmary of the ercises (F- rse enter both the
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	Credits	Workload	Semester	Cycle	Duration
	2 CP	60 h	1. Sem.	Winter and	1 Semester
				Summer Term	
Courses			Contact	Self-Study	Group Size
y) Semina	r "Selected	Topics of	Hours	t) 38 h	Students
Hadron	Physics"	-	y) 22 h		x) 30
Requirements f	or Participa	tion:			·
Formal: none					
Content-Wise: 7	The seminar	is aimed at Mas	ter students and	PhD students who	are already familiar
with the basics of	of quantum	field theory, effe	ective field theor	ies and hadron phys	sics.
Preparation: no	ne				
Learning Outco	mes				
After successful	ly completir	ng the module, th	ne students		
<ul> <li>have an</li> </ul>	overview o	f the current res	earch directions	and questions in the	e field of theoretical
hadron	physics.				
<ul> <li>have ex</li> </ul>	perience in	preparing and gi	ving a scientific p	presentation.	
Contents					
The event deals	with curren	it developments	in hadron physic	s. External experts	are increasingly
invited to provid	le the broad	dest possible ove	rview of the rese	earch topics. Lecture	es are accompanied
by intensive tec	hnical discu	ssions and offer	the opportunity	to exchange ideas v	vith the speakers.
Scientific staff fr	om the Dep	partment of Theo	oretical Hadron P	hysics also take par	t in the event.
The participating	g students a	and doctoral can	didates have the	opportunity to pres	sent their latest
results and rece	ive feedbac	k.			
Format of Teach	ning Semina	r			
Format of Exam	ination Pre	sentation			
Requirements f	or the Attril	bution of Credit	Points		
Active participat	tion in the s	essions, presenta	ation		
Iltilisation of th	<b>e Module</b> E	lective Course			
ounsation of th					
	he Mark fo	r the Final Mark	graded, but does no	of contribute to the weig	nted average final grade
Importance of t				m, Priv. Doz. Dr. He	

Seminar on	Hadron P	hysics				
	Credits	Workload	Semester	Cycle	Duration	
	2 CP	60 h	1. Sem.	Winter Term	1 Semester	
Courses			Contact	Self-Study	Group Size	
z) Seminar "Seminar on Hadron		Hours	u) 38 h	Students		
Physics" z) 22 h y) 30						
Requirements	for Participat	tion				
Formal: none						
Content-Wise:	none					
Preparation: no	one					
<ul> <li>are fam</li> <li>know th</li> <li>know th</li> <li>leaned</li> <li>got an is</li> </ul> Contents Selected topics	niliar with a so he basic cond he basic cond about differe insight in a se in the field o	epts of different epts of detector ent concepts of p election of histor f Hadron Physics	ets in the field of l detector techno readout concept performing data a ical important ex	logies s and data process	dings omponents, Data	
historical impor		•	arysis methods, i			
Format of Teac						
Format of Exan						
Requirements	for the Attrib	ution of Credit	Points			
Regular attenda	ance, at least	75% of the cont	act hours necess	ary, preparation ar	nd giving of one	
presentation. O	only the Prese	entation is grade	d			
Utilisation of the	ne Module El	ective Course				
Importance of	the Mark for	the Final Mark	graded, but does not	contribute to the weig	hted average final grade	
Module Superv	visor and Inst	ructor Prof. Dr.	Miriam Fritsch			
<b>Further Inform</b>	ation					

Plasma Phy			1		r
Modul 4e	Credits 15-25 CP	<b>Workload</b> 450-750 h	Semester 12. Sem.	<b>Cycle</b> Winter & Summer Term	Duration 2 Semesters
Courses	•		<b>Contact Hours</b> Each at least.	Self Study mind. 309 h	<b>Group Size</b> Students
q) Lecture				11111u. 509 11	
r) Exercises	least 2 CD)		q) 44 h		q) unlimited
s) Seminar (at		reas (at least E	r) 44 h s) 22 h		r) 30 s) 30
CP)	aboratory Cou	rses (at least 5	t) 35 h		t) 2
A complete ov	erview of the (	sourses can be	tj 5511		() 2
•		atalogue. The CF	þ		
	al courses resu	-			
semester hour					
semester wee	•	<b>-</b>			
Requirements		ion	·		
Formal: none	-				
<b>Content-Wise</b>	: Basic knowled	dge of plasma ph	ysics will be expe	ected	
Preparation: r	none				
Learning Outc	omes				
After successfu	ully completing	the module, the	e students		
Have a	a basic underst	anding of the im	portant method	s of plasma generati	on and the heating
mecha	anisms of plasn	na			
Are fa	miliar with imp	ortant diagnosti	c methods of pla	sma	
Have a	a deepened ur	nderstanding of	the theoretical c	oncepts to describe	plasma in differen
scales	of time and sp	ace			
<ul> <li>Can application</li> </ul>	oply methods c	of measurement	of plasma		
Know	different fields	s of application c	of plasma, like int	eraction with biolog	ical systems or wit
	es of fusion ex				
				n Plasmen wie die W	
biolog	ischen System	en oder mit den	Oberflächen eine	s Fusionsexperiment	es
Contents					
-	•			cs of the plasma bou	
surface interac	ction; plasma c	hemistry, plasma	a deposition, plas	sma etching; waves i	n plasmas, etc.
			ar, Laboratory W	/ork	
		examination of 4			
•			-	oral examination.	
•				y courses (5 CP), a	
-		-	-	an be achieved. Achi	evements made
			count towards th	ne module.	
		mpulsory-Electiv			_
Importance of	the Mark for	<b>the Final Mark</b> V	Veighed accordin	g to Credit Points	
Module Super	<b>visor</b> Prof. Dr.	von Keudell			
			olda, Prof. Dr. Gr	auer, Jun-Prof. Dr. Ir	nocenti, Prof. Dr.
von Keudell, P	-				
Further Inform	<b>nation</b> For advi	ice and coordina	tion of the course	es, please contact th	e module
supervisor. Ple	ease see the <u>co</u>	<u>urse list</u> below.			
Minton Comoo	tor				
Winter Semes 60501 Introdu					

		<b>-</b> ·
160502 Introduction to Plasma Physics II (Exercises)	von Keudell, Achim	Exercises
160515 Modeling of Atomic Populations in the Spectr		• •
Plasmas	Marchuk, Oleks	
160516 Modeling of Atomic Populations in the Spectr		
Plasmas (Exercises)	Marchuk, Oleksandr	Exercises
160618 Introduction to Space Physics	Fichtner, Horst	Lecture
160619 Introduction to Space Physics (Exercises)	Fichtner, Horst	Exercises
160511 Confinement Concepts and Advanced Materia		
Christian; Unterberg, Bernhard; Co	-	Lecture
160521 Problems of Modern Plasma Physics	Czarnetzki, Uwe; Lugge	enhölscher, Dirk Seminar
160522 Applied Plasma Physics von Keudell, Achim; B	öke, Marc	-
	en, Volker; Golda, Judith	Seminar
160517 Selected Topics of Plasma Theory Graue	r, Rainer; Dreher, Jürgen	Seminar
160523 Compact Course: "Low Temperature Plasma F		
Class "Low Temperature Plasma Physics"		-
von Keudell, Achim; Böke, Marc; Schulz	von der Gathen, Volker	Compact Seminar
160510 Turbulence and Transport in Fusion Plasmas	Püschel, M.J.	Lecture
160526 Plasma Kinetics for Experimentalists Tsanko		~ · ~ ·
100520 Plasma kinetics for experimentalists Isanko	ov, Tsanko	Compact Seminar
160250 Advanced Laboratory Course for Physics Stud	•	n; Reicherz, Gerhard
•	•	•
•	•	n; Reicherz, Gerhard
•	•	n; Reicherz, Gerhard
160250 Advanced Laboratory Course for Physics Stud	•	n; Reicherz, Gerhard
160250 Advanced Laboratory Course for Physics Stud	ents Krebs, Herman r Gathen, Volker	n; Reicherz, Gerhard Laboratory
160250 Advanced Laboratory Course for Physics Stude         Summer Semester         160505 Plasma Diagnostics       Schulz-von der	ents Krebs, Herman r Gathen, Volker r Gathen, Volker	n; Reicherz, Gerhard <i>Laboratory</i> <i>Lecture</i>
Summer Semester         160505 Plasma Diagnostics       Schulz-von der         160506 Plasma Diagnostics (Exercises)       Schulz-von der	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture
Summer Semester         160250 Plasma Diagnostics       Schulz-von der         160506 Plasma Diagnostics (Exercises)       Schulz-von der         160510 Surface Physics and Chemistry       Linsmeier, Chr         160513 Introduction to Nuclear Fusion - Plasma- Wall	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture
Summer Semester         160250 Plasma Diagnostics       Schulz-von der         160506 Plasma Diagnostics (Exercises)       Schulz-von der         160510 Surface Physics and Chemistry       Linsmeier, Chr         160513 Introduction to Nuclear Fusion - Plasma- Wall	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian I- Interactions and Plasm erberg, Bernhard	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture a Edge Physics Lecture
160250 Advanced Laboratory Course for Physics Stude         Summer Semester         160505 Plasma Diagnostics       Schulz-von der         160506 Plasma Diagnostics (Exercises)       Schulz-von der         160510 Surface Physics and Chemistry       Linsmeier, Chr         160513 Introduction to Nuclear Fusion - Plasma- Wall       Unt         160511 Modeling of Atomic Populations in the Spectre	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian I- Interactions and Plasm erberg, Bernhard	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture a Edge Physics Lecture
160250 Advanced Laboratory Course for Physics Stude         Summer Semester         160505 Plasma Diagnostics       Schulz-von der         160506 Plasma Diagnostics (Exercises)       Schulz-von der         160510 Surface Physics and Chemistry       Linsmeier, Chr         160513 Introduction to Nuclear Fusion - Plasma- Wall       Unt         160511 Modeling of Atomic Populations in the Spectre	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian - Interactions and Plasm erberg, Bernhard roscopy of Laboratory an huk, Oleksandr	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture a Edge Physics Lecture d Astrophysical Lecture
160250 Advanced Laboratory Course for Physics Stude         Summer Semester         160505 Plasma Diagnostics       Schulz-von der         160506 Plasma Diagnostics (Exercises)       Schulz-von der         160510 Surface Physics and Chemistry       Linsmeier, Chr         160513 Introduction to Nuclear Fusion - Plasma- Wall       Unt         160511 Modeling of Atomic Populations in the Spectric       Plasmas II	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian I- Interactions and Plasm erberg, Bernhard roscopy of Laboratory an huk, Oleksandr roscopy of Laboratory an	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture a Edge Physics Lecture d Astrophysical Lecture
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160250 Advanced Laboratory Course for Physics StudSummer Semester160505 Plasma DiagnosticsSchulz-von der160506 Plasma Diagnostics (Exercises)Schulz-von der160510 Surface Physics and ChemistryLinsmeier, Chr160513 Introduction to Nuclear Fusion - Plasma- Wall(not in SoSe 2023)(not in SoSe 2023)Unt160511 Modeling of Atomic Populations in the Spectr Plasmas IIMarch160512 Modeling of Atomic Populations in the Spectr Plasmas II (Exercises)Marchuk, Ole160529 Introduction to HydrodynamicsFichtn	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian - Interactions and Plasm erberg, Bernhard roscopy of Laboratory an huk, Oleksandr roscopy of Laboratory an ksandr	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture a Edge Physics Lecture d Astrophysical Lecture d Astrophysical Exercises
160250 Advanced Laboratory Course for Physics StudeSummer Semester160505 Plasma DiagnosticsSchulz-von der160506 Plasma Diagnostics (Exercises)Schulz-von der160510 Surface Physics and ChemistryLinsmeier, Chr160513 Introduction to Nuclear Fusion - Plasma- Wall(not in SoSe 2023)(not in SoSe 2023)Unt160511 Modeling of Atomic Populations in the Spectr Plasmas IIMarch160512 Modeling of Atomic Populations in the Spectr Plasmas II (Exercises)Marchuk, Ole160529 Introduction to HydrodynamicsFichtn(not in SoSe 2023)Linsme Sin the SpectrPlasmas II (Exercises)Marchuk, Ole160529 Introduction to HydrodynamicsFichtn(not in SoSe 2023)Linsme Sin the SpectrLinsmas II (Exercises)Marchuk, Ole160529 Introduction to HydrodynamicsFichtn(not in SoSe 2023)Linsme Sin the Spectr	ents Krebs, Herman r Gathen, Volker r Gathen, Volker ristian I- Interactions and Plasm erberg, Bernhard roscopy of Laboratory an huk, Oleksandr roscopy of Laboratory an ksandr ler, Horst	n; Reicherz, Gerhard Laboratory Lecture Exercises Lecture a Edge Physics Lecture d Astrophysical Lecture d Astrophysical Exercises Lecture

	Credits	Workload	Semester	Cycle	Duration
	5 CP	120 h	1. Sem.	Winter Term	1 Semester
Courses			Contact	Self-Study	Group Size
aa) Lecture	e "introducti	ion to Plasma	Hours	76 h	Students
Physics II" (4	LCP)		aa) 22 h		z) unlimited
-	es "Introduc ‹ercises)" (1 C	tion to Plasma CP)	bb)22 h		aa) 30
Requirements	or Participati	on			
Formal: none					
Content-Wise:					
-	-			e.g. through the lea	cture "Introduction to
		out not mandatory	/•		
Learning Outco		of the medule			
	•	n of the module	of the essential	characteristics of a	low-temperature
plasma	LS HAVE A DASH	c understanding c			low-temperature
•	ts know the h	eating methods a	nd ignition nhe	enomena of a plasm	a
		-		f low-temperature	
			app::00.00000000		
Contents					
			ire plasmas, p	lasmas and their s	urface layers, plasm
		nical description			
				ments, ignition of	a plasma volume v
		, ignition phenom	-		
	-	-		eating, Wave Heati	ng, Global Model fo
	-	Electronegative Pl as: DC, RF, ECR, M		NAC	
•		e plasmas: coron	•		
			a, DBD, Iniciop	///////////////////////////////////////	
Format of Tead	-				
				ecturer determines	
		ution of Credit Po		cipation in the exerc	ises) for the lecture.
•		form of examinati			
	•			nossible noints in t	he weekly exercises.
-		-		s mandatory. The fo	•
		ginning of the cou			
Utilisation of t					
			raded, but does no	ot contribute to the weigh	ted average final grade
-					
Module Superv	isor and Inst	<b>ructor</b> Prof. Dr. A	chim von Keuc	dell, Prof. Dr. Judith	Golda

# Modelling of Atomic Populations in the Spectroscopy of Laboratory and Astrophysical Plasmas II

Astrophysica	al Plasmas	II			
	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	2. Sem.	Summer Term	1 Semester
Courses			Contact	Self-Study	Group Size
cc)Lecture "Mo	delling of Ato	mic Populations	Hours	76 h	Students
-	-	Laboratory and	cc) 22 h		bb) unlimited
Astrophysica	• •		dd) 22 h		cc) 30
• •		ng of Atomic	,		,
		ectroscopy of			
Laboratory a	and Astrophy	sical Plasmas II			
(Exercises)"					
Requirements f	or Participati	on			
Formal: none					
Content-Wise:	none				
Preparation: no	one				
Learning Outco	mes				
-		the module, the	students		
<ul> <li>have a</li> </ul>	basic underst	anding of atomi	c processes re	elevant to spectrosco	pic investigations
laborate	ory and astro	physical plasmas.			
<ul> <li>are aware of the possibilities of applying numerical methods in other areas of astrophy</li> </ul>					areas of astrophysic
and pla	sma physics.				
•		basic concepts o	f the Stroß rad	iation models and de	escribe the importai
		, plasma spectroso			
<ul> <li>are fam</li> </ul>	iliar with mod	lern methods of	plasma spectro	oscopy as well as on-	line tools like FLYCH
	/nlte.nist.gov		atomic	and spectros	
	-	gov/PhysRefData	/ASD/lines fo		
				isma physics and ap	oly them to differe
	scopic observ		·	.,	
Contents	•				
The lecture sum	marises the t	basics of the aton	nic models of p	olasma spectroscopy	. At first, relevant
				for the understandir	
•		•		ntum mechanics is de	-
-	-			Indation of plasma s	
				and from astrophys	
-				v available atomic co	-
	• • • •	•		niliar with the currer	
	-			earch if required.	
Format of Teac				·	
	-	examination of 4	5 minutes		
•		ution of Credit Po			
	•	orm of examinati			
Passing the oral	examination	or obtaining at le	east 50% of the	e possible points in t	he weekly exercise
tasks. In this cas	se, active part	icipation in the e	exercise is also	compulsory. The for	m of examination is
determined at t	he beginning	of the course.			
Utilisation of th					
	i <b>e Module</b> Ele				
Importance of t		ective Course	aded, but does no	ot contribute to the weig	nted average final grade

Module Supervisor and Instructor Priv. Doz. Dr. Oleksanr Marchuk

**Further Information** 

Plasma Diag	nostics					
0	Credits	Workload	Semester	Cycle	Duration	
	4 CP	120 h	2. Sem.	Summer Term	1 Semester	
Courses			Contact	Self-Study	Group Size	
ee) Lecture	"Plasma Dia	gnostics"	Hours	v) 38 h	Students	
ff) Exercises "Plasma Diagnostics" ee) 22 h w) 38 h dd) 30						
-	-		ff) 22 h			
Requirements f Formal: none Content-Wise: Preparation: no	none	ion				
<ul> <li>Know th</li> <li>Know the</li> <li>defined</li> <li>Versteh</li> </ul>	lly passing the he most impo o make the parameters hen Studieren	of a plasma	cal methods pice of a diagn e Auswahl eine	r Diagnostikmethod	he measurement of e zu treffen für die	
atomic physical and analysis of are explained in electron density the limits of the methodology, i. addition to the molecules and i	concepts are electrical par detail, the p and temper e methods are e., the mode optical methons ons is also de	e introduced. The ameters e.g., fro parameters that ature, are discus e shown. Particu of operation an ods, energy-reso ealt with.	e lecture begins om a probe mea can be directly a ssed, and the re llar emphasis is od use of optical	diagnostics. The essent with the presentation surement. The spect and indirectly derived espective area of app also placed on teach components and de troscopy for the dete	on of measurement croscopic methods d from them, e.g., lication as well as ing the experimental vices. Finally, in	
Format of Teac	hing Lecture,	Exercises				
		•	work The course	ework can take the fo	orm of a written test	
or an interview						
•		ution of Credit				
		h at least 50% of	r the achievable	points.		
Utilisation of th						
			-	ot contribute to the weig	nted average final grade	
		ructor Prof. Dr.	Volker Schulz-v	on der Gathen		
Further Informa	ation					

	Cred	its	Workload	Semester	Cycle	Duration
	2 CP		60 h	2. Sem.	Summer Term	1 Semester
Course	es			Contact	Self-study	Group size
gg) Leo	cture "Ion trans	port a	nd fluxes in low-	hours	x) 38 h	Students
temperature plasmas"		gg) 22 h		ee) unlimited		
Forma Conter e.g. thi Prepar	rough participat	nowlee tion in	dge of the concep the Module "Intr	oduction to Pla	blogy of the Plasma p asma Physics". asma Physics II" is re	
•	processes and influence of th the students a the students k	have the io nese pr ne fan anow t	a fundamental u on transport in nor rocesses on the sp niliar with the beh	n-magnetized l patial structure navior of plasm	of the ion product ow-temperature pla e of the discharge. has with different lev eaths and quasi-neut	smas as well as of th els of collisionality.
•	plasma. the students a type of gas, e	are abl tc.) an	e to recognize the d plasma parame	e relations bet ters (electron	ds for measuring the ween the discharge temperature and de in a laboratory plasn	e ion parameters of conditions (pressure ensity) and can app
• Conter 1. 2. 3. 4. 5. 6.	plasma. the students a type of gas, e this knowledg nts Ion production Ion collisional Ion transport i Kinetics of the Ion transport a Experimental	are abl tc.) an e for t n and l proce in space ion tr and wa diagno	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in	e relations bet ters (electron he conditions and neutral p	ween the discharge temperature and de in a laboratory plasn	e ion parameters of conditions (pressure ensity) and can app
• Conter 1. 2. 3. 4. 5. 6. <b>Teachi</b>	plasma. the students a type of gas, e this knowledg nts Ion production Ion collisional Ion transport i Kinetics of the Ion transport a Experimental ng format Lectu	are abl tc.) an e for t n and l proce in space in space in space in space in space in space in space in space in space in space	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods	e relations bet iters (electron he conditions and neutral p n plasmas	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressure ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin	plasma. the students a type of gas, e this knowledg nts Ion production Ion collisional Ion transport a Kinetics of the Ion transport a Experimental ng format Lecture nation format C	are abl tc.) an e for t n and l proce in space in space i	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods	e relations bet ters (electron he conditions and neutral p n plasmas 45 min ongiver	ween the discharge temperature and de in a laboratory plasn	e ion parameters of conditions (pressure ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin Requir	plasma. the students a type of gas, e this knowledg nts lon production lon collisional lon transport i Kinetics of the lon transport a Experimental ng format Lectur nation format C	are abl tc.) an e for t n and l proce in space in space i	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods amination within rution of the credi	e relations bet ters (electron he conditions and neutral p n plasmas 45 min ongiver	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressure ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin Requir Passing	plasma. the students a type of gas, e this knowledg nts Ion production Ion collisional Ion transport i Kinetics of the Ion transport a Experimental ng format Lecturnation format C rements for the g the oral exami	are abl tc.) an e for t n and l proce in space in space i	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods amination within ution of the credin	e relations bet ters (electron he conditions and neutral p n plasmas 45 min ongiver	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressure ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examir Requir Passing Utiliza	plasma. the students a type of gas, e this knowledg nts Ion production Ion collisional Ion transport i Kinetics of the Ion transport a Experimental ng format Lecturnation format C rements for the g the oral examination of the Moo	n and l proce in space in spac	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods <u>amination within</u> ution of the credin n ective course	e relations bet ters (electron he conditions and neutral p n plasmas 45 min ongiver it points	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressur ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin Requir Passing Utiliza	plasma. the students a type of gas, e this knowledg nts lon production lon collisional lon transport i Kinetics of the lon transport a Experimental ng format Lectur nation format C rements for the g the oral exami tion of the Moo tance of the gra	n and l proce in space in spac	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods <u>amination within</u> ution of the credin n ective course	e relations bet ters (electron he conditions and neutral p n plasmas 45 min ongiver it points	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressur ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin Requir Passing Utiliza Import averag	plasma. the students a type of gas, e this knowledg nts lon production lon collisional lon transport i Kinetics of the lon transport a Experimental ng format Lecturnation format C rements for the g the oral exami tion of the Moo tance of the gra ge final grade	n and l proce in space in space in space ion tr and wa diagno <u>ure</u> <u>Dral ex</u> <b>attrib</b> ination dule El de for	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods <u>amination within</u> <b>ution of the credi</b> n ective course r <b>the final grade g</b>	e relations bet iters (electron ihe conditions and neutral p n plasmas 45 min on giver it points raded, but doo	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressur ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin Requir Passing Utiliza Import averag Modul	plasma. the students a type of gas, e this knowledg nts lon production lon collisional lon transport a Kinetics of the lon transport a Experimental ng format Lecture nation format C rements for the g the oral exami tion of the Moo tance of the grade le supervisor an	n and l proce in space in space in space ion tr and wa diagno <u>ure</u> <u>Dral ex</u> <b>attrib</b> ination dule El de for	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods <u>amination within</u> ution of the credin n ective course	e relations bet iters (electron ihe conditions and neutral p n plasmas 45 min on giver it points raded, but doo	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters of conditions (pressur ensity) and can app na.
• Conter 1. 2. 3. 4. 5. 6. Teachi Examin Requir Passing Utiliza Import averag Modul Furthe	plasma. the students a type of gas, e this knowledg nts lon production lon collisional lon transport i Kinetics of the lon transport a Experimental ng format Lectur nation format C rements for the g the oral exami tion of the Moo tance of the grad ge final grade e supervisor an ir information	are abl tc.) an e for t n and l proce in space ion tr and wa diagno in space ion tr and wa diagno <u>ure</u> Dral ex attrib inatior <b>lule</b> El od inst	le to recognize the id plasma parame he estimation of t loss processes sses with charged ce charge sheaths ransport ave phenomena in ostic methods amination within ution of the credien ective course r the final grade g	e relations bet eters (electron he conditions and neutral p n plasmas 45 min on giver it points raded, but doo	ween the discharge temperature and de in a laboratory plasm articles	e ion parameters o conditions (pressur ensity) and can app na.

## Modul 5.x Compulsory Elective Modules from the Minor Subject

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.

from the range of courses offered by the Faculty of **Chemistry and Biochemistry**:

Minor Subject:	Modules
Analytical Chemistry	Methods of Structure Analysis II
Anorganic Chemistry:	Anorganical Chemistry II
	Block Courses Anorganical Chemistry
Biochemistry	Laboratory Biochemical Working Techniques
	Introduction to Biochemistry
	Biochemistry I
Physical Chemistry	Laser Spectroscopy Laboratory
	Rasterforce Microscopy Laboratory
	Biophysical Chemistry I (not in SoSe 2023)
	Biophysical Chemistry II
	Physical-Chemical Laboratory
	Physical Chemistry II
	Concepts of Spectroscopy and Introduction in Laser Spectroscopy
	Concepts of Spectroscopy II
Technical Chemistry	Technical Chemistry I
	Technical Chemistry II
	Chemical-Technical Laboratory for Physicists
Theoretical Chemistry	Theoretical Chemistry I
	Theoretical Chemistry II
	Theoretical Chemistry III
	Theoretical-Chemical Laboratory for Physicists

From the range of courses from the Faculty of **Geosciences**:

Minor Subject:	Modules
Geophysics*	Geophysical Inverse Problems (winter)
	Seismic and Electromagnetic Field Methods (winter)
	Reservoir Geophysics (summer)
	Rock Physics (summer)
	Geophysical Pratical (winter and summer)
	Seismologic Data Analysis (summer)
	Seismic Waves: Theory and Numerical Modelling (summer)
	Physics of Earth Materials (winter)
	Earthquake Seismology and the Seismic Cylce (winter)

<sup>\*</sup> we recommend an in-person interview with 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:** 

Minor Subject:	Modules
Plasmatechnology*	Plasmatechnology I
	Fields, Waves and Particles
Nanoelektronics**	Solid State Electronics
	Nanoelektronics (not in SoSe 2023)
Microelektronics	VLSI-Design
	Integrated Digital Circuits
Technology of Energy	Introduction to Technology of Energy Systems
Systems	
	Technology of Regenerative Electric Energy
Communication Technology	Systems of High Frequency Technology
	Digital Processing of Signals
Medical Technology	Ultrasound in Medicin
	Tomographical Imaging in Medicin
	Image Processing in Medicin

\*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**:

Minor Subject:	Modules	
Laser Application Technology*	Laser Technology	
	Laser Measurement Technology	
	Laser Manufacturing Technology	
	Laser Technology in Medicin	
Systems and Economics of		
Energy	Energy Economics	
	Energy Conversion Systems	
	Regenerative Energy	
	Technology of Nuclear Power Plants	
	Technology of Nuclear Reactors	
	Water Power Plants	(not in SoSe 2023)
Material Sciences	Basic Materials	
	Material Sciences I	
	Material Sciences II	
	Polymere Materials	
	Light Metals and Composites	
	Electron and X-Ray Diffraction	

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

From the range of courses from the Faculty of Mathematics:

Minor Subject:	Modules
Algebra	Algebra I
	Algebra II (Commutative Algebra and Algebraic Geometry)
	Numbers Theory
	Theory of Representation of Lie-Groups
Geometry/Topology	Curves and Areas
	Differential Geometry I
	Differential Geometry II
	Differential Topology
	Topology I
	Algebraic Topology
Analysis	Functional Analysis
	Function Theory I
	Function Theory II
	Common Differential Equations
	Partial Differential Equations I
	Curves and Areas
	Differential Geometry I
	Differential Geometry II (not in SoSe 2023)
	Differential Topology
Numerical Mathematics	Numerics I (Numerical Treament of Differential Equations I)
	Numerics II (Numerical Treatment of Differential Equations II)
	Optimisation
Probability Theory and	
Statistics	Probability Theory I
	Probability Theory II (Stochastical Models)
	Statistics I
	Statistics II
	Mathematical Physics
	Financial Mathematics (not in SoSe 2023)
	Number Series (not in SoSe 2023)
Computer	Theoretical Computer Science
Science/Cryptography	
	Complexity Theory
	Cryptography
	Approximation Theory
	Data Structures
	Databank Systems
	Discrete Mathematics I
	Quantum Algorithms
	Efficient Algorithms
	Cryptanalysis
	Theory of Machine Learning
	Algorithmic Geometry
	Cryptographic Protocols

From the range of courses from the Faculty of **Neuroinformatics**:

Minor Subject:	Modules				
Neuroinformatics	Computational Neuroscience: Neural Dynamics				
	Computational Neuroscience: Vision and Memory (not in SoSe 2023)				
	Autonomous Robotics (lab course)				
	Autonomous Robotics: Action, Perception and Cognition				
	Machine Learning: Unsupervised Methods				
	Machine Learning: Supervised Methods				
	Machine Learning: Evolutionary Algorithms				
	Introduction to Deep Learning for Computer Vision (lab course)				
	Introduction to Perception				
	The Neural Basis of Vision (seminar)				
	Computational Cognitive Modeling (seminar)				
	Deep Learning Computer Vision				

From the range of courses from the **ICAMS**:

Minor Subject:	Modules				
Material Sciences	Elements of Microstructure				
	Assessment and Description of Materials Properties	(not in SoSe 2023)			
	Materials Processing	(not in SoSe 2023)			
	Atomistic Simulation Methods				
	Advanced Atomistic Simulation Methods				
	Interfaces and Surfaces				
	Application and Implementation of Electronic Structu	ure Methods			
	Phase Field Theory and Application				
	Phase Field Theory II				
	Programming Concepts in Materials Science				
	Quantum Mechanics in Materials Science				
	Microstructure and Mechanical Properties				
	Continuum Methods in Materials Science				
	The Calphad Method				
	Multiscale Modeling in Materials Science				
	Numerical Simulation of Fracture of Materials         (not in SoSe 2023)				
	Lattice Boltzmann Modelling: From Simple Flows to Interface Driven				
	Phenomena				
	Modelling of Metal Plasticity in Finite Element Analys	sis (not in SoSe 20			
	Solidification Processing				
	Stochastische Prozesse	(not in SoSe 2023)			

Computatio	nal Physic	s I			
Module 6a	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	from 5. Sem.	Winter Term	1 Semester
Courses			Contact Hours	Self Study	Group size
a) Lecture Com	putational Pl	nysics I	a) 22 h	76 h	Students
b) Exercises Co	mputational	Physics I	b) 22 h		a) unlimited b) 30
Requirements f	or Participat	ion			
Content-Wise:	none				
Preparation: no					
Learning Outco					
After successful		the module th	ne students		
				methods and pro	cedures for dealing
	ysical proble	-		includus and pro	cedures for dealing
			crete implementat	ion and verification	on
	•		physical model pro		
			,		
Contents					
Numerical diffe	rentiation an	id integration, o	rdinary and partia	al differential equ	ations, linear systems
of equations, FF	T, Monte Ca	rlo methods, pra	actical exercises w	ith Matlab, Pytho	n or Julia.
Format of Teac	hing Lecture,	Exercises			
Format of Exam	<b>ination</b> At th	e beginning of tl	he course, the lect	urer determines t	he form of examination
(written examir	nation of 90	min, oral exam	ination of 45 mir	n or an exercise o	certificate with weekly
homework and	active partici	ipation in the ex	ercises) for the lea	cture.	
Requirements f	ort he attrib	ution of Credit I	Points Depending	on the specified f	orm of examination:
Passing the wri	tten/oral exa	amination or ob	taining at least 5	0% of the possibl	e points in the weekly
exercises. In thi	s case, active	e participation in	the exercise is al	so compulsory. Th	e form of examination
is determined a	t the beginni	ng of the course	2.		
		ey Competences			
Importance of t	the Mark for	the Final Mark	Weighed accordin	g to Credit Points	
Module Superv	isor and Inst	<b>ructor</b> Jun-Prof.	Dr. Innocenti		
Further Informa	ation				

Module 6b	Credits	Workload	Semester	Cycle	Duration
	4 CP	120 h	From 5. Sem.	Summer Term	1 Semester
Courses			Contact Hours	•	Group size
c) Lecture Con	•	•	c) 22 h	76 h	Students
a) Exercises Co	mputational F	Physics II	a) 22 h		<ul><li>c) unlimited</li><li>a) 30</li></ul>
Requirements	for Participati	ion			
Formal: none		<b>.</b>			
	-	om Computatio	nal Physics I will b	e appreciated	
Preparation: n					
Learning Outco					
		the module, th			
		-		ethods and applica	
	•			e of numerical me	
		•	of multiscale met	hods, stochastic d	ifferential equations,
	Carlo method				
<ul> <li>are fan</li> </ul>	hillar with the	possibilities of p	parallelisation		
Cell met Stocha Paralle	thods (Boris-Pu stic differentia lisation: MPI,	ush). al equations, Mo	onte Carlo methoo	•	e Method, Particle in prithm, Ising model
Format of Tea	ching Lecture,	Exercises			
Format of Exar	nination At the	e beginning of th	ne course, the lect	urer determines th	e form of examination
(written exami	nation of 90	min, oral exam	ination of 45 min	n or an exercise c	ertificate with weekly
homework and	active partici	pation in the ex	ercises) for the lea	cture.	
Requirements	for the attribu	ution of Credit F	Points Depending	on the specified fo	orm of examination:
Passing the wr	itten/oral exa	mination or ob	taining at least 50	0% of the possible	e points in the weekly
exercises. In th	is case, active	participation in	the exercise is als	so compulsory. Th	e form of examinatior
is determined a	at the beginnir	ng of the course			
	he Module Ke	y Competences			
Utilisation of t	the Maule faul	the Final Mark	Weighed accordin	g to Credit Points	
	the wark for				
Importance of		ructor Jun-Prof.	-	0	

Module 6c	Credits	Workload	Semester	Cycle	Duration
	5 CP	120 h	ab 4. Sem.	WiSe & SoSe	1 Semester
Courses			<b>Contact Hours</b>	Self Study	Group Size
a) Seminar En			a) 22 h	98 h	Students
	omy and Othe	r Subjects			a) 30
(from Level					b) unlimited
b) Online-Exer					
Requirements	•				
		otitude through a	an entrance test (	cf. www.zfa.rub.c	le)
Content-Wise:					
Preparation: n					
<ul> <li>can extract They can u</li> <li>Students of knowledge</li> <li>can under communic</li> <li>are able to</li> </ul>	t important in use such extract can work out competently stand both es ate this clearly	formation from s sted quotations a the function an in self-produced ssential and det y, precisely, and	specialised texts b and evidence to d d form of differe l texts ailed information concisely to other	y using specific re efend their own p nt types of texts from listening a rs, both orally and	and apply this and reading texts and
• re able to counter-ar	estions on it express and as	sk for personal p point out advant	oints of view and	opinions, formul	ate arguments and sion on specialised
<ul> <li>re able to counter-ar topics and</li> <li>Contents</li> <li>The course is d times). The foc production, int are taught and Furthermore, t Learning: The c course. It there</li> <li>face-to-face</li> <li>moodle course</li> </ul>	estions on it express and as guments and topics of their livided into a f cus of the face teraction and r applied, and s the specific voi course is accor efore consists course. rse in blended	sk for personal p point out advant own interest ace-to-face phas -to-face course i mediation, both students work w cabulary in the f mpanied by a spo of two parts: learning format	oints of view and ages and disadva se (2 hours) and a s on the commun in written and spo ith authentic aud ield of physics and	opinions, formul ntages in a discus n online phase (fr icative use of lang oken form. Variou io and visual text d astronomy is tra ffer, which is an i	ate arguments and ssion on specialised reely divisible practice guage in reception, us reading strategies s on Moodle. ained. Blended ntegral part of the terials provided
<ul> <li>re able to counter-ar topics and</li> <li>Contents</li> <li>The course is d times). The foc production, int are taught and</li> <li>Furthermore, t</li> <li>Learning: The course. It there</li> <li>face-to-face</li> <li>moodle cours</li> <li>4-5 different ty</li> </ul>	estions on it express and as guments and topics of their livided into a f cus of the face- teraction and r applied, and s the specific voi course is accor efore consists course. rse in blended ypes of texts a	sk for personal p point out advant own interest ace-to-face phas -to-face course i mediation, both students work w cabulary in the f mpanied by a spe of two parts: learning format re written and re	oints of view and tages and disadva se (2 hours) and a s on the commun in written and spo ith authentic aud ield of physics and ecific e-learning o , in which, with the evised on the basi	opinions, formul ntages in a discus n online phase (fr icative use of lang oken form. Variou io and visual text d astronomy is tra ffer, which is an i	ate arguments and ssion on specialised reely divisible practice guage in reception, us reading strategies s on Moodle. ained. Blended ntegral part of the terials provided
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#### List of Additional Key Competences

In <u>justified exceptional cases</u>, 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++, Phython, 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.

#### From the catalogue of the Faculty of Computer Science

Modul	Workload/ Credits	Häufigkeit des Angebots/ weitere Infos:	Dauer:
Information Theory (VVZ-Nr.: 211007) <b>NEU</b>	5 CP	https://qi.rub.de/it_ss23 <https: qi.ruhr-uni-<br="">bochum.de/it_ss23&gt;)</https:>	1 Semester

#### From the catalogue of **RUBION**:

Module:	Workload/ Credits	Semester:	Frequency of Offering:	Duration:
Foundational Course in Radiation Protection S4.1	150 h/5 CP		s. RUBION	Block Course

#### From the catalogue of the Academic Writing Centre:

Module:	Workload/ Credits	Semester:	Frequency of Offering:	Duration:
Intensive Module Theses in Science and Engineering A or B	5 CP		s. SCHREIBZENTRUM	1 Semester

From the catalogue of the faculty of **Economic Sciences**:

#### Modules (key competences) from economic sciences

Corporate Finance I: Finanzierung & Investition Corporate Finance II: Finanzielles Risikomanagement Corporate Finance III: Kapitalmarkttheorie Start -Up I: Grundlagen der Existenzgründung Start-Up II: Coaching-Workshop für Existenzgründer Start-Up III: Grundlagen der Businessplanerstellung

	<b>a 1</b> <sup>1</sup>			<u> </u>	
Module 7	Credits	Workload	Semester	Cycle	Duration
	5 CP	150 h	ab 1. Sem.	Summer Term	1 Semester
Courses			Contact Hours	•	Group Size
a) Seminar Pro			a) 50 h	50 h	Students
b) Practical ex	ercises Projec	t Management	b) 50 h		a) 30 b) 30
Requirements	for Participat	ion			57 50
Formal: none					
Content-Wise	none				
Preparation: n	ione				
Learning Outc					
		g the module, th			
		basics of project	-		
		anding of leadin	-		
			e its implementat	ion	
<ul> <li>can ad</li> </ul>	here to time a	and formal frame	eworks		
	-	the other hand,	results from the	practical exercises	skills for project and are discussed and sk from the module
problems a supervisor. b) In the pract to a group From the p	nalysed. The f Leadership pr tical exercises, of Bachelor st preparation of	the other hand, focus is on the e otocols and prog the participants tudents and to g the exposés to	results from the xchange of inforr ress reports are p have the opport uide them in the the final poster	practical exercises mation and feedba prepared. unity to apply the a e implementation of	acquired knowledge of a SOWAS project. participants of this
problems a supervisor. b) In the pract to a group From the p module sup Format of Tea	nalysed. The f Leadership pr tical exercises, of Bachelor st preparation of pport the SOW	the other hand, focus is on the e otocols and prog the participants tudents and to g the exposés to	results from the xchange of inforr gress reports are p have the opport guide them in the the final poster n professionally a ses	practical exercises nation and feedbar prepared. unity to apply the a implementation of presentation, the	s are discussed and ck from the module acquired knowledge of a SOWAS project. participants of this
problems a supervisor. b) In the pract to a group From the p module sup Format of Tea Format of Exa Requirements	nalysed. The f Leadership pr tical exercises, of Bachelor st preparation of port the SOW ching Seminar mination Pres for the Attrib	the other hand, focus is on the e otocols and prog the participants tudents and to g the exposés to 'AS students both 'AS students both ', practical exerci entation, active	results from the xchange of inforr gress reports are p have the opport guide them in the the final poster n professionally a ses participation	practical exercises nation and feedbar orepared. unity to apply the a e implementation of presentation, the nd interdisciplinari	s are discussed and ck from the module acquired knowledge of a SOWAS project. participants of this
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Modu	ule 8	Credits	Workload	Semester	Cycle	Duration
		15 CP	450 h	3. Sem.	WiSe & SoSe	1 Semester
Cours				Contact Hours	•	Group Size
-	actical exe	rcises		a) 320 h	100 h	Students
b) Se	minar			b) 30 h		a) 30 b) 30
-		or Participat				
				s been granted, i.e		
		-		nust be proven (ind n in-depth module	-	
		•		-25 CP) and the co		2
				s to be written in t		
	•	•	ubject must be			
	ent-Wise:		,			
Prepa	aration: no	one				
Learn	ing Outco	mes				
	-		g the module, th	e students		
•	re imm	ediately fami	liar with the exp	perimental equipn	nent, theoretical i	models and compute
	codes fi	rom their sub	oject area			
•	have a	doopor updo				
	nave a	leeper unue	rstanding of the	scientific issues in	their chosen field	d of specialisation
•	are fam	iliar with the	most important	t concepts of time	management and	
•	are fam	iliar with the	most important		management and	
	are fam	iliar with the	most important	t concepts of time	management and	
•	are fam can plai	iliar with the	most important	t concepts of time	management and	
• Conte	are fam can plai	iliar with the n the upcomi	most important ing Master's the	t concepts of time sis in terms of time	management and e and content	l project work
• Conte a) li	are fam can plan ents n the prac	iliar with the n the upcomi tical exercise	most important ing Master's the s, the required c	t concepts of time sis in terms of time concrete working r	management and e and content nethods of the gro	l project work oup are learned. Afte
• Conte a) lı a	are fam can plan ents n the prac an intensiv	iliar with the n the upcomi tical exercise ve familiarisa	s, the required c	t concepts of time sis in terms of time concrete working r e students have	management and e and content nethods of the gra the opportunity	d project work oup are learned. Afte to participate in the
• Conte a) li a c	are fam can plan ents n the pract an intensiv concretisat	iliar with the n the upcomi tical exercise ve familiarisa ion of thei	s, the required c ation phase, the	t concepts of time sis in terms of time concrete working r e students have	management and e and content nethods of the gro the opportunity s. In addition, a	d project work oup are learned. Afte to participate in the a timetable for the
• Conte a) li a c ii	are fam can plan ents n the pract an intensiv concretisat mplement	iliar with the n the upcomi tical exercise ve familiarisa ion of thei ation of the l	s, the required cation phase, the r topic for the Master's thesis	t concepts of time sis in terms of time concrete working r e students have e Master's thesi s drawn up and its	management and e and content nethods of the gro the opportunity s. In addition, a feasibility is chec	d project work oup are learned. Afte to participate in the a timetable for the
• Conte a) li a c ii b) T	are fam can plan ents n the pract an intensiv concretisat mplement The semina	iliar with the n the upcomi tical exercise ve familiarisa ion of the ation of the l ar serves to d	s, the required c ation phase, the r topic for the Master's thesis is	t concepts of time sis in terms of time concrete working r e students have e Master's thesi s drawn up and its te topic for the Ma	management and e and content nethods of the gra the opportunity s. In addition, a feasibility is chec aster's thesis. At th	d project work oup are learned. Afte to participate in the a timetable for the ked.
• Conte a) li a c ii b) T s	are fam can plan ents n the pract an intensiv concretisat mplement The semina	iliar with the n the upcomi tical exercise ve familiarisa ion of thei ation of the l ar serves to d arious topics	s, the required c ation phase, the r topic for the Master's thesis is	t concepts of time sis in terms of time concrete working r e students have e Master's thesi s drawn up and its te topic for the Ma	management and e and content nethods of the gra the opportunity s. In addition, a feasibility is chec aster's thesis. At th	d project work oup are learned. Afte to participate in the a timetable for the ked. ne beginning of the
• Conte a) li c ii b) T s t Forma	are fam can plan ents n the pract oncretisat mplement The semina seminar, va the semina at of Teac	iliar with the n the upcomi tical exercise ve familiarisa ion of the ation of the l ar serves to d arious topics r series. hing practica	s, the required c ation phase, the r topic for the Master's thesis is evelop a concret are given out by	t concepts of time sis in terms of time concrete working r e students have e Master's thesi s drawn up and its te topic for the Ma the supervisors. Ir	management and e and content nethods of the gra the opportunity s. In addition, a feasibility is chec aster's thesis. At th	d project work oup are learned. Afte to participate in the a timetable for the ked. ne beginning of the
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Module 9	ninar for th	Workload	Semester	Cycle	Duration
inouule 5	15 CP	450 h	3. & 4. Sem.	WiSe & SoSe	2 Semesters
Courses			Contact Hours		Group Size
a) Seminar A			a) 100 h	320 h	Students
b) Seminar B			b) 30 h		a) 30
,			,		b) 30
Requirements	for Participa	tion			
Formal: proof	of completior	n of the module '	'Knowledge of Me	ethods and Planni	ng a
Project"					
<b>Content-Wise</b>					
Preparation: r					
Learning Outo					
		g the module, th			
	ocument the c	current status of	their project "ivia	ster's thesis" (on a	a weekly and monthly
scale) • can ar		es problems and	difficulties and w	ork out suggestio	ns for the next project
step	aryse success	es, problems and	i unneutites and w	ork out suggestio	is for the next project
•	hasic unders	tanding of how t	o communicate si	ibject content an	propriately (orally and
in writ					
Contents					
	-				ent first reports on the
	•				result of this analysis ents can be supported
				-	ime and content with
	•		as effectively as p	•	
		•			e working group. Th
-				•	nterim report" or at the
-	-				e time planning and
implement	ation are in th	e foreground in	addition to the fo	cal points of the c	ontent.
Format of Tea	-				
Format of Exa	mination Pres	sentation			
•	for the Attrik		Points active parti	icipation in the ex	ercises, individual
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presentation Utilisation oft Importance of Module Supe Astronomy. U Further Inform	he Module M f the Mark for rvisor and Ins pon application nation This mo	andatory Modu the Final Mark structor Profess on, other examine	le Weighed accordin ors and private le ers may be admitt the same time as t	g to Credit Points ecturers of the F red if necessary.	aculty of Physics and

Module 10	Credits	Workload	Semester	Cycle	Duration						
	30 CP	900 h	3. & 4. Sem.	WiSe & SoSe	2 Semester						
Courses			Contact Hours	Self Study	Group Size						
Thesis			720 h	180 h	1						
Requirements	for Participat	tion									
Formal: proof	of completion	of the module '	'Knowledge of Me	thods and Planni	ng a						
Project"											
<b>Content-Wise</b>											
Preparation:											
Learning Outo											
		g the module, th									
	•	-	ntific ways of thin								
			ons and solve defi	ned problems us	ing scientific methods						
<ul> <li>within a given period of time</li> <li>are aware of the requirements of an appropriate, written presentation of demanding and novel scientific results</li> <li>are familiar with the most important concepts of independent work organisation</li> <li>are familiar with adequate literature research, citation of sources and the principles of good</li> </ul>											
							ific practice	equate interature	e research, citatio	n of sources and	the principles of good
						Scient	inc practice				
						Contents					
	construction	of an experime	nt or a theoretic	al model, indep	endent planning and						
•		•			ts, optimisation of the						
	-	of the process ste									
The topic and	task must be f	ormulated in suc	h a way that they	can be completed	d within 9 months with						
a workload of	30 CP.										
Format of Tea	ching										
		ting a scientific p									
Requirements	s for the Attrik	oution of Credit	Points Passing the	examination							
		landatory Modu									
Importance of	f the Mark for	the Final Mark	Weighed accordin	g to Credit Points							
Module Supe	rvisor and In	structor Profess	ors and private I	ecturers of the	Faculty of Physics an						
Astronomy. U	pon applicatio	n, other examine	ers may be admitt	ed if necessary.							
					<b>.</b>						
					e "Physikstudium-Info						
					specialisation in whic						
•		as completed. In	addition, it is poss	ible to write the t	hesis in a minor subjec						
upon applicati	on										

### **Study plan Master of Science Physics**



