Curriculum for the master's degree programme in

Physics

Curriculum 2017

This curriculum was approved by the Senate of the University of Graz in the meeting dated 08.03.2017 and by the Senate of Graz University of Technology in the meeting dated 20.03.2017.

The degree programme is organised as a combined degree programme (§ 54 para. 9 UG) of the University of Graz (Uni Graz) and Graz University of Technology (TU Graz) in the context of "NAWI Graz". This degree programme is legally based on the Universities Act (UG) and on the provisions of the Statutes of Uni Graz and TU Graz as amended.

(Please note: The English version of this document is a courtesy translation. Only the German version is legally binding.)

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I General provisions

§ 1. Object of degree programme and qualification profile

The natural sciences master's degree programme in Physics comprises four semesters. The total scope of the programme is 120 ECTS credit points according to § 51 para. 2 subpara. 26 UG.

The master's degree programme in Physics is held in English according to § 71e para. 4 UG.

Graduates of this programme are awarded the university degree of "Master of Science", abbreviated: "MSc".

(1) Object of degree programme

The English-language master's degree programme in Physics at Uni Graz and TU Graz provides students with a postgraduate degree in physics as part of further education in natural sciences, with a particularly broad focus within the field and the possibility for students to choose individual specialisations.

(2) Qualification profile and competencies

The objective of the NAWI Graz master's degree programme in Physics (at Uni Graz and TU Graz) is to further educate and train internationally competitive graduates who are able to flexibly develop future solutions to problems in the field of physics/natural sciences. This is achieved through a combination of a sound, general education in physics and proximity to application, together with the possibility for personal specialisation. This allows graduates of the master's degree programme in Physics to work in various professional fields successfully and independently.

Students of the master's degree programme in Physics receive a discerning education in physics and mathematics in general, but may also choose one of the following five specialisations: "Atmospheric Physics and Climate", "Astrophysics", "Experimental Physics", "Space Physics and Aeronomy" or "Theoretical and Computational Physics". In addition to these suggested specialisations, students can compile their modules flexibly and can have individual specialisations approved on request, so as to be prepared in the best possible way for future demands.

Graduates of this degree programme

- have deepened and further developed the skills they acquired in their bachelor's degree programme;
- are familiar with the sub-areas of current physics research and can reflect on these;
- can manage complex problems by applying methods of physics and mathematics independently;
- demonstrate a high level of analytical thinking;
- possess the ability to work well in a team, which has been strengthened and trained through project work;

- are experienced in handling theoretical and experimental or computer-based methods to solve problems;
- are able to communicate the results of their work to others, both to other experts and to non-experts;
- are highly proficient in English and, with the internationally recognised degree of "Master of Science", are particularly competitive in an international context, and
- are qualified for a self-determined and autonomous continuation of their studies e.g. as part of a PhD/doctoral programme.

(3) Demand for and relevance of the degree programme for science and on the job market

The graduates with an education that is broad yet includes individual specialisations, as listed under (2), are able to work in a variety of different professional fields in Austria and abroad. They fulfil the role of highly qualified specialists in the areas of science, business and industry.

Graduates have excellent specialist qualifications as well as the valuable personal core competency often described as a physicist's mindset, which results from a combination of sound knowledge of natural sciences, familiarity with practical methods (experimental, theoretical and computer-oriented), a strong capacity for analytical thought and well-developed problem-solving abilities. Graduates are therefore sought-after employees who work in a flexible and interdisciplinary manner in new areas of responsibility. In addition, physics-related work now almost only ever takes place in working groups, which especially helps to develop the ability to work in a team. Through this broad spectrum of competencies, graduates are superbly qualified, in particular, for the professional fields in Austria and abroad listed below:

- cooperation at and management positions at public/private research and educational institutions in the areas of physics and technology;
- work in large, international research collaborations;
- modelling and simulation in the areas of science, technology and business;
- algorithm development in various fields;
- cooperation in and management positions in research and development departments of various industrial sectors, particularly in the high-tech industry;
- leadership positions in administration and logistics;
- management consultancy;
- activities in quality control, and
- advisory bodies in the area of natural sciences and technology.

II General requirements

§ 2. Admission requirements:

(1) Admission to a master's degree programme requires a subject-related bachelor's degree of a university or university of applied sciences or another equiva-

lent degree of a recognised Austrian or foreign post-secondary educational institution (§ 64 para. 5 UG).

(2) The master's degree programme in Physics builds upon the content of a bachelor's degree programme in Physics, such as the bachelor's degree programme in Physics offered as part of NAWI Graz. Graduates of this degree programme fulfil the admission requirements for the master's degree programme in Physics.

(3) If the degrees are generally equivalent and only certain supplementary qualifications are required for full equivalence, additional courses and examinations of the bachelor's degree programme in Physics with a maximum scope of 30 ECTS credit points may be prescribed in order to obtain full equivalence. According to § 10 below, recognition of these additional qualifications to be obtained is permitted up to a maximum workload of 5 ECTS credit points for the free-choice subject.

(4) In order to obtain an overall scope of 300 ECTS credit points for the postgraduate degree programmes, the assigning of the same course in the bachelor's degree programme which grants admission to the master's degree programme and this master's degree programme shall be excluded.

§ 3. Allocation of ECTS credit points

All achievements to be obtained by the students are assigned ECTS credit points. These ECTS credit points are used to determine the relative weight of the workload of the individual academic achievements; the workload of one year must comprise 1500 hours and 60 ECTS credit points are awarded for this workload (corresponding to a workload of 25 hours per ECTS credit point). The workload comprises the self-study part and the semester hours. One semester hour corresponds to 45 minutes per study week of the semester.

§ 4. Organisation of the degree programme

The master's degree programme in Physics with a workload of 120 ECTS credit points comprises four semesters and has the following modular structure:

	ECTS
Compulsory module G: General Physics	15
Compulsory module M: Preparation for the Master's Thesis	14
5 specialisation modules (each 9 ECTS credit points)	45
General elective module (Elective Topics)	9
Free-choice subject	6
Master's thesis	30
Master's examination	1
Total	120

§ 5. Types of courses

(1) Lectures (VO)*: Lectures serve as an introduction to the methods of the subject and for the teaching of an overview and specialised knowledge of accepted scientific findings in the field, the current state of research and the specific research areas of the subject.

(2) Lectures with integrated exercises (VU)*: Comprise the teaching of an overview, specialised knowledge and practical skills. These are courses with continual assessment.

(3) Exercises (UE)*: Exercises must correspond to the practical targets of the degree programmes and are designed to solve specific tasks. These are courses with continual assessment.

(4) Laboratory courses (LU)*: Laboratory courses provide knowledge and practice of experimental techniques and skills. These are courses with continual assessment.

(5) Seminars (SE)*: Seminars are designed as independent scientific work and scientific discussion of this work, for which a topic must be elaborated in writing and orally presented. A discussion on this topic must be held. These are courses with continual assessment.

(6) Projects (PT)*: In projects, experimental, theoretical and/or design applied work is carried out, or small research papers are written, taking into account all necessary steps. Projects are completed with a written paper that is part of the assessment. These are courses with continual assessment.

(7) Excursions (EX)*: Excursions help to illustrate and consolidate the taught content and take place outside of the university premises. By visiting non-university institutions of research, business or industry, it is intended, in particular, that students are provided with supplementary, relevant, practice-oriented information that constitutes a valuable addition to the university education. A report on the excursion must be completed, either written or in the form of an oral presentation by the students. Excursions can take place in Austria and abroad.

(8) Exclusive tutorial (PV)*: These are special research seminars built on lively discussions and introductory presentations on current research issues. These are courses with continual assessment.

* The types of courses stated in the Chapter "Study Law" of the Statute (Uni Graz) or Guideline (TU Graz) of the two universities shall apply. See § 1 para. 3 Chapter "Study Law" of the Statute of Uni Graz or the Guideline on the types of courses by the Curricular Committee of the Senate of TU Graz dated 6 October 2008 (published in the University Gazette of TU Graz dated 3 December 2008).

§ 6. Group sizes

For the types of courses listed below, the maximum number of participants (group sizes) are as follows:

(1) The maximum group size for exercise-based courses (UE) and exercise components of lectures with integrated exercises (VU) is 25 students. If the exercise component of the VU corresponds to a laboratory course, the maximum group size for the exercise component is 6 students.

(2) The maximum group size for laboratory courses (LU) and exclusive tutorials (PV) is 6 students.

(3) The maximum group size for projects (PT), seminars (SE) and excursions (EX) is 20 students.

§ 7. Guidelines for the allocation of places on courses

(1) If the number of students registered for a course exceeds the number of available places, parallel courses are to be provided. If necessary, these parallel courses may also be provided during the semester break.

(2) If it is not possible to offer a sufficient number of parallel courses (groups), the students are to be admitted to the course according to the following priority ranking:

a. Students are required to complete the course according to their curriculum.
b. The sum of the successfully completed courses of the respective study programme (total ECTS credit points)
c. The date (early date has priority) of the fulfilment of the participation requirement
d. Students who have already been placed on a waiting list or who have to repeat the course are to be given priority on the next course.
e. The further ranking is made according to the grade of the examination or the average grade of the examinations (weighted on the basis of the ECTS credit points) of the respective course(s) that are specified as the participation requirement.
f. Students who do not need to complete such courses in order to fulfil their curriculum are only considered based on the number of free places. It is possible to be included on a separate waiting list. The abovementioned provisions shall apply accordingly.

(3) Students who complete a part of their studies at the universities participating in NAWI Graz in the context of mobility programmes are given priority for up to 10% of the available places.

III Course content and curriculum

§ 8a. Modules, courses and semester allocation

The individual courses of this master's degree programme and their grouping into compulsory and elective modules are indicated hereinafter. The knowledge, methods or skills to be provided in the modules are described in more detail in Annex I. The semester allocation is a recommendation and ensures that the sequence of courses builds optimally on previous knowledge and that the workload is spread as evenly as possible over the intended semester. Annex II and § 9 below contain the allocation of the courses to the participating universities.

Master's degree programme in Physics								
Module	**Course**		**LV**		**Semester incl. ECTS**			
		SSt	**type**	**ECTS**	**I**	**II**	**III**	**IV**
Compulsory module G: General Physics								
	Statistical Physics[1]	2	VO	4	4			
	Statistical Physics[1]	1	UE	2	2			
	Advanced Quantum Mechanics[1]	2	VO	4	4			
	Advanced Quantum Mechanics[1]	1	UE	2	2			
	Introduction to General Relativity and Cosmology	2	VO	3	3			
Subtotal for compulsory module G		**8**		**15**	**15**			
Compulsory module M: Preparation for the Master's Thesis[2]								
Subtotal for compulsory module M				14			12	2
Total for the compulsory modules				**29**	**15**		**12**	**2**
5 specialisation modules (each 9 ECTS)				45	12	18	15	
General elective module (Elective Topics)				9		9		
Total for the elective modules according to § 9 below				**54**	**12**	**27**	**15**	
Master's thesis				**30**				30
Master's examination				**1**				1
Free-choice subject according to § 10 below				**6**	3	3		
Overall total				**120**	**30**	**30**	**27**	**33**

[1]: Held jointly with the master's degree programme in Technical Physics
[2]: This module is defined in § 8b.

§ 8b. Module M: Preparation for the Master's Thesis

Module M is intended as preparation for the master's thesis and must be related to the master's thesis in terms of content. The module is defined in the table below.

Module M: Preparation for the Master's Thesis							
Module/course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Module M0: **Preparation for the Master's Thesis**							
Practical Training in the Area of the Master's Thesis[2]	4	LU/PT	10	X	X	X	
Tutorial in the Area of the Master's Thesis[2]	2	PV	2	X	X	X	
Master's Seminar in the Area of the Master's Thesis[2]	2	SE	2		X	X	

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

[2]: These courses can also be offered with a subheading that describes the subject area of the master's thesis in more detail.

If the master's thesis is written in one of the fields Astrophysics, Atmospheric Physics and Climate, or Space Physics and Aeronomy, the following specification shall apply for module M by way of derogation:

Module M: Preparation for the Master's Thesis in…							
Module/course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Module M1: **Preparation for the Master's Thesis in Astrophysics**							
Data Analysis in Astrophysics[2]	3	VO	4	X		X	
Data Analysis in Astrophysics[2]	2	UE	3	X		X	
Selected Problems in Astrophysical Data Analysis[2]	2	SE	3	X		X	
Tutorial for Master's Students in Astrophysics	2	PV	2	X		X	
Master's Seminar in Astrophysics[2]	2	SE	2		X	X	
Module M2: **Preparation for the Master's Thesis in Atmospheric Physics and Climate**							
Field Course Atmospheric and Climate Physics[2]	3	PT	6	X		X	
Climate and Environmental Change – Current Research Topics	2	SE	3		X	X	
Selected Topics in Atmospheric and Climate Physics[2]	2	SE/VO	3	X		X	
Tutorial for Master's Students in Atmospheric Physics and Climate	2	PV	2	X		X	
Module M3: **Preparation for the Master's Thesis in Space Physics and Aeronomy**							
Practical Training in Space Physics and Aeronomy[2]	3	PT	6	X		X	
Master's Seminar in Space Physics and Aeronomy	2	SE	3		X	X	
Selected Topics in Space Physics and Aeronomy[2]	2	SE/VO	3	X		X	
Tutorial for Master's Students in Space Physics and Aeronomy	2	PV	2	X		X	

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

[2]: This course is offered every two years.

§ 9. Elective modules: catalogues of courses

(1) Specialisations

At the student's request, one of the specialisations listed below may be shown on the master's degree certificate. For this purpose, the master's thesis and preparation module M must correspond to this specialisation in terms of the subject area, and specialisation modules (see § 9 para. 3) must be completed according to the following list:

- **Astrophysics**: modules A1, A2, A3, A4, A5
- **Atmospheric Physics and Climate:** modules C1, C2, C3, C4, C5
- **Experimental Physics:** at least three modules from E1, E3, E4, E5 and E7. E5 and E7 may not be selected together.
- **Space Physics and Aeronomy:** modules S1, S2, S3, S4, C2
- **Theoretical and Computational Physics:** modules T1, T2 and T3

At the student's request, a different specialisation from those listed here may be approved by the officer responsible for study matters, whereby a corresponding list of specialisation modules must be determined.

(2) Mentoring

As assistance in the individual compilation of the specialisation modules, students are recommended to choose a mentor in the course of the first semester and to have a discussion with him/her. This is intended to ensure optimum study progress for the students. A list of potential mentors is made available to the students via the websites of the institutes of physics or the student representatives.

(3) Specialisation modules

Five specialisation modules with 9 ECTS credit points each must be completed. In each of the chosen modules, it is compulsory to complete the courses marked (♦).

Specialisation modules							
Module/course	SSt	LV type	ECTS	Semester allocation WS	Semester allocation SS	Uni Graz[1]	TU Graz[1]
Module A1: **Stellar Astrophysics**							
♦ Stellar Structure and Evolution[2]	3	VO	4		X	X	
♦ Stellar Structure and Evolution[2]	1	UE	2		X	X	
♦ The Galaxy and Extragalactic Systems[2]	2	VO	3	X		X	
Module A2: **Theoretical Astrophysics**							
♦ The Physics of Stellar Atmospheres[2]	3	VO	4	X		X	
♦ The Physics of Stellar Atmospheres[2]	1	UE	2	X		X	
♦ Magneto-hydrodynamics and Solar-Terrestrial Modeling[2]	2	VO	3		X	X	

Specialisation modules							
Module/course	SSt	LV type	ECTS	Semester allocation WS	Semester allocation SS	Uni Graz[1]	TU Graz[1]
Module A3: **Physics of the Solar System**							
♦ Introduction to Solar Physics[2]	2	VO	3		X	X	
♦ Introduction to Solar Physics[2]	1	UE	2		X	X	
♦ Solar Physics Lab[2]	1	PT	1		X	X	
♦ Introduction to Planetology[2]	2	VO	3	X		X	
Module A4: **Observing Techniques in Astrophysics**							
♦ Instrumentation and Observing Techniques in Astrophysics[2]	2	VO	3	X		X	
♦ Astrophysics Lab[2]	2	PT	3	X		X	
♦ Astrophysical Seminar[2]	2	SE	3		X	X	
Module A5: **Selected Topics in Astrophysics**							
Exoplanets and Astrobiology[2]	2	VO	3		X	X	
Introduction to Space Plasma Physics[2]	2	VO	3	X		X	
Astrophysics Lab 2[2]	2	PT	3			X	
Celestial Mechanics[2]	2	VO	3		X	X	
Hydrodynamics[2]	2	VO	3			X	
Sun and Space Weather[2]	2	VO	3		X	X	
Advanced General Relativity and Quantum Gravity[2]	2	VO	3	X		X	
Astroparticle Physics[2]	2	VO	3		X	X	
Further Lectures on Selected Astrophysical Topics[2]	2	VO/SE	3	X		X	
Module C1: **Principles of the Climate System**							
♦ Earth's Climate System and Climate Change[2]	2	VO	3	X		X	
♦ Physical Oceanography, Hydrology and Climate[2]	2	VO	3		X	X	
♦ Paleoclimatology[2]	2	VO	3	X		X	
Module C2: **Data Analysis and Simulation**							
♦ Methods of Modeling and Simulation[2]	2	VO	3	X		X	
♦ Methods of Modeling and Simulation[2]	2	UE	3	X		X	
♦ Time Series Analysis[2]	2	VO	3	X		X	
Module C3: **Atmospheric Physics**							
♦ Atmospheric Dynamics[2]	2	VO	3		X	X	
♦ Atmospheric Composition and Chemistry[2]	2	VO	3	X		X	
♦ Radiation and Energy Balance[2]	2	VO	3	X		X	
Module C4: **Climate Physics**							
♦ Climate Modeling[2]	2	VO	3		X	X	
♦ Climate Dynamics[2]	2	VO	3	X		X	
♦ Selected Topics in Climate Science[2]	2	VO/SE	3	X		X	
Module C5: **Atmospheric Measurement Methods and Observing Systems**							
♦ Atmospheric Measurement Methods: Remote Sensing[2]	2	VO	3		X	X	
♦ Atmospheric Measurement Methods: in situ[2]	2	VO	3	X		X	

Specialisation modules							
Module/course	SSt	LV type	ECTS	Semester allocation WS	Semester allocation SS	Uni Graz[1]	TU Graz[1]
♦ Seminar on Measurement Methods in Atmospheric Physics[2]	2	SE	3		X	X	
Module E1: **Surface Science: Basic Principles**							
Surface Science	2	VO	3	X		X	
♦ Experimental Methods in Surface Science	2	VU[4]	3		X	X	X
Thin Film Science and Processing	2	VO	3		X		X
Module E2: **Surface Science: Advanced Topics**							
Molecular Interfaces[2]	2	VO	3		X	X	
Scanning Probe Techniques	2	VO	3		X	X	
Synchrotron Radiation Techniques	2	VO	3	X		X	
Surface Chemistry	2	VO	3		X		X
Vacuum Technology	2	VO	3	X		X	X
Special Topics in: „Surface Science“[2]	2	VO	3			X	
Module E3: **Spectroscopy**							
♦ Spectroscopy	2	VO	3	X		X	X
♦ Research Laboratory Spectroscopy	2	LU	3		X	X	X
Synchrotron Radiation Techniques	2	VO	3	X		X	
X-ray and Neutron Scattering	2	VO	3		X		X
Magnetic Resonance: NMR and ESR[2]	2	VO	3		X	X	
Application of Group Theory	2	VO	3		X	X	
Module E4: **Nano-optics and Laser Optics** [5]							
♦ Advanced Optics	2	VO	3	X		X	
♦ Research Laboratory Nano and Laser Optics	2	LU	3	X		X	X
Nano Optics	2	VO	3		X	X	
Laser Physics	2	VO	3	X		X	
Ultrafast Laser Physics	2	VO	3		X		X
Module E5: **Quantum Optics and Molecular Physics** [5]							
♦ Fundamental Optics	2	VO	3	X	X		X
♦ Research Laboratory Quantum Optics and Molecular Physics	2	LU	3	X	X	X	X
Laser Physics	2	VO	3	X		X	
Ultrafast Laser Physics	2	VO	3		X		X
Quantum Optics	2	VO	3	X			X
Modelling of Molecular Systems	2	VO	3	X			X
Module E6: **Nano and Quantum Matter**							
♦ Solid-state Physics: Size Effects and Quantum Phenomena	2	VO	3	X		X	
Modern Materials[2]	2	VO	3	X		X	
Scanning Probe Techniques	2	VO	3	X		X	
Nano- and Quantum Magnetism[2]	2	VO	3	X		X	
Application of Group Theory	2	VO	3		X	X	
Theory of Superconductivity	2	VO	3	X			X
Phase Transitions and Critical Phenomena	2	VO	3	X			X
Theory of Magnetism and Collective Phenomena	2	VO	3	X			X

Specialisation modules							
Module/course	SSt	LV type	ECTS	Semester allocation WS	Semester allocation SS	Uni Graz[1]	TU Graz[1]
Quantum Transport Theory	2	VO	3		X	X	X
Exotic States in Solids	2	VO	3		X	X	
Nanostructures and Nanotechnology	2	VO	3		X		X
Module E7: **Biological Applications**							
♦ Research Laboratory Biophysics	2	LU	3		X	X	
Molecular Biophysics 1	2	VO	3	X		X	
Molecular Biophysics 2	2	VO	3		X	X	
Biological and Biobased Materials	2	VO	3		X		X
Biophotonics	2	VO	3		X	X	
Biomagnetism[2]	2	VO	3	X		X	
Soft Matter Physics	2	VO	3	X			X
Module E8: **Industrial Applications**							
♦ Topics of Industrial Relevance	2	VO	3	X		X	
♦ Signal Theory and Signal Processing	2	VU[6]	3		X	X	X
Patent Law and Technology Transfer	2	VO	3		X	X	
Ultrasound Methods[2]	2	VO	3		X	X	
Thin Film Science and Processing	2	VO	3		X		X
Modelling and Simulations of Semiconductors	2	VO	3		X		X
Temperature Measurements	2	VO	3	X			X
Light Engineering	2	VO	3	X			X
Excursion	1	EX	1	X		X	
Module S1: **Fundamentals of Space Physics and Aeronomy**							
♦ Introduction to Planetology[2]	2	VO	3	X		X	
♦ Introduction to Aeronomy[2]	2	VO	3	X		X	
♦ Introduction to Space Plasma Physics[2]	2	VO	3	X		X	
Module S2: **Solar and Heliospheric Physics**							
♦ Introduction to Solar Physics[2]	2	VO	3		X	X	
♦ Magneto-hydrodynamics and Solar-terrestrial Modeling[2]	2	VO	3		X	X	
♦ Introduction to Solar Physics[2]	1	UE	2		X	X	
♦ Solar Physics Lab[2]	1	PT	1		X	X	
Module S3: **Physics of Planetary Atmospheres and Magnetospheres**							
♦ Physics of Planetary Atmospheres[2]	2	VO	3		X	X	
♦ Earth and Planetary Magnetic Fields[2]	2	VO	3		X	X	
♦ Planetary Magnetospheres[2]	2	VO	3		X	X	
Module S4: **Measurement Methods and Observing Systems**							
♦ Measurement Methods in Space Physics[2]	2	VO	3		X	X	
♦ Space Missions and Experiments Design[2]	2	VO	3		X	X	
♦ Seminar on Measurement Methods in Space Physics[2]	2	SE	3		X	X	
Module T1: **Advanced Theoretical Physics 1**							
♦ Advanced Mathematical Methods	3	VO	4.5	X		X	
♦ Quantum Field Theory	3	VO	4.5		X	X	

Specialisation modules

Module/course	SSt	LV type	ECTS	Semester allocation WS	SS	Uni Graz[1]	TU Graz[1]
Module T2: **Advanced Theoretical Physics 2**							
♦ Advanced Quantum Mechanics 2	2	VO	3	X		X	
♦ Advanced Statistical Physics	2	VO	3	X		X	X
♦ Basic Concepts of Solid-state Theory	2	VO	3	X		X	
Module T3: **Computational Physics**							
♦ Numerical Methods in Linear Algebra	2	VU[3]	3	X		X	
♦ Monte-Carlo Methods	2	VU[3]	3	X		X	
Computational Methods in Solid-state Physics	2	VU[3]	3	X		X	
Computational Methods in Particle Physics	2	VU[3]	3		X	X	
Module T4: **Theoretical Solid-state Physics** [5]							
♦ Green's Functions for Solid-state Physics	2	VU [3]	3		X	X	
Fundamentals of Electronic Structure Theory	2	VO	3		X	X	X
Theory of Magnetism and Collective Phenomena	2	VO	3	X			X
Theory of Superconductivity	2	VO	3	X			X
Phase Transitions and Critical Phe-nomena	2	VO	3	X			X
Exotic States in Solids	2	VO	3		X	X	
Quantum Transport Theory	2	VO	3		X	X	X
Computational Methods in Solid-state Physics	2	VU[3]	3	X		X	
Module T5: **Theoretical Nanophysics**							
Theoretical Nano- and Quantum Physics	2	VO	3		X	X	
Plasmonics	2	VO	3		X	X	
Quantum Transport Theory	2	VO	3		X	X	X
Fundamentals of Electronic Structure Theory	2	VO	3		X	X	X
Exotic States in Solids	2	VO	3		X	X	
Module T6: **Modelling of Materials** [5]							
♦ Fundamentals of Electronic Structure Theory	2	VO	3		X	X	X
♦ Simulating Materials Properties from First Principles	2	UE	3		X	X	X
Applications of Electronic Structure Methods	2	VO	3		X		X
Ab-initio Methods for Correlated Mate-rials	2	VO	3	X			X
Advanced Ab-Initio Techniques	2	VO	3	X		X	X
Modelling of Molecular Systems	2	VO	3	X			X
Module T7: **Foundations of Particle Physics**							
♦ Quantum Field Theory 2: Gauge The-ories	4	VU[3]	6	X		X	
Lattice Field Theory	2	VO	3		X	X	
Functional Methods in Quantum Field	2	VO	3	X		X	

Specialisation modules							
Module/course	SSt	LV type	ECTS	Semester allocation WS	Semester allocation SS	Uni Graz[1]	TU Graz[1]
Theory[2]							
Computational Methods in Particle Physics	2	VU[3]	3		X	X	
Special Topics in: "Foundations of Particle Physics"	2	VO	3	X		X	
Advanced Mathematical Methods 2 [2]	2	VO	3	X		X	
Project in: "Foundations of Particle Physics"	2	PT	3		X	X	
Module T8: **Phenomenology of Particle Physics**							
♦ Hadron Physics	2	VO	3		X	X	
Electroweak Physics[2]	2	VO	3		X	X	
Supersymmetry[2]	2	VO	3	X		X	
Physics Beyond the Standard Model[2]	2	VO	3		X	X	
Advanced General Relativity and Quantum Gravity[2]	2	VO	3	X		X	
Astroparticle Physics[2]	2	VO	3		X	X	
Special Topics in: "Phenomenology of Particle Physics" [2]	2	VO	3		X	X	
Project in: "Phenomenology of Particle Physics"	2	PT	3	X		X	

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

[2]: This course is offered every two years.

[3]: 2/3 SSt/lecture component, 1/3 SSt/exercise component

[4]: 1/4 SSt/lecture component, 3/4 SSt/exercise component. The exercise component corresponds to a laboratory course.

[5]: Joint module in this master's degree programme in Physics and in the master's degree programme in Technical Physics

[6]: 2/3 SSt/lecture component (VO), 1/3 SSt/exercise component. The exercise component corresponds to a laboratory course.

(4) General elective module (Elective topics)

The general elective module comprises courses with a scope of 9 ECTS credit points.

For the general elective module, the following courses may be chosen:

- Courses from the catalogue of the abovementioned specialisation modules (§ 9 para. 3), that were not already used in the chosen specialisation modules
- Compulsory and elective courses of the NAWI Graz master's degree programme in Technical Physics, taking into consideration the relevant admission requirements, if they were not already used in the chosen specialisation modules
- Courses to deepen knowledge of a foreign language (English or German) with a scope of up to 3 ECTS credit points
- Courses from the following catalogue "General elective module"
- German-language courses from the following catalogue "Bachelor's specialisation General Physics" of the NAWI Graz bachelor's degree programme in Physics in consideration of § 2 para. 4

Catalogue of courses: General elective module							
Course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Advanced Mathematical Methods	1	UE	1.5	X		X	
Quantum Field Theory	1	UE	1.5		X	X	
Halbleiterphysik und Mikroelektronik[2]	2	VO	4		X	X	
Digitalelektronik[2]	1	VU[3]	2	X		X	
Journal Club[2,4]	2	PV	3	X		X	
Mechanische Fertigungstechniken[2]	1	VU[3]	2	X		X	

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

[2]: Held in German

[3]: 1/4 SSt/lecture component, 3/4 SSt/exercise component. The exercise component corresponds to a laboratory course.

[4]: This course is offered every two years.

Catalogue of courses: Bachelor's specialisation General Physics							
Course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Moderne Kapitel der experimentellen Physik[2]	2	VO	3		X	X	
Moderne Kapitel der theoretischen Physik[2]	2	VO	3		X	X	
Einführung in die Astrophysik[2]	2	VO	3	X		X	
Einführung in die Geophysik[2]	2	VO	3		X	X	
Einführung in die Meteorologie und Klimaphysik[2]	2	VO	3	X		X	

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

[2]: Held in German

§ 10. Free-choice subject

(1) The courses to be completed as part of the free-choice subject for the master's degree programme in Physics are designed to provide individual emphasis and further development of the students. They can be freely selected from the courses offered by any recognised Austrian or foreign universities, as well as any Austrian universities of applied sciences and university colleges for education. Annex III contains recommendations for free-choice courses.

(2) If no ECTS credit points are assigned to a free-choice course, one ECTS credit point is awarded for every semester hour (SSt) of this course. If such courses are lecture-type courses (VO), they are assigned 1.5 ECTS credit points for each semester hour.

(3) Students also have the possibility of completing a vocational internship or short study periods abroad as part of the free-choice subject according to § 13 below.

§ 11. Master's thesis

(1) The master's thesis is proof of the student's capability to perform scientific research and development tasks independently and which are academically grounded as far as content and methodology are concerned. The scope of work

of the master's thesis must enable students to finish their thesis within a period of six months.

(2) The topic of the master's thesis must be taken from one of the compulsory or elective modules. The officer responsible for study matters shall decide on exceptions.

(3) Before a student starts work on their master's thesis, it must be registered via the responsible dean's office with the involvement of the officer responsible for study matters. The topic, the area of expertise of the topic and the supervisor as well as the institute must be stated.

(4) 30 ECTS credit points are awarded for the master's thesis.

(5) The master's thesis is to be submitted for evaluation in printed and in electronic form.

§ 12. Registration requirements for courses/examinations

(1) Admission to the master's examination before a committee requires proof of the positive assessment of all examination results according to §§ 8a, 8b and 9 above and the positive assessment of the master's thesis.

(2) Students who are required to fulfil admission requirements for the master's degree programme in Physics according to § 2 para. 3 above must have successfully completed these before participating in laboratory courses (LU) and lectures with integrated exercises (VU) with laboratory course components.

§ 13 Study periods abroad and internship

(1) Recommended studies abroad

Students are recommended to complete a semester abroad during their degree programme. For this purpose, the second and third semesters of this master's degree programme are particularly worth considering. Modules or courses completed during the studies abroad shall be recognised by the officer responsible for study matters in the case of equivalence. Students are referred to § 78 para. 5 UG (prenotification) for the recognition of examinations during studies abroad.

In addition, an application may be sent to the officer responsible for study matters to have achievements from shorter study periods abroad such as active participation in international summer or winter schools recognised as part of the free-choice subject.

(2) Internship

It is possible to complete a vocational internship as part of the free-choice subject.

In this context, every working week in full-time employment shall correspond to 1.5 ECTS credit points. Active participation in a scientific event shall also be valid as an internship. This internship shall be approved by the officer responsible for study matters and should be a meaningful addition to the degree programme.

IV Examination regulations and degree certificate

§ 14. Examination regulations

Courses are evaluated individually.

(1) Examinations for courses held as lectures (VO) cover the complete content of the course. Examinations are held exclusively orally, exclusively in writing, or in writing and orally as a combination.

(2) For courses held as lectures with integrated exercises (VU), exercise-based courses (PT, UE), laboratory courses (LU), design exercises (KU), seminar-type courses (SE, SP), and exclusive tutorials (PV), a student's performance is continually assessed on the basis of that student's contributions and/or through accompanying tests. The assessment must always consist of at least two examinations.

(3) Examinations with positive results are to be assessed as "very good" (1), "good" (2), "satisfactory" (3) or "sufficient" (4); those with negative results are to be assessed as "insufficient" (5). The courses marked EX in the catalogue of courses are assessed as "successful participation" or "unsuccessful participation".

(4) If a module includes separate examinations for the relevant courses, the overall module grade is to be determined by:

a. multiplying the grade of each examination result in connection with the module with the ECTS credit points of the corresponding course;
b. adding the values calculated according to lit. a;
c. dividing the result of the addition by the sum of the ECTS credit points of the courses, and
d. rounding the result of the division to a whole-numbered grade if required. The grade must be rounded up if the decimal place exceeds 0.5. Otherwise, the grade must be rounded down.
e. A positive module grade can only be awarded if every individual examination result is positively assessed.
f. Courses whose assessment is exclusively determined by the successful/unsuccessful participation shall not be included in this calculation according to lit. a to d.

(5) The master's examination before a committee consists of

- the presentation of the master's thesis (maximum duration: 20 minutes);
- the defence of the master's thesis (oral examination), and
- an oral examination on topics from the module to which the master's thesis is assigned, as well as from another module according to §§ 8a and 9 above, the topic of which is not assigned to the topic of the master's thesis.

The topics are determined by the officer responsible for study matters of the university to which the student is admitted on a proposal by the candidate. The total duration of the master's examination before a committee is generally 60 minutes and shall not exceed 75 minutes.

(6) The master's examination senate consists of the supervisor of the master's thesis and two further members nominated by the officer responsible for study matters after the hearing of the candidates. The senate is chaired by a member of the examination senate who is not the supervisor of the master's thesis. In the selection of the examination senate, particular consideration shall be given to a broad representation of fields. The further members in addition to the supervisor of the master's thesis may not have a close connection with this master's thesis and should work in different working groups from that in which the master's thesis was completed.

(7) The grade of this examination before a committee is determined by the examination senate.

(8) In order to assist students in completing their degrees in a timely manner, courses with continual assessment must allow students to submit, supplement or repeat partial course requirements, in any case at least one partial course requirement to be determined by the course director, by no later than four weeks after the course has ended. If the registration period for a key course ends within this time frame, this possibility must be extended until the end of the registration period. Laboratory courses are excluded from this regulation.

(9) For registration and deregistration as well as for holding examinations, the provisions of the statute of each university tasked with holding the relevant examination shall apply. If an examination is held jointly by both universities, information shall be published in the online system on which statute will apply. The regulations shall apply for lectures (selective examination) and for courses with continual assessment.

§ 15. Degree certificate

(1) The master's degree programme is completed by attaining a positive assessment of the courses of all the compulsory and elective modules, the free-choice subject, the master's thesis and the master's examination before a committee.

(2) A degree certificate shall be issued for successful completion of the degree programme. The degree certificate for the master's degree programme in Physics contains

a. a list of all modules (examination subjects) according to § 4 above (including the ECTS credit points) and their assessments. Only the English name of the module shall be listed without specification of the module code letters, i.e. "General Physics" or "Stellar Astrophysics", etc.

b. the title and the assessment of the master's thesis;

c. the assessment of the final examination before a committee;

d. the entirety of the ECTS credit points for the free-choice subject according to § 10 above, and

e. the overall assessment of the degree programme.

The overall assessment "pass" shall be awarded for the degree programme if every module, the master's thesis and the master's examination before a committee have been assessed positively. The overall assessment "pass with distinction" shall be awarded if no module nor the master's thesis and the master's examination before a committee has been awarded a lower assessment than "good" and if at least half of the assessments awarded (modules, master's thesis, master's examination before a committee) are "very good".

f. If a specialisation was chosen, it shall be shown.

V Legal validity and transitional provisions

§ 16. Legal validity

This curriculum 2017 (UNIGRAZonline abbreviation 17W, TUGRAZonline abbreviation 17U) shall come into effect on 1 October 2017.

§ 17. Transitional provisions

When this curriculum comes into effect on 1 October 2017, students of the master's degree programme in Physics of Uni Graz (curriculum 2013) are entitled to complete their degree programme within 6 semesters according to the provisions of the curriculum 2013. If the degree programme is not completed by 30 September 2020, students are subject to the curriculum for the master's degree programme in Physics as amended. Students are entitled to voluntarily opt for the new curriculum at any time within the admission periods. To this end, a written irrevocable declaration must be sent to the officer responsible for study matters.

Students who have completed the bachelor's degree programme in Technical Physics according to the curriculum 2009 or an older curriculum and who begin the NAWI master's degree programme in Physics according to this curriculum 2017 must complete the courses Electrodynamics, VO (2 SSt, 4 ECTS credit points) and Electrodynamics, UE (1 SSt, 2 ECTS credit points) instead of the courses Statistical Physics, VO (2 SSt, 4 ECTS credit points) and Statistical Physics, UE (1 SSt, 2 ECTS credit points).

NAWI Graz Natural Sciences

Annex to the curriculum for the master's degree programme in Physics

Annex I

Module descriptions of the compulsory modules

Module G	**General Physics**
ECTS credit points	15
Subject content	♦ Statistical Physics: Introduction; probability; classical statistical physics (microcanonical, canonical and grand canonical ensembles, ideal gas, etc.); quantum statistics (density operator, ensembles, Bose-Einstein and Fermi-Dirac statistics, ideal Bose gas, black-body radiation, etc.) ♦ Advanced Quantum Mechanics: Scattering theory; non-relativistic quantum field theory (second quantisation); many-particle quantum theory; coupling to electromagnetic field; gauge invariance; addition of angular momenta; Wigner-Eckart theorem ♦ Introduction to General Relativity and Cosmology: Manifolds and tensors, Einstein-Hilbert action and Einstein equation; linearised gravity and gravitational waves; homogenous and isotropic (Friedmann-Robertson Walker) cosmology; Schwarzschild metric; Kerr metric; numerical relativity and nonlinear gravitational waves
Learning outcomes	After having participated successfully in the module, students are able to • understand the basic principles of statistical physics and of general relativity and cosmology; • apply advanced methods in quantum theory, and • perform successful standard-type calculations in these fields. After having completed the module, students have gained profound knowledge of • classical statistical physics; • some aspects of quantum statistics, and • some of the more advanced techniques in quantum physics, and some basic understanding of the most prominent physical effects in general relativity.
Teaching and learning activities and methods	Lectures, exercise courses
Previous knowledge expected	Theory courses at bachelor's level
Frequency of offer	Every year

Module M0	**Preparation for the Master's Thesis**
ECTS credit points	14
Subject content	♦ Practical Training in the Area of the Master's Thesis: Participation in current research topics related to the planned master's thesis; working and solving problems in teams; training in required theoretical and/or practical tools; presentation of the results in short talks ♦ Tutorial in the Area of the Master's Thesis: Students are introduced to the current literature and methods of their planned master's thesis project. Discussion and short presentations of physical knowledge required for the planned master's theses ♦ Master's Seminar in the Area of the Master's Thesis: Presentation of the ongoing (thesis) work of the participating advanced MSc students (and PhD students), complemented by recent and ongoing work of further presenters (e.g. of scientific guests)
Learning outcomes	After having participated successfully in the module, students are able to • solve problems in research-related topics; • present the results in short talks, and • discuss recent advances in the research field connected to the master's thesis.
Teaching and learning activities and methods	The module consists of a practical project, a tutorial and a seminar.
Previous knowledge expected	None
Frequency of offer	Every year

Module M1	Preparation for the Master's Thesis in Astrophysics
ECTS credit points	14
Subject content	♦ Tutorial and Seminars for Master's Students in Astrophysics: Discussions and guidance for ongoing master's thesis projects of the participating MSc students; solar and stellar physics, stellar-planetary relations; observations and modelling; scientific writing; presentation skills; scientific ethics; preparation for the master's thesis defence; future perspectives in science with a focus on research frontiers in astrophysics ♦ Data Analysis and Selected Problems in Astrophysics: Data handling and scientific data reduction, data analysis and interpretation; space-borne and ground-based observations; numerical modelling; independent investigations in the framework of scientific projects; presentation of project results; group discussions; current understanding of fundamental physical processes in astrophysics; preparation of results in the form of figures and written text to be used for scientific publications
Learning outcomes	After having participated successfully in the module, students are able to • perform scientific projects on observational data analysis and numerical modelling on physical processes in astrophysics; • handle (large) astrophysical data sets and reduce them properly; • design observing campaigns; • analyse, interpret, and critically examine derived results; • contribute to the debate on astrophysical processes; • contribute to the debate on emerging topics in atmospheric physics; • plan and structure scientific work by themselves; • participate constructively in scientific discussions and discourse; • adequately document the results of scientific work in written form; • provide valuable contributions when working as a member of a scientific team, and • process results to be presented in scientific talks. After having completed the module, students have gained knowledge of • data analysis and interpretation; • numerical modelling of astrophysical processes; • the current understanding of astrophysics and major problems in astrophysics to be solved in future research; • the fundamentals of astrophysics and research frontiers in astrophysics, and • thesis design and good scientific practices.
Teaching and learning activities and methods	The module consists of one practical course, one lecture, two seminars and one tutorial.
Previous knowledge expected	None
Frequency of offer	At least every two years, tutorial and master's seminar at least every year

Module M2	Preparation for the Master’s Thesis in Atmospheric Physics and Climate
ECTS credit points	14
Subject content	♦ Tutorial for Master’s Students: Atmospheric Physics and Climate: The earth’s climate system; physical climate mechanisms and geobiochemical cycles; climate modelling and prediction; anthropogenic climate change, global warming and current research topics in climate and environmental change; guidance for ongoing thesis work of the participating MSc students ♦ Field Course Atmospheric and Climate Physics: Field measurements of meteorological parameters and climate variables; campaign design, instrument setup and calibration; data storage and data transfer; data analyses and interpretation ♦ Current Research Topics and Selected Topics: Understanding of fundamental physical processes in the atmosphere and climate system; current research frontiers in atmospheric and climate physics
Learning outcomes	After having participated successfully in the module, students are able to • perform meteorological measurements outside of laboratory environments; • calibrate meteorological instruments and facilitate data storage and transmission; • design and implement measurement campaigns; • analyse and interpret measurement records; • contribute to the debate on climate and environmental change on a global and regional scale; • contribute to the debate on emerging topics in atmospheric physics; • plan and structure scientific work by themselves; • participate constructively in scientific discussions and discourse; • adequately document the results of scientific work in written form, and • provide valuable contributions when working as a member of a scientific team. After having completed the module, students have gained knowledge of • instrument setup and calibration; • the design and implementation of meteorological field campaigns; • data analysis and interpretation; • the climate system, future projections of climate change and research frontiers in climate and environmental research; • the fundamentals of atmospheric and climate physics and research frontiers in atmospheric and climate physics, and • thesis design and good scientific practices.
Teaching and learning activities and methods	The module consists of one practical course, two seminars and one tutorial.
Previous knowledge expected	None
Frequency of offer	At least every two years, tutorial at least every year

Module M3	Preparation for the Master's Thesis in Space Physics and Aeronomy
ECTS credit points	14
Subject content	♦ Tutorial for Master's Students: Space Physics and Aeronomy: For example, cosmic rays: historical development; V. F. Hess. Primary/secondary cosmic rays; (Fermi) acceleration mechanism; spallation; energy spectrum; Forbush decrease; geophysical effects; Stoermer trajectories; CRAND; Van Allen belts; air shower; particle detectors; cosmic ray observatories; Cerenkov radiation; CERN; interpretation of data. Discussion and support of the current level of knowledge in the field of the master's thesis; teamwork ♦ Practical Training in Space Physics and Aeronomy: Analysis of data obtained from in situ and remote measurements from ongoing space missions: in situ measurement of space plasma; data processing and analysis (calibration); single and multi-point measurements; comparison of observational results with models and theory. Remote measurement of planetary/solar radio waves; development of dynamic spectra. Analysis and interpretation of radio spectra; radio wave generation mechanism; source region; wave polarisation; propagation. Comparison with models and theory ♦ Master's Seminar and Selected Topics: Presentation of the ongoing (thesis) work of the participating advanced MSc students (and PhD students), complemented by recent and ongoing work of further presenters (e.g. of scientific guests)
Learning outcomes	After having participated successfully in the module, students understand • the fundamental physics principles of in situ and remote measurements; • the sequence of data acquisition, processing and analysis (calibration), modelling and simulation, and • the basics regarding selected topics in space physics and aeronomy. Students have gained • competence in space science through knowledge of experiment performance, data acquisition, physical processes interpretation, modelling and simulation; • profound knowledge of scientific literature search, oral presentations, writing scientific reports and papers, and • experience in various forms of scientific work (single, teamwork with different roles of responsibility).
Teaching and learning activities and methods	Practical training, seminar, teamwork, tutorial, lecture
Previous knowledge expected	Knowledge of astrophysics, astronomy, physics, geophysics, electromagnetism, hydrodynamics, electronics, plasma physics, elementary particle physics, waves theory at bachelor's level
Frequency of offer	At least every two years, tutorial at least every year

Module descriptions of the specialisation modules

Module A1	**Stellar Astrophysics**
ECTS credit points	9
Subject content	♦ Stellar Structure and Evolution: Basic equations of stellar structure; thermonuclear fusion in stars; protostars; main sequence stars; post-main sequence stellar evolution; final stages of stellar evolution; circumstellar disks and formation of planets ♦ Exercises in Stellar Structure and Evolution: Training in the methods introduced in the associated lecture by solving problems related to stellar properties and stellar evolution ♦ The Galaxy and Extragalactic Systems: Composition and structure of the galaxy and extragalactic systems; galaxy clusters; galactic distance indicators
Learning outcomes	After having participated successfully in the module, students are able to • understand the structure and evolution of stars with different masses; • understand basic stellar structure equations; • obtain physical stellar parameters from observations; • understand the basic structure of the universe, and • apply the knowledge obtained after having passed the mandatory exercises.
Teaching and learning activities and methods	The module consists of two mandatory courses in which the theoretical concepts are taught. In the mandatory exercises, students use practical examples to train and apply their knowledge.
Previous knowledge expected	None
Frequency of offer	Four-semester cycle

Module A2	Theoretical Astrophysics
ECTS credit points	9
Subject content	♦ The Physics of Stellar Atmospheres: Theory of stellar atmospheres; stellar spectra and spectral classification; qualitative and quantitative analysis of stellar spectra; theoretical description of spectral line profiles and comparison with observations; stellar model atmospheres ♦ Exercises in Stellar Atmospheres: Training in the methods introduced in the associated lecture by solving problems related to the analysis of stellar spectra ♦ Magnetohydrodynamics and Solar-terrestrial Modelling: Basic magnetohydrodynamics (MHD) equations; magnetic reconnection; interaction of the solar wind with planetary atmospheres; solar-terrestrial relations
Learning outcomes	After having completed the module successfully, students are able to • analyse and interpret stellar spectra; • understand stellar model atmospheres and the physics behind them; • compare theoretical models with other models and observations, and • understand the basic concepts of MHD and apply them to the solar-terrestrial interactions.
Teaching and learning activities and methods	The module consists of two mandatory lectures where the theoretical concepts are taught and their relation to observations is discussed. In the mandatory exercises, stellar spectra are classified, numerical methods and models to describe stellar atmospheres are discussed, and the models are compared with observations.
Previous knowledge expected	None
Frequency of offer	Four-semester cycle

Module A3	Physics of the Solar System
ECTS credit points	9
Subject content	♦ Introduction to Solar Physics: The sun as a star; determination of basic physical parameters describing the sun and stars; solar interior structure; thermonuclear fusion in the solar core; solar neutrinos; helioseismology; solar atmosphere; phenomena of the quiet and the active sun; solar activity cycle; solar dynamo; solar wind; flares, coronal mass ejections; space weather ♦ Exercises in Solar Physics: Training in the methods introduced in the associated lecture by solving problems related to Solar Physics. ♦ Solar Physics Lab: Practical exercises at Kanzelhöhe Observatory to obtain an insight into state-of-the-art methods of ground-based observations of the sun ♦ Introduction to Planetology: Overview of the solar system (terrestrial planets, gas giants, moons, planetary ring systems, asteroids, and comets); structure and composition of planetary bodies (energy budget and dynamics); thermal models; tidal interactions; exploration of the solar system by satellite missions and ground-based observatories
Learning outcomes	After having participated successfully in the module, students are able to • understand the physics and structure of the sun and the solar system; • describe the most relevant phenomena of the quiet and the active sun; • understand the solar activity and its variability with the solar dynamo theory; • gain practical experience of how to obtain solar data with observations from ground-based and space-borne instruments; • describe the structure and composition of planetary bodies, and • understand the exploration of the solar system with in situ and remote sensing techniques.
Teaching and learning activities and methods	The module consists of two mandatory lectures that teach the basic theoretical concepts of the physics of the sun and the solar system. After having attended the two theoretical courses successfully, students improve their knowledge through practical exercises and observations in the Solar Physics Laboratory.
Previous knowledge expected	None
Frequency of offer	Four-semester cycle

Module A4	Observation Techniques in Astrophysics
ECTS credit points	9
Subject content	♦ Instrumentation and Observing Techniques in Astrophysics: Introduction to classical and modern astrophysical techniques; observing electromagnetic radiation from radio to gamma rays; basics of optics; construction and operation of astronomical instruments; technology and application of detectors; telescopes; mountings; adaptive optics; interferometry; operation and usage of modern, large observatories; satellite observations; remote sensing and in situ instrument techniques; application to solar and stellar observations ♦ Astrophysics Lab: Planning and execution of practical observations at Lustbühel Observatory; practical methods for data reduction and data analysis ♦ Astrophysical Seminar: Platform for presenting and discussing selected topics in astrophysics using ground-based and space-based observations
Learning outcomes	After having participated successfully in the module, students are able to • understand modern telescopes and instruments and their fields of application; • understand astrophysical observing techniques (remote sensing and in situ); • plan own observations with telescopes and perform own photometric and spectroscopic measurements; • reduce observational data and present the results, and • obtain an overview of the modern topics in observational astrophysics.
Teaching and learning activities and methods	The module offers a lecture where the basics of modern astrophysical observing techniques are discussed. In the practical exercises, students have the possibility of carrying out their own observations with telescopes. The obtained data is analysed and discussed in the corresponding seminar. In the seminar, modern astrophysical topics are discussed.
Previous knowledge expected	None
Frequency of offer	Four-semester cycle

Module A5	Selected Topics in Astrophysics
ECTS credit points	9
Subject content	Students can make their own selection from a range of lectures. The goal is to specialise in specific fields of astrophysics by deepening knowledge. The topics include exoplanets and astrobiology; physics of space plasmas; an advanced observational laboratory; celestial mechanics; hydrodynamics; sun and space weather; advanced general relativity, and other topics (depending on topicality and possibilities).
Learning outcomes	• Students can specialise in theory and by practicing in specific topics and specific research fields of modern astrophysics.
Teaching and learning activities and methods	In the module, three lectures must be selected. These could be classical lectures, advanced laboratories or seminars. A total of 9 ECTS credit points is required.
Previous knowledge expected	None
Frequency of offer	Four-semester cycle

Module C1	Principles of the Climate System
ECTS credit points	9
Subject content	♦ The Earth's Climate System and Climate Change: The earth's climate system (terminology, subsystems, scales, balance principle, budgets and cycles); brief context of paleoclimate and history of climate; climate observations, climate elements, climate classification; physical climate mechanisms, water and energy cycles; the earth's radiation balance, and imbalances due to anthropogenic forcings and feedbacks; anthropogenic climate change; climate modelling, prediction, and projection; state-of-the-art physical climate change, adaptation, mitigation knowledge, IPCC and beyond ♦ Physical Oceanography, Hydrology and Climate: Descriptive oceanography, topography, plate tectonics; physical properties of water, chemistry of seawater; thermodynamics and hydrodynamics; equations of motion; waves, tides, and ocean circulation; sea ice and cryosphere; measurement techniques and instruments; oceans and climate ♦ Paleoclimatology: Climate change and environmental changes throughout the earth's history; physical mechanisms that caused these changes; scientific methods for the detection of past climate change and environmental changes
Learning outcomes	After having participated successfully in the module, students are able to • understand and critically appraise physical climate system and climate change knowledge; • adequately appreciate IPCC assessment report knowledge and conclusions; • apply the principles and methods of physical climatology, oceanography and hydrology; • contribute with expertise to the discourse on contemporary anthropogenic climate change and its consequences, in the proper context of paleoclimate and historical climate processes and dynamics; • describe the important processes influencing the oceans and the oceans' role in the climate system, and • provide an overview of the field of oceanography and discuss relevant current events (e.g. the increased melting of sea ice). After having completed the module, students have gained knowledge of • the earth's physical climate system and anthropogenic climate change; • key climate science methodologies including field modelling based on balance principles and state equations, network modelling based on budgets and cycles, climatic time series analysis from paleo-ages to the present; • physical oceanography and hydrology, and their relation to climate dynamics; • relations and interactions between the hydrosphere and the atmosphere, and • paleoclimatology and climate history of the Holocene and the previous millennia and centuries.
Teaching and learning activities and methods	The module consists of three lectures. The relevant theoretical concepts are taught in detail and illustrated with examples and applications.
Previous knowledge expected	None
Frequency of offer	At least every two years

Module C2	Data Analysis and Simulation
ECTS credit points	9
Subject content	♦ Methods of Modelling and Simulation: Overview and basic methods of modelling and simulation of systems in atmospheric, climate and environmental sciences. Modelling and numerical simulation of deterministic, stochastic and dynamical systems. Mathematical and physical modelling/simulation via ordinary and partial differential equations, random processes, discrete automata. Basic numerical solution methods. Empirical modelling via linear and nonlinear regression methods. State estimation/measurement model estimation. Error analysis. Optimal estimation, inverse modelling and data inversion methods ♦ Exercises in Methods of Modelling and Simulation: Practical training in the topics of the associated lecture on methods of modelling and simulation. Selected examples of modelling/simulating systems in atmosphere, climate and environmental sciences ♦ Time Series Analysis: Probability theory: random variables, distributions, statistical moments. Statistical inference: maximum likelihood estimation. Statistical modelling: linear, generalised and vector regression models. Stochastic processes: ARMA processes, Yule-Walker equations, simulation. Spectral analysis: spectrum, phase spectrum, cross spectrum, coherence, wavelet spectrum. Pattern methods: principal component analysis, canonical correlation analysis
Learning outcomes	After having participated successfully in the module, students are able to • understand the basic principles of system modelling/simulation and statistical time series analysis; • formulate and build mathematical/physical models; • apply suitable (numerical) methods for solving modelling problems; • apply suitable methods for the analysis of time series and data records, and • analyse and interpret model/simulation results. After having completed the module, students have gained • knowledge of different methods of modelling/simulation in atmosphere, climate and environmental sciences; • knowledge of fundamental concepts and different methods of time series analysis, and • problem solving skills for practical modelling/simulation and data analysis problems.
Teaching and learning activities and methods	The module consists of two lectures and an accompanying exercise on modelling and simulation. In the lectures, the material is presented theoretically and explained with selected examples. In the exercise, practical training, mainly computer-based, is provided for the topics covered by the associated lecture, supported by adequate software for modelling and simulation. The training covers both independent problem solving (supported by advice) and joint problem solving in a team.
Previous knowledge expected	Basic knowledge of a programming language at bachelor's level
Frequency of offer	Mandatory courses (♦) every year

Module C3	Atmospheric Physics
ECTS credit points	9
Subject content	♦ Atmospheric Dynamics: Thermodynamics; equations of motion; balanced flow, scale analysis; circulation and vorticity; atmospheric waves; extra-tropical weather systems; general circulation; air masses and fronts; tropical and polar weather ♦ Atmospheric Composition and Chemistry: Development and evolution of planetary atmospheres; composition and vertical structure of the earth's atmosphere; fundamentals of stratospheric and tropospheric chemistry; chemical cycling; air pollution and air quality; photochemistry; gas-phase chemistry; aerosol nucleation and growth; aerosol-cloud chemistry; chemistry-climate connections; chemical geoengineering ♦ Radiation and Energy Balance: Radiative transfer in planetary atmospheres; radiative forcing; interaction of radiation (UV/VIS, IR) with gases and clouds; atmospheric energy budget
Learning outcomes	After having participated successfully in the module, students are able to • apply scale analysis to simplify the equations of motion; • apply perturbation analysis to study atmospheric waves; • solve chemical reaction equations; • contribute to the debate on stratospheric ozone depletion/recovery, degrading air quality and chemistry-climate connections, and • perform radiative transfer calculations. After having completed the module, students have gained knowledge of • the physical principles governing large-scale and mesoscale atmospheric flow and atmospheric thermodynamics; • the composition and evolution of planetary atmospheres and fundamental chemical cycles; • the principles of stratospheric and tropospheric chemistry and chemistry-climate connections, and • radiative forcing and transfer in planetary atmospheres, the earth's energy balance.
Teaching and learning activities and methods	The module consists of three lectures. The relevant theoretical concepts are taught in detail and illustrated with many examples and applications.
Previous knowledge expected	None
Frequency of offer	At least every two years

Module C4	Climate Physics
ECTS credit points	9
Subject content	♦ Climate Modelling: Hierarchy of climate models; parameterisations; finite differencing; climate model experiments; uncertainties; skill of climate models; global climate projections; regional climate modelling ♦ Climate Dynamics: Geophysical fluid dynamics; energy balance models; climate equilibria and stability (warm and cold climates); large-scale atmospheric energy and momentum transport; air-sea fluxes; physics of large-scale climate modes (ENSO, NAO, PNA); inter-annual to centennial climate variability ♦ Selected Topics in Climate Science: Current status of climate observations and climate projections; current research frontiers in climate research
Learning outcomes	After having participated successfully in the module, students are able to • critically interpret the design of climate model experiments and future projections of global and regional climate change; • interpret fingerprints of large-scale climate modes; • apply fundamental geophysical fluid dynamics in process analyses, and • contribute to the debate on climate change on a global and regional scale. After having completed the module, students have gained knowledge of • the principles of climate modelling at an introductory level; • a wide range of possibilities of using climate models; • the benefits and limitations of climate models; • geophysical fluid dynamics and energy and momentum transport; • large-scale climate modes, their underlying drivers and their role in the climate system; • inter-annual to centennial climate variability, and • the current understanding of the climate system, future projections of climate change and research frontiers in climate research.
Teaching and learning activities and methods	The module consists of three lectures. The relevant theoretical concepts are taught in detail and illustrated with many examples and applications.
Previous knowledge expected	None
Frequency of offer	At least every two years

Module C5	Atmospheric Measurement Methods and Observing Systems
ECTS credit points	9
Subject content	♦ <u>Atmospheric Measurement Methods: Remote Sensing</u>: Introduction to and an overview of remote sensing of the atmosphere and climate. Types and classification of remote sensing systems, sensors, platforms, and basic measurement geometries. Physics of remote sensing. Relevant properties of electromagnetic radiation and interaction processes with matter, radiative transfer. Applications for remote sensing of thermodynamic variables, wind, and atmospheric composition ♦ <u>Atmospheric Measurement Methods: In situ</u>: Introduction to and an overview of in situ measurement methods for meteorological parameters, tropospheric trace gases, air pollutants, atmospheric properties and climate variables. Instrument types and underlying measurement/sampling/recording principles. Application of in situ measurements in atmospheric and climate research. Overview of global/regional in situ monitoring networks ♦ <u>Seminar on Measurement Methods in Atmospheric Physics</u>: Specific selected topics from the field of remote sensing and in situ atmospheric measurement methods for deepening knowledge of the topics in the associated lectures. Important measurement methods/techniques, instruments/sensors, data processing methods for atmospheric thermodynamic variables and atmospheric composition e.g. temperature, trace gas and wind sounding
Learning outcomes	After having participated successfully in the module, students are able to • name, classify, explain and distinguish important atmospheric measurement methods; • discuss advantages and disadvantages of individual methods; • select suitable observing systems for practical applications; • relate measurement principles to basic physical and chemical processes; • undertake literature research and cite scientific literature according to given standards; • prepare and summarise information on a scientific topic, and • present a scientific topic. After having completed the module, students have gained knowledge of • different atmospheric remote sensing measurement methods; • different atmospheric in situ measurement methods; • physical and chemical principles of individual measurement techniques, and • scientific presentation.
Teaching and learning activities and methods	The module consists of two lectures and an accompanying seminar. In the lectures, the material is presented theoretically. In the seminar, knowledge of the topics covered by the associated lectures is deepened. The seminar prepares students for independent work, and presentation and discussion of research-related topics on important or new atmospheric measurement methods.
Previous knowledge expected	None
Frequency of offer	At least every two years

Module E1	Surface Science: Basic Principles
ECTS credit points	9
Subject content	♦ Surface Science: Geometric and electronic structure of surfaces (theory and methods); adsorption; (thermodynamics, growth processes) ♦ Experimental Methods in Surface Science: Combination of lectures and laboratory courses; the focus is on understanding the principles of modern experimental surface science techniques (morning lectures) and gaining direct hands-on experience (afternoon laboratory course) with the techniques available at the surface science groups at Uni Graz and TU Graz. ♦ Thin Film Science and Processing: Principles of thin film growth; thermodynamics and kinetics; adsorption; desorption; diffusion; techniques (PVD, CVD, LB, spin coating); nanostructure fabrication (etching, etc.)
Learning outcomes	After having participated successfully in the module, students are able to • understand the fundamental (geometric and electronic) properties of surfaces as a representation of a truncated crystalline bulk material; • understand the principles of, operate, and interpret the results obtained with state-of-the-art ultra-high vacuum-based surface science methods and standard surface analytical methods for industry, and • understand the principles and methods of adsorption on surfaces, self-assembly, thin film growth and nanostructuring.
Teaching and learning activities and methods	Lectures, laboratory course
Previous knowledge expected	None
Frequency of offer	Every year

Module E2	Surface Science: Advanced Topics
ECTS credit points	9
Subject content	Molecular Interfaces: Bonding; orbitals; band structure; interfaces; angle-resolved UPS; orbital tomography Scanning Probe Techniques: Scanning tunnelling microscopy (theory; operation; measurement modes; spectroscopy; applications; spin-polarised STM; inelastic STM/STS; manipulation). Atomic force microscopy (theory; interaction forces; modes (static, dynamic); force-distance curves; Kelvin probe; magnetic force spectromicroscopy: PEEM; LEEM; μ-XPS Synchrotron Radiation Techniques: Synchrotron light generation (history, accelerators, etc.); synchrotron XPS (time-resolved; data analysis; line shapes; curve fitting, etc.); X-ray absorption spectroscopy (EXAFS, XANES) Surface Chemistry: Chemical reactions on surfaces (heterogeneous catalysis; photocatalysis; electrochemistry) Vacuum Technology: Gas kinetics; pumps; pressure measurements; vacuum chambers; safety
Learning outcomes	These advanced courses are partly intended as preparation for and as accompanying lectures during the master’s research project. They provide students with deeper knowledge of the systems and techniques of surface physics and surface chemistry.
Teaching and learning activities and methods	Lectures
Previous knowledge expected	None
Frequency of offer	Every year

Module E3	Spectroscopy
ECTS credit points	9
Subject content	General aspects of spectroscopic methods in modern physical research together with some selected special topics ♦ Spectroscopy: General aspects of spectroscopic methods; wave-particle dualism; energy and momentum conservation; dispersion relation (classical, relativistic); mass and massless excitations; scattering processes (elastic, inelastic); cross sections; Fermi's golden rule; dissipation-fluctuation theorem; selection rules; optical spectroscopy; interaction of photons with matter; electron spectroscopy; physics of EELS; EELS imaging; edge fine structure ELNES/EXELFS; photoelectron spectroscopy; neutron scattering; µSR; NMR; ESR; interpretation of spectra; line shapes (Lorentzian, Gauss, Voigt, Fano); selected practical examples: determination of coordination; valences; bond lengths; composition; vibrational frequencies; lifetime of states; Fermi resonance; difference in classical and highly correlated systems (nested Fermi surface, marginal Fermi liquid, superconductors, correlated electron states, spin systems) ♦ Research Laboratory Spectroscopy: Practical use and interpretation of the spectra. Laboratory course with practical training in selected spectroscopic methods Synchrotron Radiation Techniques: Synchrotron light generation (history, accelerators, etc.); synchrotron XPS (time-resolved; data analysis; line shapes; curve fitting, etc.); X-ray absorption spectroscopy (EXAFS, XANES) X-ray and Neutron Scattering: Basic principles of elastic and inelastic scattering techniques to study the structure and dynamics of materials at the atomic and molecular level Magnetic resonance: NMR and ESR: Nuclear and electron spins; density matrix and internal energy; thermodynamic equilibrium; Bloch equation; 2 level systems and quantum computing; spin coupling by dipoles and Suhl-Nakamura interaction; hyperfine interactions; Knight shift; Korringa relaxation; spin diffusion; vortex ordering and fluctuations in superconductors; experimental setup; pulse and Fourier spectroscopy; spin-echo methods Application of Group Theory: Symmetries in physics; groups; linear operators; tensors; point symmetries; representations and characters; projection operators; G-independent subspaces; selection rules; translational symmetry; Bloch theorem; symmetry restriction on material properties; simplification of eigenvalue problems; application on vibrations; phonons; electronic structure, etc.
Learning outcomes	After having participated successfully in the module, students • understand the basic principles of spectroscopic methods in modern physical research; • have an overview of spectroscopic methods; • are able to interpret spectroscopic data with respect to physical behaviour of molecules and solids; • are able to use some selected spectroscopic methods practically in the laboratory, and • have more detailed knowledge of some selected spectroscopic methods.
Teaching and learning activities and methods	Lectures, laboratory course
Previous knowledge expected	Attending the laboratory course requires the knowledge from the mandatory lecture (♦).
Frequency of offer	Mandatory courses (♦) every year; others at least every two years

Module E4	Nano-optics and Laser Optics
ECTS credit points	9
Subject content	♦ Advanced Optics: Light and matter; interference and diffraction; beam and pulse propagation; layered media and waveguides; microscopy; sources and detectors ♦ Research Laboratory Nano-optics and Laser Optics: Practical training in advanced experimental techniques with the opportunity to choose topics according to interests and lectures attended Nano-optics: Super-resolution microscopy; near-field microscopy; quantum emitters; photonic crystals; plasmonics; metamaterials Laser Physics: Emission and absorption; Einstein coefficients; laser theory and rate equations; optical resonators and modes; laser pulses; laser types; laser safety Ultrafast Laser Physics: Introduction to the state-of-the-art research field of femtosecond time-resolved molecular spectroscopy: generation and amplification of femtosecond laser pulses; pulse propagation in media, dispersion compensation; pulse characterisation; methods and examples of femtosecond time-resolved spectroscopy; strong field effects; applications
Learning outcomes	After having participated successfully in the module, students are able to • understand and apply the concepts of ray and wave optics; • understand and apply the concepts of optical material properties and light-matter interaction at all length scales, and • understand and apply the physical and technical principles of (ultrafast) lasers. After having completed the module, students have acquired • the ability to design optical and laser setups, and • the basis for the master's thesis in a research laboratory in the fields of modern optics and photonics.
Teaching and learning activities and methods	Lectures, laboratory course
Previous knowledge expected	Experimental physics, quantum mechanics, electrodynamics and mathematical concepts at bachelor's level
Frequency of offer	Every year

Module E5	Quantum Optics and Molecular Physics
ECTS credit points	9
Subject content	Concepts of light-matter interaction are introduced and described with semiclassical and quantum physics. Topics ranging from light propagation in solids to the investigation of processes in isolated molecules with femtosecond laser pulses and their modelling are covered. ♦ Fundamental Optics: Basics of optics for research and industrial applications: light propagation in isotropic materials; conducting media and birefringent crystals; polarisation optics; nonlinear optics; Fraunhofer and Fresnel diffraction; Fresnel zone plates; coherence and interference; holography; Fourier optics ♦ Research Laboratory Quantum Optics and Molecular Physics: Practical training in advanced experimental techniques with the opportunity to choose topics according to interests and lectures attended. Students also participate in one of the research experiments. Ultrafast Laser Physics: Introduction to the state-of-the-art research field of femtosecond time-resolved molecular spectroscopy: generation and amplification of femtosecond laser pulses; pulse propagation in media, dispersion compensation; pulse characterisation; methods and examples of femtosecond time-resolved spectroscopy; strong field effects; applications Laser Physics: Emission and absorption; Einstein coefficients; laser theory and rate equations; optical resonators and modes; laser pulses and types; laser safety Quantum Optics: Correlated photons; theory of light-pressure force; laser cooling and trapped atomic ensembles; atom interferometry; quantum interference; foundations and theory of atomic clocks and optical magnetometers Modelling of Molecular Systems: Non-Born-Oppenheimer effects; rovibronic interactions; group theory; excited states; post-Hartree-Fock techniques; solvation, QM/MM embedding; reaction dynamics and transition state theory
Learning outcomes	After having participated successfully in the module, students are able to • solve optics-related tasks in research and industry, equipped with a substantial fundamental and practical basis; • understand light-induced molecular processes, their investigation with (femtosecond) laser radiation, as well as their modelling; • design and construct optical setups for laser applications, and • carry out a master’s thesis in a research laboratory in the field of modern optics or laser spectroscopy.
Teaching and learning activities and methods	Lectures, laboratory course
Previous knowledge expected	Experimental physics, quantum mechanics, electrodynamics and mathematical concepts at bachelor’s level
Frequency of offer	Every year

Module E6	Nano and Quantum Matter
ECTS credit points	9
Subject content	♦ Solid-state Physics: Size Effects and Quantum Phenomena: Building crystals from atoms; chemical bond; translational symmetry; zone mapping; phonons; band structure; magnetism; surface and interfaces; heterojunctions; low-dimensional systems; confined states in, exotic quantum effects in nanostructures; spin transport and magnetisation switching; dimensionality; periodic boundary conditions at finite size; development of Bloch states; oligomers-polymers; carbon nanophases; quantum dots; Born-Oppenheimer; Hückel; tight-binding; Hubbard; Heisenberg; magnons; quantum Hall; topological insulators; superconductivity and superfluidity; polaritons; plasmons; mass of photons; soft modes; phase transitions Modern Materials: Shape-dependent and size-dependent properties; nanoanalytic; nanostructures; quantisation effects; single-electron effects; molecular electronics; nanoparticles; polymers and biological materials; smart materials Scanning Probe Techniques: Scanning tunnelling microscopy (theory; operation; measurement modes; spectroscopy; applications; spin-polarised STM; inelastic STM/STS; manipulation) Atomic force microscopy (theory; interaction forces; modes (static, dynamic); force-distance curves; Kelvin probe; magnetic force; spectromicroscopy: PEEM; LEEM; µ-XPS Nanomagnetism and Quantum Magnetism: Mean field approximation; Curie-Weiss law; spin-spin interaction models; spontaneous order; magnetic anisotropy; magnetoelastic coupling; exchange bias; magneto-optics; interlayer exchange coupling; RKKY interaction; GMR; superparamagnetism; SQUID magnetometry; magnetic force microscopy; X-ray circular dichroism Application of Group Theory: Symmetries in physics; groups; linear operators; tensors; point symmetries; representations and characters; projection operators; G-independent subspaces; selection rules; translational symmetry; Bloch theorem; symmetry restriction on material properties; simplification of eigenvalue problems; application on vibrations; phonons; electronic structure, etc. Theory of Superconductivity: Phenomenology of superconductors; the Meissner effect; London equations. Microscopic theory: BCS theory at zero and finite temperatures; introduction to strong-coupling Migdal-Eliashberg theory Phase Transitions and Critical Phenomena: Lattice models and applications of statistical physics. Mean field; perturbation series; transfer matrix; renormalisation group; mapping between representations. Simulation techniques and practical examples, including cluster Monte Carlo and Kosterlitz-Thouless transition Theory of Magnetism and Collective Phenomena: Magnetic exchange mechanisms; models for magnetic materials; response functions and phase transitions; Brown theory of micromagnetism; magnetic domains Quantum Transport Theory: Introduction to basic approaches to quantum transport theory, e.g. semiclassical Boltzmann equation; Wigner function approach; Green's function techniques. Selected applications in nanophysics Exotic States in Solids: Berry phase; topological matter; the quantum Hall and spin Hall effect; topological insulators; Dirac and Majorana fermions; monopoles; vortices, etc.

	Nanostructures and Nanotechnology: Overview of physical nanoscience: physics of low-dimensional systems. Electronic transport and magnetic properties on the nanoscale. Nanoparticles, nanocrystalline and nanoporous materials. Lateral nanostructuring. Nanowires, nanotubes and nanodots. Scanning probe techniques
Learning outcomes	After having participated successfully in the module, students • understand modern physics based on size effects, dimensionality and quantum phenomena; • have gained an experimental and theoretical insight into methods of modern physics, and • have acquired knowledge and an understanding of the principles of modern materials and their use in new products.
Teaching and learning activities and methods	Lectures
Previous knowledge expected	Knowledge of solid-state physics, quantum mechanics, experimental and computational techniques at bachelor's level
Frequency of offer	Mandatory courses (♦) every year; others at least every two years

Module E7	Biological Applications
ECTS credit points	9
Subject content	Molecular Biophysics 1: Origin, evolution and building elements of life; structure of cells and biological materials; intermolecular forces and interactions; diffusion and dynamics; molecular interplay in cellular processes Molecular Biophysics 2: Selected topics in molecular biophysics, including protein conformation, lipid membranes, lipid/protein interactions, motor proteins, cytoskeleton/membrane interactions, membrane processes Biophotonics: Interaction of light with biological tissue, including models of light transport; therapeutic effects of light and optical imaging methods in biology and medicine, including special microscopy techniques, optical coherence tomography and photoacoustic imaging Biomagnetism: Basics: superparamagnetism and blocked mono-domain particles; iron inclusions in biological tissue; SQUID magnetometry; detection of iron oxide-marked cells; medical applications of magnetic fields Soft Matter Physics: Structural, mechanical and optical properties of soft matter, such as colloids, gels, liquid crystals, polymers and biological systems; hierarchical structures; self-assembly; internal surfaces; metastable states and phase separation Biological and Biobased Materials: Mutual dependencies of physicochemical properties and function of biological materials; hierarchical construction and the resulting material properties both on the molecular and the macroscopic levels; applications in the form of biosensors or synthetic fibres ♦ Research Laboratory Biophysics: Practical training in advanced experimental techniques, including photoacoustic spectroscopy and imaging, small angle X-ray diffraction, X-ray reflectivity, with the opportunity to choose topics according to interests and lectures attended
Learning outcomes	After having participated successfully in the module, students are able to • understand the hierarchical structure of biological systems; • specify methods for determining physical properties of biological materials, and • use selected experimental methods for the characterisation of biological materials.
Teaching and learning activities and methods	Lectures, laboratory course
Previous knowledge expected	None
Frequency of offer	Mandatory course (♦) every year; others at least every two years

Modul E8	Industrial Applications
ECTS credit points	9
Subject content	♦ Topics of Industrial Relevance: External lecturers present a course on technological and analytic methods and current innovative developments of industrial relevance challenging physicists. The main aspect is the perspective from outside the university on research and development and the specific expectations of physicist graduates. Specific topics from various fields of industrial relevance are offered on an annual basis. ♦ Signal Theory and Signal Processing: Introduction to the fundamentals of signal theory, digital filters, spectral analysis (FFT, wavelets, Hilbert transform), noise measurements and correlation techniques, embedding software in hardware solutions Patent Law and Technology Transfer: Basics of intellectual property rights (IPRs) with a special focus on patents; (rough) overview of patent systems (esp. USA and Europe); search for patent literature; tools for technology transfer, licensing contracts and case study Ultrasound Methods: Theory of ultrasound in fluids and solids, ultrasonic waves in bulk, at surfaces and interfaces; ultrasound generation and measurement techniques; ultrasound applications: non-destructive evaluation of materials, acoustic microscopy, biomedical imaging, photoacoustic imaging Thin Film Science and Processing: Principles of thin film growth, thermodynamics and kinetics, adsorption, desorption, diffusion, techniques (PVD, CVD, LB, spin coating), nanostructure fabrication (etching, etc.) Modelling and Simulation of Semiconductors: Introduction to the electronic structure of semiconductors; scattering mechanisms for electrons; transport modelling techniques (drift diffusion, Monte Carlo, Boltzmann equation); organic and nanotube field-effect transistors Temperature Measurements: Temperature measurements by: fixed points, expansion of liquids and metals, electrical resistance, thermoelectric effects; optical temperature measurement: pyrometry, emissivity, black-body radiation Light Engineering: Photometry, colorimetry; radiation flux and intensity, radiance, irradiance; visual measurements; physical and visual photometry, spectral luminous efficiency; the CIE chromaticity of black-body radiation Excursion: An excursion to companies or external laboratory courses.
Learning outcomes	After having participated successfully in the module, students • have gained suitable knowledge of the concepts of how physical research is transferred to industrial applications and methods; • have acquired some specific professional skills in management and legal aspects (protection of intellectual property rights, patent law), and • are able to use modern experimental equipment and methods in industry. After having completed the module, students • have gained experience to use basic physical knowledge in industry; • are familiar with industrial practice to assess industrial projects, and • possess competence in the specialised elective courses.
Teaching and learning activities and methods	Lectures, laboratory courses at the university or (externally) in industry, excursion to specific companies
Previous knowledge expected	Knowledge of solid-state physics, quantum mechanics, experimental and computational techniques at bachelor's level
Frequency of offer	Mandatory courses (♦) every year; others at least every two years

Module S1	Fundamentals of Space Physics and Aeronomy
ECTS credit points	9
Subject content	♦ Introduction to Planetology: Overview of the solar system (terrestrial planets, gas giants, moons, planetary ring systems, asteroids and comets); structure and composition of planetary bodies (energy budget and dynamics); thermal models; tidal interactions ♦ Introduction to Aeronomy: Basis of atmospheric physics in general (composition and structure, transport processes, radiation, chemistry); special situation of upper atmospheres; examples; overview of experimental methods; overview of models; review: ionospheres ♦ Introduction to Space Plasma Physics: Fundamentals of the motion of charged particles in electric and magnetic fields; magnetohydrodynamic equations; elementary wave phenomena in plasmas; magnetohydrodynamic and electrodynamic waves in plasmas; magnetoplasmas in planetary magnetospheres
Learning outcomes	After having participated successfully in the module, students are able to • give an overview of the physical properties of the bodies in our planetary system; • explain the differences and commonalities of the planets and their physical causes; • describe the basic physical processes governing planetary atmospheres – with a focus on the upper atmosphere; • give an overview of the basic physical processes in planetary ionospheres, and • explain the fundamentals of magnetohydrodynamics and electrodynamic waves in plasmas. After having completed the module, students have gained knowledge of • terrestrial planets, gas giants, moons, planetary ring systems, asteroids, and comets; • the energy budget and dynamics of planets and tidal interactions; • methods and research systems in the aeronomy of the upper atmospheres of the earth and the planets with an emphasis on the neutral gas part; • the fundamentals of the motion of charged particles in electric and magnetic fields, and • the behaviour of space plasmas and wave phenomena in magnetoplasma.
Teaching and learning activities and methods	The module consists of three lectures. The relevant theoretical concepts are taught in detail and illustrated with examples and applications.
Previous knowledge expected	None
Frequency of offer	At least every two years

Module S2	Solar and Heliospheric Physics
ECTS credit points	9
Subject content	♦ Introduction to Solar Physics: The sun as a star; determination of basic physical parameters describing the sun and stars; solar interior structure; thermonuclear fusion in the solar core; solar neutrinos; helioseismology; solar atmosphere; phenomena of the quiet and the active sun; solar activity cycle; solar dynamo; solar wind; flares, coronal mass ejections and space weather ♦ Magnetohydrodynamics and Solar-terrestrial Modelling: Basic magnetohydrodynamics (MHD) equations; magnetic reconnection; interaction of the solar wind with planetary atmospheres; solar-terrestrial relations ♦ Exercises in Solar Physics: Training in the methods introduced in the associated lecture by solving problems related to Solar Physics. ♦ Solar Physics Lab: Practical exercises at Kanzelhöhe Observatory to obtain an insight into state-of-the-art methods of ground-based observations of the sun
Learning outcomes	After having participated successfully in the module, students are able to • understand the physics and structure of the sun and the solar system; • describe the most relevant phenomena of the quiet and the active sun; • understand solar activity and its variability with the solar dynamo theory; • understand the basic concepts of MHD and apply them to the solar-terrestrial interactions, and • give an overview of plasma physical phenomena and their applications in the solar system and astrophysical systems. After having completed the module, students have gained knowledge of • the solar interior structure and helioseismology; • solar wind, flares, coronal mass ejections, and space weather; • basic magnetohydrodynamics; • magnetic reconnection and interaction of the solar wind with planetary atmospheres; • practical analysis methods for space plasmas (waves, shock waves, turbulence, reconnection), and • the plasma physical picture of the solar system.
Teaching and learning activities and methods	The module consists of three lectures. The relevant theoretical concepts are taught in detail and illustrated with examples and applications.
Previous knowledge expected	None
Frequency of offer	At least every two years

Module S3	Physics of Planetary Atmospheres and Magnetospheres
ECTS credit points	9
Subject content	♦ Physics of Planetary Atmospheres: Overview of the origin and evolution of planetary atmospheres. Solar system planets versus exoplanets. Atmosphere structure and escape. Sources of initial atmospheres and water inventories of terrestrial planets. Formation of mineralogical (silicate) atmospheres and exospheres. The role of impacts by comets and asteroids. Spacecraft techniques for atmosphere detection on planets beyond the earth ♦ Earth's and Planetary Magnetic Fields: Concept of magnetic fields. Planetary core dynamics of electrically conducting fluids. Elements of magnetohydrodynamics. Dynamo mechanisms (twisting and stretching effects). Potential field description using spherical harmonic analysis. Surface remanent magnetisation. Paleomagnetism. Ionospheric and magnetospheric sources. Time variation of magnetic fields. Magnetic fields of solar system bodies. Measurement techniques ♦ Planetary Magnetospheres: Physics of interaction between the solar wind plasma and planetary magnetic fields. Magnetospheric structures and internal processes of magnetised solar system planets: electric fields, charged particle motion, Van Allen belts. Auroral processes, planetary non-thermal radio emission. Specifics of giant planets magnetospheres (Jupiter-Io interaction, Saturn microsignatures, magnetospheric structure changes of oblique rotators). Magnetic indices
Learning outcomes	After having participated successfully in the module, students understand • the fundamental physics principles of planetary atmospheres; • the concept of magnetic fields and their origin, and • the basic plasma physics involved in particle and field interactions. Students have gained • an insight into complex interconnected areas of aeronomy and habitability; • competence in space science through magnetic fields, and • profound knowledge of solar system plasma physics.
Teaching and learning activities and methods	Lectures
Previous knowledge expected	Knowledge of astrophysics, astronomy, geophysics (earth's interior structure), chemistry, electromagnetism, hydrodynamics, plasma physics, electromagnetic and plasma waves at bachelor's level
Frequency of offer	At least every two years

Modul S4	Measurement Methods and Observing Systems
ECTS credit points	9
Subject content	♦ Measurement Methods in Space Physics: Plasma, fields and waves as measurement parameters in a near-planetary environment, interplanetary space and from the ground. Remote and in situ measurements by satellites, spacecraft and telescopes. Fundamental measurement methods and techniques by single/multiple (simultaneous) experiments. Data acquisition and analysis of significance, error, and interpretation. Connection between experiment reliability and data quality ♦ Space Missions and Experiments Design: Physics objectives of space target and corresponding space mission development. Concept of spacecraft/satellite construction and science payload. Experiments design, power, data storage, communication and housekeeping systems. Interconnectivity and complementarity of experiments, issues of experiment and data calibration. Optimisation of choice of spacecraft/satellite trajectory and sequence of experiment operations ♦ Seminar on Measurement Methods in Space Physics: The content of the lecture Measurement Methods in Space Physics is treated interactively and enforced by students' presentations, discussions and teamwork. Additional related issues and objectives have to be identified, analysed, interpreted and presented by students' literature and media search.
Learning outcomes	After having participated successfully in the module, students understand • the fundamental physics principles of remote and in situ measurement methods; • the concept of space mission development, experiment performance, observation, and data acquisition, and • the basics regarding data quality, significance and error analysis. Students have gained • an insight into the complex interconnection of experiment and observational data; • competence in space science through knowledge of experiment performance, data acquisition and physical process interpretation, and • profound knowledge of measurement methods and techniques.
Teaching and learning activities and methods	Lectures and seminar
Previous knowledge expected	Knowledge of astrophysics, astronomy, physics, geophysics, electromagnetism, hydrodynamics, electronics, plasma physics and waves theory at bachelor's level
Frequency of offer	At least every two years

Module T1	Advanced Theoretical Physics 1
ECTS credit points	9
Subject content	♦ Advanced Mathematical Methods: Group theory (discrete groups, Lie algebras and Lie groups); complex analysis (Cauchy's integral theorem, residue theorem, conformal maps, etc.), basic elements of geometry and topology (manifolds, homotopy groups) Advanced Mathematical Methods Exercises: Problem solving for the topics of the lecture ♦ Quantum Field Theory: Klein-Gordon, Dirac and Maxwell fields; canonical formalism, functional integrals, Feynman rules, renormalisation, leading order QED processes Quantum Field Theory Exercises: Problem solving for the topics of the lecture
Learning outcomes	After having participated successfully in the module, students are able to • perform successful standard-type calculations involving group representations and algebras, with complex functions and distributions, and with elementary topological quantities; • understand the basic principles of quantum field theory; • apply basic methods in quantum field theory, and • perform successful standard-type calculations in quantum field theory. After having completed the module, students have gained • profound knowledge of group theory, complex analysis and the basics of quantum field theory.
Teaching and learning activities and methods	Lectures, exercise-based courses
Previous knowledge expected	Theory courses at bachelor's level and General Physics module
Frequency of offer	Every year

Module T2	Advanced Theoretical Physics 2
ECTS credit points	9
Subject content	♦ Advanced Statistical Physics: Phase transitions; renormalisation group; Bose-Einstein condensates; spontaneous symmetry breaking and Goldstone theorem ♦ Advanced Quantum Mechanics 2: Scattering theory (continued); open quantum systems; density operator; quantum measurement; quantum information; quantum optics ♦ Basic Concepts in Solid-state Theory: Electron gas; Bloch theorem and Bloch waves; spin-orbit coupling; ion lattices and phonons; electron-phonon interaction and (conventional) superconductivity; Hartree-Fock approximation; screening
Learning outcomes	After having participated successfully in the module, students are able to • understand properties of physical systems from the thermodynamic limit in statistical physics; • apply further advanced methods in quantum theory, and • perform successful standard-type calculations in these fields. After having completed the module, students have gained • profound knowledge of phase transitions, properties of systems with spontaneously broken symmetries and exotic types of quantum matter as well as modern developments in quantum theory, and • basic knowledge of the underlying principles of solid state theory.
Teaching and learning activities and methods	Lectures
Previous knowledge expected	Theory courses at bachelor's level and General Physics module
Frequency of offer	Every year

Module T3	Computational Physics
ECTS credit points	9
Subject content	♦ Numerical Methods in Linear Algebra: Numerical methods of linear algebra and partial differential equations; direct and iterative methods for solving linear systems of equations and eigenvalue problems; finite difference approach to partial differential equations; von Neumann stability ♦ Monte Carlo Methods: Random numbers; random walks; importance sampling; Metropolis algorithm; cluster and worm algorithms; data analysis. Applications: spin systems, lattice field theories Computational Methods in Solid-state Physics: Computational approaches in solid-state physics, with an emphasis on dynamic processes e.g. spontaneous magnetisation and self-consistency; quantum interference effects in qubit control; spin-selective transport in semiconductor heterostructures; Andreev reflection, etc. Computational Methods in Particle Physics: Numerical solution of functional equations, e.g. exact renormalisation group equations, Dyson-Schwinger equations and Bethe-Salpeter equations
Learning outcomes	After having completed the module, students are able to • apply direct and iterative methods for the numerical solution of linear systems of equations; • characterise and analyse finite difference approximations of partial differential equations by a von Neumann stability analysis and compute their solution; • classify various Monte Carlo methods; • apply Monte Carlo methods to physical problems, and • convert physical problems of solid-state physics or elementary particle physics into numerical algorithms and obtain their numerical solutions.
Teaching and learning activities and methods	The module consists of two compulsory lectures teaching the theoretical basis of the numerical algorithms, knowledge of which is deepened by solving problems by writing computer programs. In a further lecture, either numerical methods specific to problems of solid-state theory or particle physics are treated.
Previous knowledge expected	None
Frequency of offer	Every year

Module T4	Theoretical Solid-state Physics
ECTS credit points	9
Subject content	♦ Green's Functions for Solid-state Physics: Physical response and Green's functions (finite T); functional integral representation; contour ordering; perturbation theory; irreducible diagrams and integral equations; zero-temperature Green's Functions: linear response; Fermi liquid theory, etc. Fundamentals of Electronic Structure Theory: Electronic band structure; free-electron bands and tight-binding approximation. Self-consistent field approximation; density functional theory; basis functions; full-potential and pseudopotential methods; advanced topics Theory of Magnetism and Collective Phenomena: Magnetic exchange mechanisms; models for magnetic materials; response functions and phase transitions; Brown theory of micromagnetism; magnetic domains Theory of Superconductivity: Phenomenology of superconductors; the Meissner effect; London equations. Microscopic theory: BCS theory at zero and finite temperatures; introduction to strong-coupling Migdal-Eliashberg theory Phase Transitions and Critical Phenomena: Lattice models and applications of statistical physics. Mean field; perturbation series; transfer matrix; renormalisation group; mapping between representations. Simulation techniques and practical examples, including cluster Monte Carlo and Kosterlitz-Thouless transition Quantum Transport Theory: Introduction to basic approaches to quantum transport theory, e.g. semiclassical Boltzmann equation, Wigner function approach, Green's function techniques. Selected applications in nanophysics Exotic States in Solids: Berry phase; topological matter; the quantum Hall and spin Hall effect; topological insulators; Dirac and Majorana fermions; monopoles; vortices, etc. Computational Methods in Solid-state Physics: Computational approaches in solid-state physics, with an emphasis on dynamic processes e.g. spontaneous magnetisation and self-consistency; quantum interference effects in qubit control; spin-selective transport in semiconductor heterostructures; Andreev reflection, etc.
Learning outcomes	After having participated successfully in the module, students have a clear overview of the fundamental methods and open problems of modern theoretical solid-state physics. After having completed the module, students have acquired the basic skills to solve related problems at the level of a master's thesis.
Teaching and learning activities and methods	Lectures with multimedia material
Previous knowledge expected	Knowledge of solid-state physics, quantum mechanics and statistical physics at master's level
Frequency of offer	Mandatory courses (♦) every year; others at least every two years

Module T5	Theoretical Nanophysics
ECTS credit points	9
Subject content	Theoretical Nanophysics and Quantum Physics: Quantisation of the electromagnetic field; basic concepts of quantum optics; Green's function; optical near fields; surface plasmons Plasmonics: Theoretical foundations of nano-optics and nanophysics: basic concepts of plasmonics (metallic nanoparticles; optical near fields; interaction with quantum emitters; energy transfer; sensing); introduction to computational simulation models; plasmon imaging (tomography; EELS); nonlinear and nonlocal effects; metamaterials Quantum Transport Theory: Introduction to basic approaches to quantum transport theory, e.g. semiclassical Boltzmann equation; Wigner function approach; Green's function techniques. Selected applications in nanophysics Fundamentals of Electronic Structure Theory: Electronic band structure; construction of free-electron bands and tight-binding approximation. Self-consistent field approximation; density functional theory; basis functions; full-potential and pseudopotential methods; advanced topics Exotic States in Solids: Berry phase; topological matter; the quantum Hall and spin Hall effect; topological insulators; Dirac and Majorana fermions; monopoles; vortices, etc.
Learning outcomes	After having completed the module, students are able to • understand and apply concepts of quantum optics; • comprehend the foundations and applications of plasmonics; • classify and apply quantum and semiclassical approaches of transport theory; • explain the foundations of density functional theory and interpret typical results of DFT calculations, and • classify various quantum states of modern solid-state physics.
Teaching and learning activities and methods	Lectures
Previous knowledge expected	Knowledge of solid-state physics, quantum mechanics and statistical physics at master's level
Frequency of offer	Mandatory courses (♦) every year; others at least every two years

Module T6	Modelling of Materials
ECTS credit points	9
Subject content	Students are introduced to modern simulation techniques for electronic and nuclear motion in atoms, molecules and bulk structures. They are taught topical problems inspired by current research and industrial needs. ♦ Fundamentals of Electronic Structure Theory: Electronic band structure; free-electron bands and tight-binding approximation. SCF approximation; density functional theory (DFT); basis functions; full-potential and pseudo-potential approximations; advanced topics ♦ Simulating Materials Properties from First Principles: Tutorial and scientific exercise. Molecular properties; excitations; vibrations; visualisation; band-structure calculations; ab initio MD; interaction driven Mott transition Advanced Ab Initio Techniques: Going beyond semi-local functionals. Perturbative approaches beyond DFT – G0W0 and GW. Dispersion corrections; RPA; the Bethe-Salpeter equation for simulating excitations; time-dependent DFT Modelling of Molecular Systems: Non-Born-Oppenheimer effects; rovibronic interactions; group theory; excited states; post-Hartree-Fock techniques; solvation, QM/MM embedding; reaction dynamics and transition state theory Applications of Electronic Structure Methods: Interpretation of electronic structure calculations; global structure determination; ab initio thermodynamics, vibrations, phonon bands and heat transport; optical and core-level excitations; scanning probe experiments Ab Initio Methods for Correlated Materials: Introduction to correlated materials; localised basis sets; Hubbard model and calculation of interaction parameters; (non-)Fermi liquids; dynamical mean field theory; Mott-Hubbard transition
Learning outcomes	The module offers a solid methodical and computational background as well as practical knowledge regarding program packages and libraries at the edge of current research. Participants are equipped with substantial knowledge in the field of materials modelling and electronic structure theory, which makes them valuable job candidates at materials research facilities.
Teaching and learning activities and methods	Lectures, laboratory course
Previous knowledge expected	Quantum mechanics, electrodynamics, advanced quantum mechanics
Frequency of offer	Every year

Module T7	Foundations of Particle Physics
ECTS credit points	9
Subject content	♦ Quantum Field Theory 2: Gauge Theories: Geometry of gauge fields; gauge fixing; Faddeev-Popov quantisation; BRST symmetry; lattice regularisation; one-loop quantum corrections; instantons Other lectures and project: Advanced methods in elementary particle physics and neighbouring areas
Learning outcomes	After having participated successfully in the module, students are able to • investigate contemporary research questions in elementary particle physics and neighbouring areas.
Teaching and learning activities and methods	Lectures, exercises and project
Previous knowledge expected	Theory courses at bachelor's level, General Physics module as well as module T1
Frequency of offer	Lecture Quantum Field Theory II and project every year; other lectures and exercises every two years

Module T8	Phenomenology of Particle Physics
ECTS credit points	9
Subject content	♦ Hadron Physics: QCD Lagrangian; Green's functions; gauge fixing; renormalisation; running coupling; flavour symmetries; current algebra; Ward-Takahashi identities; bound states; decay constants; hadron spectrum; flavour multiplets and flavour wave functions; spontaneous chiral symmetry breaking; axial anomaly; sigma model and chiral perturbation theory; quark models; hadron matrix elements and form factors; deep inelastic scattering; scaling violations; parton model Other lectures and project: Selected phenomenological aspects of particle physics, astroparticle physics and related areas
Learning outcomes	After having participated successfully in the module, students are able to • understand the phenomena in elementary particle physics (hadron physics, electroweak physics, theories beyond the Standard Model) and neighbouring areas e.g. astroparticle physics, quantum gravity models, etc.
Teaching and learning activities and methods	Lectures and project
Previous knowledge expected	Theory courses at bachelor's level, General Physics module as well as module T1
Frequency of offer	Lecture Hadron Physics and project every year; other lectures and exercises every two years

Annex II

Curriculum for the master's degree programme in Physics

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics (module G)	2	VO	4	X	X
Statistical Physics (module G)	1	UE	2	X	X
Advanced Quantum Mechanics (module G)	2	VO	4	X	X
Advanced Quantum Mechanics (module G)	1	UE	2	X	X
Introduction to General Relativity and Cosmology (module G)	2	VO	3	X	
Specialisation modules	8		12	X	X
Free-choice subject	2		3	X	X
Total for the 1st semester	18		30		
2nd semester					
Specialisation modules	14		21	X	X
General elective module (Elective Topics)	4		6	X	X
Free-choice subject	2		3	X	X
Total for the 2nd semester	20		30		
3rd semester					
Specialisation modules	8		12	X	X
Practical Training in the Area of the Master's Thesis (module M0)	4	LU/PT	10	X	
Tutorial for Master's Students in the Area of the Master's Thesis (module M0)	2	PV	2	X	
General elective module (Elective Topics)	2		3	X	X
Total for the 3rd semester	16		27		
4th semester					
Master's Seminar in the Area of the Master's Thesis (module M0)	2	SE	2	X	
Master's thesis			30	X	
Master's examination			1		
Total for the 4th semester			33		
Total ECTS			120		

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

Curriculum for the specialisation “Astrophysics”

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics (module G)	2	VO	4	X	X
Statistical Physics (module G)	1	UE	2	X	X
Advanced Quantum Mechanics (module G)	2	VO	4	X	X
Advanced Quantum Mechanics (module G)	1	UE	2	X	X
Cosmology and Introduction to General Relativity (module G)	2	VO	3	X	
The Galaxy and Extragalactic Systems (module A1)	2	VO	3	X	
The Physics of Stellar Atmospheres (module A2)	3	VO	4	X	
The Physics of Stellar Atmospheres (module A2)	1	UE	2	X	
Introduction to Planetology (module A3)	2	VO	3	X	
Free-choice subject	2		3	X	X
Total for the 1st semester	18		30		
2nd semester					
Stellar Structure and Evolution (module A1)	3	VO	4	X	
Stellar Structure and Evolution (module A1)	1	UE	2	X	
Magneto-hydrodynamics and Solar-terrestrial Modeling (module A2)	2	VO	3	X	
Introduction to Solar Physics (module A3)	2	VO	3	X	
Introduction to Solar Physics (module A3)	1	UE	2	X	
Solar Physics Lab (module A3)	1	PT	1	X	
LV1 from module A5	2	VO	3	X	
LV2 from module A5	2	VO	3	X	
General elective module (Elective Topics)	4		6	X	X
Free-choice subject	2		3	X	X
Total for the 2nd semester	20		30		
3rd semester					
Instrumentation and Observing Techniques in Astrophysics (module A4)	2	VO	3	X	
Astrophysics Lab (module A4)	2	PT	3	X	
Astrophysical Seminar (module A4)	2	SE	3	X	
Data Analysis in Astrophysics (module M1)	3	VO	4	X	
Data Analysis in Astrophysics (module M1)	2	UE	3	X	
Selected Problems in Astrophysical Data Analysis (module M1)	2	SE	3	X	
Tutorial for Master Students in Astrophysics (module M1)	2	PV	2	X	
LV3 from module A5	2	VO	3	X	
General elective module (Elective Topics)	2		3	X	X
Total for the 3rd semester	17		27		
4th semester					
Master’s Seminar in: Astrophysics (module M1)	2	SE	2	X	
Master’s thesis			30	X	
Master’s examination			1		
Total for the 4th semester			33		
Total ECTS			120		

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

Curriculum for the specialisation “Atmospheric Physics and Climate”

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics (module G)	2	VO	4	X	X
Statistical Physics (module G)	1	UE	2	X	X
Advanced Quantum Mechanics (module G)	2	VO	4	X	X
Advanced Quantum Mechanics (module G)	1	UE	2	X	X
Cosmology and Introduction to General Relativity (module G)	2	VO	3	X	
Earth's Climate System and Climate Change (module C1)	2	VO	3	X	
Paleoclimatology (module C1)	2	VO	3	X	
Methods of Modelling and Simulation (module C2)	2	VO	3	X	
Methods of Modelling and Simulation (module C2)	2	UE	3	X	
Time Series Analysis (module C2)	2	VO	3	X	
Total for the 1st semester	18		30		
2nd semester					
Physical Oceanography, Hydrology and Climate (module C1)	2	VO	3	X	
Atmospheric Dynamics (module C3)	2	VO	3	X	
Climate Modeling (module C4)	2	VO	3	X	
Atmospheric Measurement Methods: Remote Sensing (module C5)	2	VO	3	X	
Seminar on Measurement Methods in Atmospheric Physics (module C5)	2	SE	3	X	
Field Course in Atmospheric and Climate Physics (module M2)	3	PT	6	X	
Selected Topics in Atmospheric and Climate Physics (module M2)	2	SE/VO	3	X	X
Free-choice subject	4		6	X	X
Total for the 2nd semester	20		30		
3rd semester					
Atmospheric Composition and Chemistry (module C3)	2	VO	3	X	
Radiation and Energy Balance (module C3)	2	VO	3	X	
Climate Dynamics (module C4)	2	VO	3	X	
Selected Topics in Climate Science (module C4)	2	VO/SE	3	X	
Atmospheric Measurement Methods: In Situ (module C5)	2	VO	3	X	
Tutorial for Master's Students in Atmospheric Physics and Climate (module M2)	2	PV	2	X	
General elective module (Elective Topics)	6	SE/VO	9	X	
Total for the 3rd semester	16		26		
4th semester					
Climate and Environmental Change – Current Research Topics (module M2)	2	SE	3	X	
Master's thesis			30	X	
Master's examination			1		
Total for the 4th semester			34		
Total ECTS			120		

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

Curriculum for the specialisation "Experimental Physics"

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics (module G)	2	VO	4	X	X
Statistical Physics (module G)	1	UE	2	X	X
Advanced Quantum Mechanics (module G)	2	VO	4	X	X
Advanced Quantum Mechanics (module G)	1	UE	2	X	X
Cosmology and Introduction to General Relativity (module G)	2	VO	3	X	
LV1 from specialisation module 1 (E1, E3, E4 or E5/E7)	2		3	X	X
LV1 from specialisation module 2 (E1, E3, E4 or E5/E7)	2		3	X	X
LV1 from specialisation module 3 (E1, E3, E4 or E5/E7)	2		3	X	X
LV1 from specialisation module 4	2		3	X	X
Free-choice subject 1	2		3	X	X
Total for the 1st semester	18		30		
2nd semester					
LV2 from specialisation module 1 (E1, E3, E4 or E5/E7)	2		3	X	X
LV2 from specialisation module 2 (E1, E3, E4 or E5/E7)	2		3	X	X
LV2 from specialisation module 3 (E1, E3, E4 or E5/E7)	2		3	X	X
LV2 from specialisation module 4	2		3	X	X
LV1 from specialisation module 5	2		3	X	X
LV3 from specialisation module 1 (E1, E3, E4 or E5/E7)	2		3	X	X
LV3 from specialisation module 2 (E1, E3, E4 or E5/E7)	2		3	X	X
LV3 from specialisation module 3 (E1, E3, E4 or E5/E7)	2		3	X	X
LV3 from specialisation module 4	2		3	X	X
Free-choice subject 2	2		3	X	X
Total for the 2nd semester	20		30		
3rd semester					
LV2 from specialisation module 5	2		3	X	X
LV3 from specialisation module 5	2		3	X	X
General elective module (Elective Topics)	6		9	X	X
Tutorial in the Area of the Master's Thesis (module M0)	2	PV	2	X	
Practical Training in the Area of the Master Thesis (module M0)	4	LU/PT	10	X	
Total for the 3rd semester	16		27		
4th semester					
Master's Seminar in the Area of the Master's Thesis (module M0)	2	SE	2	X	
Master's thesis			30	X	
Master's examination			1		
Total for the 4th semester			33		
Total ECTS			120		

Curriculum for the specialisation “Space Physics and Aeronomy”

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics (module G)	2	VO	4	X	X
Statistical Physics (module G)	1	UE	2	X	X
Advanced Quantum Mechanics (module G)	2	VO	4	X	X
Advanced Quantum Mechanics (module G)	1	UE	2	X	X
Cosmology and Introduction to General Relativity (module G)	2	VO	3	X	
Introduction to Planetology (module S1)	2	VO	3	X	
Introduction to Aeronomy (module S1)	2	VO	3	X	
Introduction to Space Plasma Physics (module S1)	2	VO	3	X	
General elective module (Elective Topics)	2		3	X	X
Free-choice subject	2		3	X	X
Total for the 1st semester	18		30		
2nd semester					
Introduction to Solar Physics (module S2)	2	VO	3	X	
Magneto-Hydrodynamics and Solar-Terrestrial Modeling (module S2)	2	VO	3	X	
Introduction to Solar Physics (module S2)	1	UE	2	X	
Solar Physics Lab (module S2)	1	PT	1	X	
Physics of Planetary Atmospheres (module S3)	2	VO	3	X	
Earth and Planetary Magnetic Fields (module S3)	2	VO	3	X	
Planetary Magnetospheres (module S3)	2	VO	3	X	
Measurement Methods in Space Physics (module S4)	2	VO	3	X	
Space Missions and Experiments Design (module S4)	2	VO	3	X	
Seminar on Measurement Methods in Space Physics (module S4)	2	SE	3	X	
Free-choice subject	2		3	X	X
Total for the 2nd semester	20		30		
3rd semester					
Methods of Modelling and Simulation (module C2)	2	VO	3	X	
Methods of Modelling and Simulation (module C2)	2	UE	3	X	
Time Series Analysis (module C2)	2	VO	3	X	
General elective module (Elective Topics)	4		6	X	X
Tutorial for Master’s Students: Space Physics and Aeronomy (module M3)	2	PV	2	X	
Practical Training in Space Physics and Aeronomy (module M3)	3	PT	6	X	
Selected Topics in Space Physics and Aeronomy (module M3)	2	SE/VO	3	X	
Total for the 3rd semester	16		26		
4th semester					
Master’s Seminar in Space Physics and Aeronomy (module M3)	2	SE	3	X	
Master’s thesis			30	X	
Master’s examination			1		
Total for the 4th semester			34		
Total ECTS			120		

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

Curriculum for the specialisation "Theoretical and Computational Physics"

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics (module G)	2	VO	4	X	X
Statistical Physics (module G)	1	UE	2	X	X
Advanced Quantum Mechanics (module G)	2	VO	4	X	X
Advanced Quantum Mechanics (module G)	1	UE	2	X	X
Cosmology and Introduction to General Relativity (module G)	2	VO	3	X	
Advanced Mathematical Methods (module T1)	3	VO	4.5	X	
Advanced Statistical Physics (module T2)	2	VO	3	X	X
Advanced Quantum Mechanics 2 (module T2)	2	VO	3	X	
Basic Concepts of Solid-state Theory (module T2)	2	VO	3	X	
Total for the 1st semester	17		28.5		
2nd semester					
Quantum Field Theory (module T1)	3	VO	4.5	X	
Specialisation modules	12		18	X	X
General elective module (Elective Topics)	2		3	X	X
Free-choice subject	4		6	X	X
Total for the 2nd semester	21		31.5		
3rd semester					
Numerical Methods in Linear Algebra (module T3)	2	VU	3	X	
Monte-Carlo Methods (module T3)	2	VU	3	X	
Elective LV from module T3	2	VU	3	X	
General elective module (Elective Topics)	4		6	X	X
Tutorial in the Area of the Master's Thesis (module M0)	2	PV	2	X	
Practical Training in the Area of the Master's Thesis (module M0)	4	LU/PT	10	X	
Total for the 3rd semester	16		27		
4th semester					
Master's Seminar in the Area of the Master's Thesis (module M0)	2	SE	2	X	
Master's thesis			30	X	
Master's examination			1		
Total for the 4th semester			33		
Total ECTS			120		

[1]: Allocation of the course to the participating universities; both universities are indicated if the course is offered by both universities jointly, in parallel or alternately.

Annex III

Recommended courses for the free-choice subject

Free-choice courses can be freely chosen from the courses offered at any recognised Austrian and foreign universities, and Austrian universities of applied sciences and university colleges for education according to § 10 of this curriculum.

In order to broaden students' basic knowledge in the modules of this degree programme, courses in foreign languages, social competence, technology assessment and women's and gender studies are recommended. In particular, we would like to refer students to the courses offered by the TU Graz service department Languages, Key Competencies and In-House Training or treffpunkt sprachen of Uni Graz, the Centre for Social Competence of Uni Graz as well as the Inter-University Research Centre for Technology, Work and Culture (IFZ).

As qualification for future leadership and management positions, the offer of the Transfer Initiative for Management and Entrepreneurship Basics, Awareness, Training und Employability ("TIMEGATE") of Uni Graz is recommended.

Annex IV

Equivalence list and recognition list

Courses for which the equivalence or recognition is defined in this part of the Annex to the curriculum do not require separate recognition by the officer responsible for study matters. Individual recognition awarded by official decision from the officer responsible for study matters according to § 78 UG is also possible.

For students of the master's degree programme in Physics, curriculum 2013, at Uni Graz, the following tables regulate the recognition of courses between the expiring curriculum for the master's degree programme in Physics in the version 2013 (13W), and this curriculum (17W).

a. Students of Uni Graz who do not opt for this curriculum may replace courses of the curriculum for the master's degree programme in Physics in the version 2013 (13W), with courses of this curriculum (17W) according to the following table.

Course from the expiring curriculum 2013 (13W)				**Course from this curriculum 2017 (17W)**			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
General Physics							
Statistische Physik	VO	3	4	Statistical Physics (G)	VO	2	4
Übungen Statistische Physik	UE	1	2	Statistical Physics (G)	UE	1	2
Allgemeine Relativitätstheorie und Kosmologie	VO	2	4	Introduction to General Relativity and Cosmology (G)	VO	2	3

Course from the expiring curriculum 2013 (13W)				Course from this curriculum 2017 (17W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Physik moderner Materialien	VO	2	4	Modern Materials (E6)	VO	2	3
Special subject Astrophysics							
Einführung in die Plasmaphysik	VO	2	3	Introduction to Space Plasma Physics (A5, S1)	VO	2	3
Sternaufbau und Sternentwick-lung	VO	3	6	Stellar Structure and Evolution (A1)	VO	3	4
Sternaufbau und Sternentwick-lung	UE	1	2	Stellar Structure and Evolution (A1)	UE	1	2
Einführung in die Sonnenphysik	VO	2	3	Introduction to Solar Physics (A3, S2)	VO	2	3
Einführung in die Sonnenphysik	UE	1	2	Introduction to Solar Physics (A3, S2)	UE	1	2
Physik der Sternatmosphären	VO	3	6	The Physics of Stellar Atmospheres (A2)	VO	3	4
Physik der Sternatmosphären	UE	1	2	The Physics of Stellar Atmospheres (A2)	UE	1	2
Galaxis und extragalaktische Systeme	VO	2	3	The Galaxy and Extra-galactic Systems (A1)	VO	2	3
Astrophysikalisches Seminar	SE	2	3	Astrophysical Seminar (A4)	SE	2	3
Instrumente und Beobachtungs-techniken der Astrophysik	VO	2	3	Instrumentation and Observing Techniques in Astrophysics (A4)	VO	2	3
Astronomisches Praktikum	PR	2	3	Astrophysics Lab (A4)	PT	2	3
Astrophysikalische Datenanalyse	VO	3	5	Data Analysis in Astro-physics (M1)	VO	3	4
Astrophysikalische Datenanalyse	UE	2	3	Data Analysis in Astro-physics (M1)	UE	2	3
Ausgewählte Probleme der ast-rophysikalischen Datenanalyse	SE	2	3	Selected Problems in Astrophysical Data Analysis (M1)	SE	2	3
Einführung in die Planetologie	VO	2	3	Introduction to Plane-tology (A3, S1)	VO	2	3
Sonne und Space Weather	VO	2	3	Sun and Space Weather (A5)	VO	2	3
Praktikum Sonnenphysik	PR	1	1	Solar Physics Lab (A3)	PT	1	1
Magnetohydrodynamik und solar-terrestrische Modellierung	VO	2	3	Magneto-Hydrodynamics and Solar-Terrestrial Mod-eling (A2, S2)	VO	2	3
Astrobiology: astrophysical as-pects	VO	2	3	Exoplanets and Astro-biology (A5)	VO	2	3
Himmelsmechanik	VO	2	3	Celestial Mechanics (A5)	VO	2	3
Privatissimum aus Astrophysik für DiplomandInnen	PV	2	3	Tutorial for Master Students in Astrophys-ics (M)	PV	2	2

Course from the expiring curriculum 2013 (13W)				Course from this curriculum 2017 (17W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Special subject Experimental Physics							
Physik der kondensierten Materie <u>or</u> Anregungen im Festkörper	VO	2	4	Solid-state Physics: Size Effects and Quantum Phenomena (E6)	VO	2	3
Signalverarbeitung	VO	2	4	Signal Theory and Signal Processing (E8)	VU	2	3
Quantenoptik	VO	2	4	Quantum Optics (E5)	VO	2	3
Spektroskopie	VO	2	4	Spectroscopy (E3)	VO	2	3
Oberflächenphysik	VO	2	4	Surface Science (E1)	VO	2	3
Anwendungen der Gruppentheorie in Molekül- und Festkörperphysik	VO	2	3	Application of Group Theory (E3, E6)	VO	2	3
Seminar Experimentalphysik	SE	2	2	Master's Seminar in the Area of the Master' Thesis (M0)	SE	2	2
Labor Oberflächenphysik	LU	3	6	Practical Training in the Area of the Master's Thesis (M0)	LU/PT	4	10
Labor Experimentalphysik	LU	6	10	3 from: Experimental Methods in Surface Science (E1) <u>or</u> Research Laboratory Spectroscopy (E3) <u>or</u> Research Laboratory Nano and Laseroptics (E4) <u>or</u> Research Laboratory Quantum Optics and Molecular Physics (E5) <u>or</u> Research Laboratory Biophysics (E7)	LU/VU	6	9
Privatissimum Oberflächenphysik	PV	2	2	Tutorial in the Area of the Master's Thesis (M0)	PV	2	2
Labor Photonik	LU	3	6	Practical Training in the Area of the Master's Thesis (M0)	LU/PT	4	10
Privatissimum Photonik	PV	2	2	Tutorial in the Area of the Master's Thesis (M0)	PV	2	2
Labor Spektroskopie und Magnetismus	LU	3	6	Practical Training in the Area of the Master's Thesis (M0)	LU/PT	4	10
Privatissimum Spektroskopie und Magnetismus	PV	2	2	Tutorial in the Area of the Master's Thesis (M0)	PV	2	2

Course from the expiring curriculum 2013 (13W)				Course from this curriculum 2017 (17W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Fortgeschrittene Optik	VO	2	4	Advanced Optics (E4)	VO	2	3
Allgemeine Methoden der Oberflächenphysik	VO	2	4	Experimental Methods in Surface Science (E1)	VU	2	3
Synchrotronstrahlungsmethoden	VO	2	4	Synchrotron Radiation Techniques (E2, E3)	VO	2	3
Biophotonik	VO	2	4	Biophotonics (E7)	VO	2	3
Photonen und Ultraschall	VO	2	4	Ultrasound Methods (E8)	VO	2	3
Rastersondenmethoden	VO	2	4	Scanning Probe Techniques (E2, E6)	VO	2	3
Grundlagen des Magnetismus in reduzierten Dimensionen (Nano-Magnetismus)	VO	2	4	Nano- and Quantum Magnetism (E6)	VO	2	3
Nano-Optik	VO	2	4	Nano Optics (E4)	VO	2	3
Special subject Geophysics							
Klimasystem der Erde und Klimawandel	VO	2	3	Earth's Climate System and Climate Change (C1)	VO	2	3
Methoden der Modellierung und Simulation	VO	2	4	Methods of Modeling and Simulation (C2)	VO	2	3
Übungen zu Methoden der Modellierung und Simulation	UE	2	4	Methods of Modeling and Simulation (C2)	UE	2	3
Seminar Messmethoden der Geophysik - Atmosphären- und Klimaphysik	SE	1	2	Seminar on Measurement Methods in Atmospheric Physics (C5)	SE	2	3
Seminar Messmethoden der Geophysik – Weltraumphysik und Aeronomie	SE	1	2	Seminar on Measurement Methods in Space Physics (S4)	SE	2	3
Magnetismus und Magnetfeld der Erde	VO	2	3	Earth and Planetary Magnetic Fields (S3)	VO	2	3
Methoden der Datenanalyse und Dateninversion	VO	2	4	Time Series Analysis (C2)	VO	2	3
Ausgewählte Kapitel der Geophysik (Atmospheric Chemistry and Climate)	VO	2	3	Atmospheric Composition and Chemistry (C3)	VO	2	3
Ausgewählte Kapitel der Geophysik (Klima- und Umweltveränderungen im Laufe der Erdgeschichte)	VO	2	3	Paleoclimatology (C1)	VO	2	3
Ausgewählte Kapitel der Geophysik (Remote Sensing of Atmospheres and Climate Change)	VO	2	3	Selected Topics in Climate Science (C4)	VO /SE	2	3
Privatissimum aus Geophysik für DiplomandInnen	PV	2	3	Tutorial for Master's Students in Atmospheric Physics and Climate (M2)	PV	2	2

Course from the expiring curriculum 2013 (13W)				Course from this curriculum 2017 (17W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Privatissimum aus Geophysik für DiplomandInnen	PV	2	3	Tutorial in for Master's Students in Space Physics and Aeronomy (M3)	PV	2	2
Physik der Atmosphäre 1 (Zusammensetzung und Dynamik)	VO	2	3	Atmospheric Dynamics (C3)	VO	2	3
Physik der Atmosphäre 2 (Strahlungs- und Energiehaushalt)	VO	2	3	Radiation and Energy Balance (C3)	VO	2	3
Einführung in die Aeronomie	VO	2	3	Introduction to Aeronomy (S1)	VO	2	3
Physikalische Ozeanogrphie, Hydrologie und Klima	VO	2	3	Physical Oceanography, Hydrology and Climate (C1)	VO	2	3
Messmethoden der Atmosphären und Klimaphysik	VO	2	3	Atmospheric Measurement Methods: Remote Sensing (C5)	VO	2	3
Klima- und Umweltwandel: Aktuelle Forschungsbeiträge	SE	2	3	Climate and Environmental Change - Current Research Topics (M2)	SE	2	3
Praktikum aus Atmosphären- und Klimaphysik	PR	3	6	Field Course Atmospheric and Climate Physics (M2)	PT	3	6
Ausgewählte Kapitel der Atmosphären und Klimaphysik	VO/SE	2	3	Selected Topics in Climate Science (C4)	VO/SE	2	3
Planetenmagnetosphären	VO	2	3	Planetary Magnetospheres (S3)	VO	2	3
Messmethoden der Weltraumphysik und Aeronomie	VO	2	3	Measurement Methods in Space Physics (S4)	VO	2	3
Praktikum aus Weltraumphysik und Aeronomie	PR	3	6	Practical Training in Space Physics and Aeronomy (M3)	PT	3	6
Special subject Theoretical and Computer-oriented Physics							
Höhere Quantenmechanik 1	VO	2	4	Advanced Quantum Mechanics (G)	VO	2	4
Theoretische Festkörperphysik 1	VO	2	3	Basic Concepts of Solid-state Theory (T2)	VO	2	3
Computational Physics 1	VU	2	4	Monte-Carlo Methods (T3)	VU	2	3
Höhere Quantenmechanik 2	VO	2	3	Advanced Quantum Mechanics 2 (T2)	VO	2	3
Computational Physics 2	VU	2	4	Numerical Methods in Linear Algebra (T3)	VU	2	3
Funktionentheorie *and* Gruppentheorie	VO	2 + 2	4 + 3	Advanced Mathematical Methods VO (T1) *and* Advanced Mathematical Methods UE	VO + UE	3 + 1	4.5 + 1.5
Theoretische Elementarteilchenphysik	VO	4	8	Quantum Field Theory 2: Gauge Theories	VU	4	6

Course from the expiring curriculum 2013 (13W)				Course from this curriculum 2017 (17W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
				(T7)			
Projektpraktikum Theoretische Physik	PP	4	8	Practical Training in the Area of the Master's Thesis (M0)	LU/PT	4	10
Quantenfeldtheorie	VO	3	6	Quantum Field Theory VO (T1) und Quantum Field Theory UE	VO + UE	3 + 1	4.5 + 1.5
Theoretische Festkörperphysik 2	VO	2	4	Fundamentals of Electronic Structure Theory (T4, T5, T6)	VO	2	3
Computermethoden der Festkörperphysik	VU	2	4	Computational Methods in Solid-state Physics (T3, T4)	VU	2	3
Computermethoden der Elementarteilchenphysik	VU	2	4	Computational Methods in Particle Physics (T3, T7)	VU	2	3
Theoretische Nano- und Quantenoptik	VO	2	4	Theoretical Nano- and Quantum Physics (T5)	VO	2	3
Einführung in die Gitterfeldtheorie	VO	2	3	Lattice Field Theory (T7)	VO	2	3

b. Students of Uni Graz who opt for this curriculum (17W) may replace courses of this curriculum (17W) with courses of the curriculum for the master's degree programme in Physics in the version 2013 (13W), according to the following table. After students have opted for this curriculum, only courses of this curriculum may be completed.

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
				General Physics			
Statistical Physics (G)	VO	2	4	Statistische Physik	VO	3	4
Statistical Physics (G)	UE	1	2	Übungen Statistische Physik	UE	1	2
Introduction to General Relativity and Cosmology (G) *and* 1 ECTS for the general elective module (Elective Topics)	VO	2	3 + 1	Allgemeine Relativitätstheorie und Kosmologie	VO	2	4
Modern Materials (E6) *and* 1 ECTS for the general elective module (Elective Topics)	VO	2	3 + 1	Physik moderner Materialien	VO	2	4

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
				Special subject Astrophysics			
Introduction to Space Plasma Physics (A5, S1)	VO	2	3	Einführung in die Plasmaphysik	VO	2	3
Stellar Structure and Evolution (A1) *and* 2 ECTS for the general elective module (Elective Topics)	VO	3	4 + 2	Sternaufbau und Sternentwicklung	VO	3	6
Stellar Structure and Evolution (A1)	UE	1	2	Sternaufbau und Sternentwicklung	UE	1	2
Introduction to Solar Physics (A3, S2)	VO	2	3	Einführung in die Sonnenphysik	VO	2	3
Introduction to Solar Physics (A3, S2)	UE	1	2	Einführung in die Sonnenphysik	UE	1	2
The Physics of Stellar Atmospheres (A2) *and* 2 ECTS for the general elective module (Elective Topics)	VO	3	4 + 2	Physik der Sternatmosphären	VO	3	6
The Physics of Stellar Atmospheres (A2)	UE	1	2	Physik der Sternatmosphären	UE	1	2
The Galaxy and Extragalactic Systems (A1)	VO	2	3	Galaxis und extragalaktische Systeme	VO	2	3
Astrophysical Seminar (A4)	SE	2	3	Astrophysikalisches Seminar	SE	2	3
Instrumentation and Observing Techniques in Astrophysics (A4)	VO	2	3	Instrumente und Beobachtungstechniken der Astrophysik	VO	2	3
Astrophysics Lab (A4)	PT	2	3	Astronomisches Praktikum	PR	2	3
Data Analysis in Astrophysics (M1) *and* 1 ECTS for the general elective module (Elective Topics)	VO	3	4 + 1	Astrophysikalische Datenanalyse	VO	3	5
Data Analysis in Astrophysics (M1)	UE	2	3	Astrophysikalische Datenanalyse	UE	2	3
Selected Problems in Astrophysical Data Analysis (M1)	SE	2	3	Ausgewählte Probleme der astrophysikalischen Datenanalyse	SE	2	3
Introduction to Planetology (A3, S1)	VO	2	3	Einführung in die Planetologie	VO	2	3
Sun and Space Weather (A5)	VO	2	3	Sonne und Space Weather	VO	2	3
Solar Physics Lab (A3)	PT	1	1	Praktikum Sonnenphysik	PR	1	1
Magneto-Hydrodynamics and Solar-Terrestrial Modeling (A2, S2)	VO	2	3	Magnetohydrodynamik und solar-terrestrische Modellierung	VO	2	3

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Exoplanets and Astrobiology (A5)	VO	2	3	Astrobiology: astrophysical aspects	VO	2	3
Celestial Mechanics (A5)	VO	2	3	Himmelsmechanik	VO	2	3
Tutorial for Master Students in Astrophysics (M1) *and* 1 ECTS for the general elective module (Elective Topics)	PV	2	2 + 1	Privatissimum aus Astrophysik für DiplomandInnen	PV	2	3
				Special subject Experimental Physics			
Solid-state Physics: Size Effects and Quantum Phenomena (E6) *and* 1 ECTS for the general elective module (Elective Topics)	VO	2	3 + 1	Physik der kondensierten Materie or Anregungen im Festkörper	VO	2	4
Signal Theory and Signal Processing (E8) *and* 1 ECTS for the general elective module (Elective Topics)	VU	2	3 + 1	Signalverarbeitung	VO	2	4
Quantum Optics (E5)	VO	2	3	Quantenoptik	VO	2	4
Spectroscopy (E3) *and* 1 ECTS for the general elective module (Elective Topics)	VO	2	3 + 1	Spektroskopie	VO	2	4
Surface Science (E1)	VO	2	3	Oberflächenphysik	VO	2	4
Application of Group Theory (E3, E6)	VO	2	3	Anwendungen der Gruppentheorie in Molekül- und Festkörperphysik	VO	2	3
Master's Seminar in the Area of the Master' Thesis (M0)	SE	2	2	Seminar Experimentalphysik	SE	2	2
Practical Training in the Area of the Master's Thesis (M0)	LU/ PT	4	10	Labor Oberflächenphysik	LU	3	6
3 from: Experimental Methods in Surface Science (E1) or Research Laboratory Spectroscopy (E3) or Research Laboratory Nano and Laseroptics (E4) or Research Laboratory Quantum Optics and Molecular Physics (E5) or Research Laboratory Biophysics (E7) *and* 1 ECTS for the general elec-	LU/ VU	6	9 + 1	Labor Experimentalphysik	LU	6	10

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
tive module (Elective Topics)							
Tutorial in the Area of the Master's Thesis (M0)	PV	2	2	Privatissimum Oberflächenphysik	PV	2	2
Practical Training in the Area of the Master's Thesis (M0)	LU/ PT	4	10	Laborübungen Photonik	LU	3	6
Tutorial in the Area of the Master's Thesis (M0)	PV	2	2	Privatissimum Photonik	PV	2	2
Practical Training in the Area of the Master's Thesis (M0)	LU/ PT	4	10	Labor Spektroskopie und Magnetismus	LU	3	6
Tutorial in the Area of the Master's Thesis (M0)	PV	2	2	Privatissimum Spektroskopie und Magnetismus	PV	2	2
Advanced Optics (E4) *and* 1 ECTS for the general elective module (Elective Topics)	VO	2	3 + 1	Fortgeschrittene Optik	VO	2	4
Experimental Methods in Surface Science (E1)	VU	2	3	Allgemeine Methoden der Oberflächenphysik	VO	2	4
Synchrotron Radiation Techniques (E2, E3)	VO	2	3	Synchrotronstrahlungsmethoden	VO	2	4
Biophotonics (E7)	VO	2	3	Biophotonik	VO	2	4
Ultrasound Methods (E8)	VO	2	3	Photonen und Ultraschall	VO	2	4
Scanning Probe Techniques (E2, E6)	VO	2	3	Rastersondenmethoden	VO	2	4
Nano- and Quantum Magnetism (E6)	VO	2	3	Grundlagen des Magnetismus in reduzierten Dimensionen (Nano-Magnetismus)	VO	2	4
Nano Optics (E4)	VO	2	3	Nano-Optik	VO	2	4
				Special subject Geophysics			
Earth's Climate System and Climate Change (C1)	VO	2	3	Klimasystem der Erde und Klimawandel	VO	2	3
Methods of Modeling and Simulation (C2)	VO	2	3	Methoden der Modellierung und Simulation	VO	2	4
Methods of Modeling and Simulation (C2)	UE	2	3	Übungen zu Methoden der Modellierung und Simulation	UE	2	4
Seminar on Measurement Methods in Atmospheric Systems (C5)	SE	2	3	Seminar Messmethoden der Geophysik - Atmosphären- und Klimaphysik	SE	1	2
Seminar on Measurement Methods in Space Physics (S4)	SE	2	3	Seminar Messmethoden der Geophysik – Weltraumphysik und Aeronomie	SE	1	2
Earth and Planetary Magnetic Fields (S3)	VO	2	3	Magnetismus und Magnetfeld der Erde	VO	2	3

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Time Series Analysis (C2) *and* 1 ECTS for the general elective module (Elective Topics)	VO	2	3 + 1	Methoden der Datenanalyse und Dateninversion	VO	2	4
Atmospheric Composition and Chemistry (C3)	VO	2	3	Ausgewählte Kapitel der Geophysik (Atmospheric Chemistry and Climate)	VO	2	3
Paleoclimatology (C1)	VO	2	3	Ausgewählte Kapitel der Geophysik (Klima- und Umweltveränderungen im Laufe der Erdgeschichte)	VO	2	3
Selected Topics in Climate Science (C4)	VO /SE	2	3	Ausgewählte Kapitel der Geophysik (Remote Sensing of Atmospheres and Climate Change)	VO	2	3
Tutorial for Master's Students in Atmospheric Physics and Climate (M2) *and* 1 ECTS for the general elective module (Elective Topics)	PV	2	2 + 1	Privatissimum aus Geophysik für DiplomandInnen	PV	2	3
Tutorial in for Master's Students in Space Physics and Aeronomy (M3) *and* 1 ECTS for the general elective module (Elective Topics)	PV	2	2 + 1	Privatissimum aus Geophysik für DiplomandInnen	PV	2	3
Atmospheric Dynamics (C3)	VO	2	3	Physik der Atmosphäre 1 (Zusammensetzung und Dynamik)	VO	2	3
Radiation and Energy Balance (C3)	VO	2	3	Physik der Atmosphäre 2 (Strahlungs- und Energiehaushalt)	VO	2	3
Introduction to Aeronomy (S1)	VO	2	3	Einführung in die Aeronomie	VO	2	3
Physical Oceanography, Hydrology and Climate (C1)	VO	2	3	Physikalische Ozeanogrphie, Hydrologie und Klima	VO	2	3
Atmospheric Measurement Methods: Remote Sensing (C5)	VO	2	3	Messmethoden der Atmosphären und Klimaphysik	VO	2	3
Climate and Environmental Change - Current Research Topics (M2)	SE	2	3	Klima- und Umweltwandel: Aktuelle Forschungsbeiträge	SE	2	3
Field Course Atmospheric and Climate Physics (M2)	PT	3	6	Praktikum aus Atmosphären- und Klimaphysik	PR	3	6
Selected Topics in Climate Science (C4)	VO/ SE	2	3	Ausgewählte Kapitel der Atmosphären und Klimaphysik	VO/SE	2	3

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Planetary Magnetospheres (S3)	VO	2	3	Planetenmagneto-sphären	VO	2	3
Measurement Methods in Space Physics (S4)	VO	2	3	Messmethoden der Weltraumphysik und Aeronomie	VO	2	3
Practical Training in Space Physics and Aeronomy (M3)	PT	3	6	Praktikum aus Welt-raumphysik und Aero-nomie	PR	3	6
				Special subject Theo-retical and Computer-oriented Physics			
Advanced Quantum Mechan-ics (G)	VO	2	4	Höhere Quanten-mechanik 1	VO	2	4
Basic Concepts of Solid-state Theory (T2)	VO	2	3	Theoretische Festkörperphysik 1	VO	2	3
Monte-Carlo Methods (T3) *and* 1 ECTS for the general elec-tive module (Elective Topics)	VU	2	3 + 1	Computational Physics 1	VU	2	4
Advanced Quantum Mechan-ics 2 (T2)	VO	2	3	Höhere Quanten-mechanik 2	VO	2	3
Numerical Methods in Linear Algebra (T3) *and* 1 ECTS for the general elec-tive module (Elective Topics)	VU	2	3 + 1	Computational Physics 2	VU	2	4
Advanced Mathematical Methods VO (T1) *and* Advanced Mathematical Methods UE *and* 1 ECTS for the general elec-tive module (Elective Topics)	VO + UE	3 + 1	4.5 + 1.5 + 1	Funktionentheorie *and* Gruppentheorie	VO	2 + 2	4 + 3
Quantum Field Theory 2: Gauge Theories (T7) *and* 2 ECTS for the general elec-tive module (Elective Topics)	VU	4	6 + 2	Theoretische Elemen-tarteilchenphysik	VO	4	8
Practical Training in the Area of the Master's Thesis (M0)	LU/ PT	4	10	Projektpraktikum Theo-retische Physik	PP	4	8
Quantum Field Theory VO (T1) *and* Quantum Field Theory UE	VO + UE	3 + 1	4.5 + 1.5	Quantenfeldtheorie	VO	3	6
Fundamentals of Electronic Structure Theory (T4, T5, T6) *and* 1 ECTS for the general elec-tive module (Elective Topics)	VO	2	3 + 1	Theoretische Festkörperphysik 2	VO	2	4

Course from this curriculum 2017 (17W)				Course from the expiring curriculum 2013 (13W)			
Course	**LV type**	**SSt**	**ECTS**	**Course**	**LV type**	**SSt**	**ECTS**
Computational Methods in Solid-state Physics (T3, T4)	VU	2	3	Computermethoden der Festkörperphysik	VU	2	4
Computational Methods in Particle Physics (T3, T7)	VU	2	3	Computermethoden der Elementarteilchenphysik	VU	2	4
Theoretical Nano- and Quantum Physics (T5)	VO	2	3	Theoretische Nano- und Quantenoptik	VO	2	4
Lattice Field Theory (T7)	VO	2	3	Einführung in die Gitterfeldtheorie	VO	2	3

Annex V

Glossary

Glossary of the names used, which are different in the statutes and guidelines of both universities

Name in this curriculum (NAWI Graz)	Name at Uni Graz	Name at TU Graz
SSt (semester hour)	KStd.	SSt.
elective module	Gebundes Wahlfach	Wahlfach
free-choice subject	Freies Wahlfach	Freifach

Abbreviations used in this curriculum: EX: excursion; KU: design exercise; LU: laboratory course; LV: course; PT: project; PV: exclusive tutorial; SE: seminar; SP: seminar project; SS: summer semester; SSt: semester hours; UE: exercise; VO: lecture; VU: lecture with integrated exercises; WS: winter semester