Curriculum for the Master's Degree Programme

Physics

Curriculum 2017 in the version of 2023

This curriculum was approved by the Senate of the University of Graz at the meeting of May 17, 2023, and by the Senate of Graz University of Technology at the meeting of May 22, 2023.

The degree programme is organised as a combined degree programme (§ 54 (e) UG) of the University of Graz (Uni Graz) and Graz University of Technology (TU Graz) in the context of "NAWI Graz". The legal basis of this degree programme are the Universities Act 2002 (UG) and the Legal Regulations for Academic Affairs in the statutes of TU Graz and Uni 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 Information

§ 1. Subject matter of degree programme and qualification profile

The NAWI Master's Degree Programme Physics comprises four semesters. The total scope of the programme is 120 ECTS credits.

The Master's Degree Programme Physics is held in English.

Graduates of this programme are awarded the university degree of 'Master of Science', abbreviated as 'MSc'.

(1) Object of degree programme

The English-language Master's Degree Programme Physics, which is offered jointly by Graz University of Technology and the University of Graz, provides students with a scientific education in the subject of physics. It allows students to choose courses from a wide range of specializations and thus to set their individual concentrations.

(2) Qualification profile and skills

The educational goal of the NAWI Master's Degree Programme Physics (at the University of Graz and the Graz University of Technology) is to train internationally competitive graduates who are able to flexibly solve problems in the physical/scientific field. This is achieved by a solid foundation in general physics that has been applied to many real world examples combined with the possibility of pursuing individual subject-specific concentrations. As a result, graduates of the Master's Degree Programme Physics can work successfully and independently in various professional fields.

In the Master's Degree Programme Physics, students receive a high-level general physical and mathematical education and can set an individual focal point for their education by choosing one of the following five specializations: atmospheric physics and climate, astrophysics, experimental physics, space physics and aeronomy, and theoretical and computational physics. In addition to these proposed specializations, students have the opportunity to flexibly combine modules, thus creating their own individual concentrations in order to be well prepared for their desired future careers.

Graduates of this degree programme

- have deepened and further developed the skills they acquired in their bachelor's degree programme.
- are familiar with sub-areas of current physical research and can reflect on them.
- can independently deal with complex problems using physical-mathematical methods.
- have a high degree of analytical thinking.
- are highly suited for working in teams due to their experience with many projects.
- are well-versed in dealing with theoretical, experimental and computer-based problem-solving methods.
- can communicate the results of their work to other experts as well as to laypeople.

- have a good command of the English technical language and are particularly competitive in an international context as Masters of Science.
- have the qualifications required for a continuation of their studies, e.g., in the form of a PhD/doctoral programme.

(3) Need and relevance of the degree programme for science and the labor market

Graduates have a broad general education, which is both individual and in-depth, as mentioned under (2), and are thus qualified to work in a number of different professional fields in Austria and abroad. They are highly qualified specialists in the scientific, economic, and industrial sectors.

In addition to their general excellent professional qualifications, graduates have what is often referred to as ‘physical thinking’, that is valuable core competences resulting from a combination of solid scientific knowledge, familiarity with practical methods (experimental, theoretical and computer-oriented), highly analytical thinking skills and pronounced problem-solving skills. As a result, graduates are sought-after specialists who can be used flexibly and across disciplines for newly emerging challenges. In addition, they have the teamworking skills required for a professional career in physics as research in this field practically only takes place in working groups. Thanks to their broad skillset, graduates are particularly well-suited for the following professional fields in Austria and abroad:

- Research and management in public/private physics and engineering research and educational institutions
- Participation in large international research collaborations
- Modelling and simulation for science, engineering and economy
- Algorithm development for various fields
- Research and management in R&D departments for various industrial sectors, especially high-tech industry
- Management in administration and logistics
- Business consulting
- Quality control
- Advisory positions in the scientific and technical field

II General Provisions

§ 2. Admission requirements

(1) The Master's Degree Programme Physics builds on the Bachelor's Degree Programme Physics offered by NAWI Graz. Graduates of this bachelor's degree thus meet the admission requirements for the Master's Degree Programme Physics. Furthermore, the following degree programmes are eligible for admission to the Master's Degree Programme Physics without further requirements:

- Any bachelor's degree programme in physics and/or technical physics of a higher educational institution in one of the following countries: Belgium, Bulgaria, Denmark, Germany, Estonia, Finland, France, Greece, Ireland, Italy, Iceland, Croatia, Latvia, Lichtenstein, Lithuania, Luxembourg, Malta, the Netherlands, Norway, Austria, Poland, Portugal, Romania, Sweden, Switzerland, Slovakia, Slovenia, Spain, the Czech Republic, Hungary, the United Kingdom and Cyprus.

(2) Any degree programmes that are not mentioned in (1) are considered eligible for admission if at least 105 ECTS credits have been positively completed in the following subject areas:

- 35 ECTS credits from courses on experimental physics
- 30 ECTS credits from courses on theoretical physics
- 35 ECTS credits from courses on mathematics
- 5 ECTS credits from courses on programming

(3) Any degree programmes that do not satisfy (1) or (2) are not considered equivalent to this degree programme. However, if at least 75 ECTS credits have been completed in the subject areas mentioned in (2), full equivalence may be established by requiring supplementary examinations. The extent of these supplementary examinations must not exceed 30 ECTS credits.

(4) Any degree programmes that do not satisfy (1), (2), or (3) are not close enough in subject matter to establish full equivalency. In such cases, admission to the Master's Degree Programme Physics is not possible.

(5) Proof of sufficient English language skills is a prerequisite for admission to the degree programme. The type of proof required is specified in a regulation issued by the rectorate.

§ 3. Allocation of ECTS credits

All study activities completed by the students are allocated certain numbers of ECTS credits. ECTS credits reflect the workload of each course or assignment relative to the workload of an academic year, which is intended to be 1500 real hours corresponding to 60 ECTS credits (i.e., 25 actual hours per 1 ECTS credit). This workload includes both the time spent in self-study and the classroom hours. One semester course hour is equivalent to 45 minutes per week of the semester.

§ 4. Structure of the degree programme

The Master's Degree Programme Physics with a workload of 120 ECTS credits covers four semesters and is structured in modules, as follows:

	ECTS
Compulsory Module G: General Physics	15
Compulsory Module M: Preparation for the Master's Thesis	14
5 Specialization Modules (9 ECTS each)	45
Elective Topics	9
Free Electives	6
Master's thesis	30
Master's examination	1
Total	120

§ 5. Types of courses

The types of courses provided at Uni Graz and TU Graz are regulated by the statutes of these universities.

§ 6. Group sizes

The following maximum numbers of participants (group sizes) are stipulated for the following types of courses:

(1) For exercises (UE) and for the exercise parts of lectures with integrated exercises (VU), the maximum group size is 25. For any laboratory exercises that are part of lectures with integrated exercises (VU), the maximum group size is 6.

(2) For laboratory courses (LU) and exclusive tutorials (PV), the maximum group size is 6.

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

§ 7. Guidelines for the allocation of places in courses

(1) If the number of students exceeds the number of available places, students are allocated places in the course according to the following priority criteria, whereby the individual criteria are to be applied in the order given:

a. Position of the course in the curriculum (acc. to § 8 and § 9): Priority is given to students for whom the course is compulsory according to their curriculum over those who are taking the course as part of an elective module.

b. Total of completed/recognized ECTS credits for the degree programme: All study achievements completed in the degree programme for which the student wants to take the course are taken into account for the ranking. Students with the highest total of ECTS credits already completed in their current degree programme are ranked preferentially.

c. Number of semesters spent studying in the degree programme so far: Students are ranked according to the number of semesters they have already studied in the degree programme, whereby priority is given to those who have studied longer.

d. Decision by lot: If it is not possible to rank students according to the above criteria, admission to the course is decided by lot.

(2) Up to 10% of the existing places in the course are reserved for students completing part of their studies at a NAWI Graz university as part of a mobility programme.

III Course Content and Structure

§ 8. Modules, courses and semester

The individual courses of this master's degree programme and their designation as compulsory and elective modules are set out below. The knowledge, methods or skills to be taught in each course are described in detail in Appendix I. The assignment of courses to particular semesters is a recommendation and ensures that the sequence of courses is best able to build on prior knowledge and that the workload of an academic year does not exceed 60 ECTS credits. The allocation of the courses to the participating universities is defined in Appendix II and § 9.

Master's Degree Programme Physics **Module** / **Course**	**SSt.**	**Course Type**	**ECTS**	**Sem. ECTS credits** **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 Compulsory Module G	**8**		**15**	**15**			
Compulsory Module M: Preparation for the Master's Thesis							
Subtotal Compulsory Module M			14			12	2
Total of Compulsory Modules			**29**	**15**		**12**	**2**
5 Specialization Modules (9 ECTS each)			45	12	18	15	
Elective Topics			9		6	3	
Total of Elective Modules described under § 9			**54**	**12**	**24**	**18**	
Master's thesis			**30**				30
Master's examination			**1**				1
Free Electives acc. to § 10			**6**	3	3		
Overall total			**120**	**30**	**27**	**30**	**33**

[1]: This module is held together with the Master's Degree Programme Technical Physics.

Module M: Preparation for the Master’s Thesis

Module M is intended to prepare students for their master's thesis and must therefore be thematically related to the topic of the master's thesis. It is defined in the table below.

Module M: Preparation for the Master’s Thesis							
Module/course		Course		Semester		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]: Assignment of the course to the participating universities. Both universities are named if the course is offered at both universities in combination, in parallel or alternately.

[2]: These courses may have a descriptive subheading that further specify the subject matter of the course in relation to a master's thesis subject area.

If the topic of the master's thesis is part of the fields of Astrophysics, Atmospheric Physics and Climate, or Space Physics and Aeronomy, the following applies to Module M:

Module M: Preparation for the Master’s Thesis in …							
Module/course		Course		Semester		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	X	
Master’s Seminar in Astro- and Space Physics	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	X	
Module M3: **Preparation for the Master’s Thesis in Space Physics and Aeronomy**							
Practical Training in Space Physics and Aeronomy[2]	3	PT	7	X		X	
Master’s Seminar in Astro- and Space Physics	2	SE	2		X	X	
Selected Topics in Space Physics and Aeronomy	2	SE/VO	3		X	X	
Tutorial for Master’s Students in Space Physics and Aeronomy	2	PV	2	X	X	X	

[1]: Assignment of the course to the participating universities. Both universities are named if the course is offered at both universities in combination, in parallel or alternately.

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

§ 9. Elective modules

(1) Specializations

At the request of the student, the master's certificate and diploma can designate one of the Specializations listed below. This is only possible, however, if the master's thesis, the corresponding preparatory Module M as well as the Specialization Modules (see § 9 (3)) are in this Specialization. The required modules are as follows:

- **Astrophysics**: Module A1, A2, A3, A4, A5.
- **Atmospheric Physics and Climate:** Module C1, C2, C3, C4, C5.
- **Experimental Physics:** At least 3 modules from E1, E3, E4, E5, E7. However, E4 and E5 cannot be chosen together.*
- **Space Physics and Aeronomy:** Module S1, S2, S3, S4, C2.
- **Theoretical and Computational Physics:** Module T1, T2, T3.

A specialization other than those listed here may be approved by the dean of studies at the request of the student. In such cases, a corresponding list of Specialization modules must be defined.

(2) Mentoring

Students who wish to design their own individual specialization and must therefore decide on individual Specialization Modules are advised to set up a meeting with a mentor to be chosen during the first semester. This is to ensure an optimal course of study for the students. Potential mentors can be anyone of the teaching staff listed on the websites of the different Institutes of Physics. Useful advice on the selection of a mentor can be obtain by consulting the Student Representation for Physics.

* Excluded from this are students who have already successfully passed examinations for these two modules when this curriculum comes into force.

(3) Specialization modules

Students must complete a total of 5 Specialization Modules worth 9 ECTS credits each. The courses marked with (♦) must be completed.

Specialization Modules								
Module/course		Course		Semester		Uni Graz[1]	TU Graz[1]
	SSt.	Type	ECTS	WS	SS		
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 System[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	
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 Tour	1	EX	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	LU[4]	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	VO	3	X		X	
Astrophysics Lab 2[2]	2	LU[4]	3		X	X	
Hydrodynamics[2]	2	VO	3		X	X	
Sun and Space Weather[2]	2	VO	3	X		X	
Advanced General Relativity and Quantum Gravity	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	
Exoplanets and Our Place in the Universe – An Interdisciplinary Approach	2	VO	3		X		X
Module C1: **Principles of the Climate System**							
♦ Earth's Climate System and Climate Change	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	4	VU	6	X		X	
♦ Time Series Analysis[2]	2	VO[8]	3		X	X	
Module C3: **Atmospheric Physics**							

Specialization Modules								
Module/course			Course		Semester		Uni Graz[1]	TU Graz[1]
		SSt.	Type	ECTS	WS	SS		
♦	Atmospheric Dynamics	2	VO[8]	3		X	X	
♦	Atmospheric Composition and Chemistry	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[8]	3		X	X	
♦	Selected Topics in Climate Science	2	VO/SE	3	X		X	
Module C5: **Atmosphere and Climate Measurement Methods**								
♦	Atmosphere and Climate Measurement Methods: Remote Sensing[2]	2	VO	3		X	X	
♦	Atmosphere and Climate Measurement Methods: In Situ[2]	2	VO	3	X		X	
♦	Seminar on Atmosphere and Climate Measurement Methods[2]	2	SE	3		X	X	
Module E1: **Surface Science: Basic Principles**								
♦	Research Laboratory Surface Science	2	LU[7]	3		X	X	X
	Surface Science	2	VO	3	X		X	
	Thin Film Science and Processing	2	VO	3		X		X
Module E2: **Surface Science: Advanced Topics**								
	Molecular Interfaces	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	X	X	
Module E3: **Photon Science**								
♦	Research Laboratory Photon Science	2	LU[7]	3	X	X	X	X
	Laser Spectroscopy	2	VO	3	X			X
	Photonics: Light, Matter, and Time	2	VO	3		X		X
	Structured Light and Nanoscale Wave Phenomena	2	VO	3	X		X	
	Optical Waveguides, Photonic Circuitry and Applications	2	VO	3		X	X	
	Optical Measurement Techniques	2	VO	3	X			X
Module E4: **Nano- and Laser-Optics[5]**								
♦	Optics – A Photonics Perspective	2	VO	3	X		X	
♦	Research Laboratory Nano and Laser Optics	2	LU[7]	3	X	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]**								
♦	Optics – A Spectroscopy Perspective	2	VO	3	X			X
♦	Research Laboratory Quantum Optics and Molecular Physics	2	LU[7]	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

Specialization Modules								
	Module/course		Course		Semester		Uni Graz[1]	TU Graz[1]
		SSt.	Type	ECTS	WS	SS		
	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	
	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
	2D Materials	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	
	Theoretical Biophysics	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
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	VO	3	X		X	
Module S2: Solar and Heliospheric Physics								
♦	Introduction to Solar Physics[2]	2	VO	3		X	X	
♦	Introduction to Solar Physics[2]	1	UE	2		X	X	
♦	Magneto-Hydrodynamics and Solar-Terrestrial Modeling[2]	2	VO	3		X	X	
♦	Solar Physics Lab Tour	1	EX	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								

Specialization Modules							
Module/course	SSt.	Course Type	ECTS	Semester WS	Semester SS	Uni Graz[1]	TU Graz[1]
♦ Advanced Mathematical Methods	3	VO	4.5	X		X	
♦ Quantum Field Theory	3	VO	4.5		X	X	
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 Nano Physics	2	VU[3]	3		X	X	
Computational Methods in Particle Physics	2	VU[3]	3		X	X	
Quantum Computing	2	VO	3		X	X	
Module T4: **Theoretical Solid-State Physics[5]**							
♦ Quantum Theory of Many-Body Systems	2	VU[3]	3		X	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 Phenomena	2	VO	3	X			X
Special Topics in: Theoretical Solid-State Physics	2	VO	3		X	X	
Module T5: **Theoretical Nano Physics**							
Theoretical Nano- and Quantum Optics	2	VO	3		X	X	
Fundamentals of Electronic Structure Theory	2	VO	3	X		X	X
Quantum Computing	2	VO	3		X	X	
Computational Methods in Nano Physics	2	VU[3]	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 Materials	2	VO	3	X			X
Advanced Electronic Structure Theory	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 Theories	4	VU[3]	6		X	X	
Lattice Field Theory[2]	2	VO	3		X	X	
Computational Methods in Particle Physics	2	VU[3]	3		X	X	
Special Topics in: Particle Physics	2	VO	3		X	X	

Specialization Modules							
Module/course		Course		Semester		Uni Graz[1]	TU Graz[1]
	SSt.	Type	ECTS	WS	SS		
Advanced Mathematical Methods 2[2]	2	VO	3		X	X	
Module T8: **Phenomenology of Particle Physics**							
Standard Model	3	VO	4.5	X		X	
Beyond the Standard Model	3	VO	4.5	X		X	
Advanced General Relativity and Quantum Gravity[2]	2	VO	3		X	X	
Astroparticle Physics[2]	2	VO	3		X	X	
Experimental Particle Physics[2]	2	VO	3	X		X	
Collider Phenomenology[2]	2	VO	3	X		X	
Project in: Particle Physics	2	PT	3		X	X	

[1]: Assignment of the course to the participating universities. Both universities are named if the course is offered at both universities in combination, in parallel or alternately.
[2]: This course is offered every two years. The degree programme can thus still be completed within four semesters.
[3]: 2/3 lecture part, 1/3 exercise part
[4]: This laboratory course (LU) has a maximum group size of 10 people.
[5]: This module is part of the curriculum for both the Master's Degree Programme Technical Physics and the Master's Degree Programme Physics.
[6]: 2/3 lecture part, 1/3 exercise part. The exercise part is held as a laboratory course.
[7]: This laboratory course (LU) has a maximum group size of 3 people.
[8]: Depending on the available resources, this course may also be offered as a lecture with integrated exercises (VU) with 2/3 of the semester course hours held as lectures and 1/3 as exercises.

(1) Elective Topics

The Elective Topics module is comprised of courses worth 9 ECTS credits.

The following courses can be chosen for the Elective Topics:

- Courses from the course catalogue of the above-mentioned Specialization Modules (§ 9 (3)) that have not already been completed as part of the selected Specialization Modules.
- Any compulsory and elective courses of the NAWI Master's Degree Programme Technical Physics provided the student meets the respective course requirements and has not already completed the course as part of the selected Specialization Modules.
- Any foreign language courses (English or German language courses only if the student is not a native speaker of the respective language) worth a maximum of 3 ECTS credits.
- Courses from the course catalogue “Further Elective Topics” below.
- German-language courses from the course catalogue “Bachelor's Degree Programme Physics” below.

Course catalogue: Further Elective Topics							
Course		Course		Semester		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[4]	2	VO	4		X	X	
Digitalelektronik[4]	1	VU[3]	2	X		X	

Course catalogue: Further Elective Topics

Course	SSt.	Course Type	ECTS	Semester WS	Semester SS	Uni Graz[1]	TU Graz[1]
Journal Club[4]	2	PV	3	X		X	
Mechanische Fertigungstechniken[4]	1	VU[3]	2	X		X	
Physics of Sustainable Energy	2	VO	3	X			X
Weltraumplasmaphysik[2,4]	1	VO	2		X		X
Fortgeschrittene Weltraumplasmaphysik[2,4]	1	VO	2		X		X
Aktive Plasmaexperimente im Weltraum[2,4]	1	VO	2		X		X

[1]: Assignment of the course to the participating universities. Both universities are named if the course is offered at both universities in combination, in parallel or alternately.

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

[3]: 1/4 lecture part, 3/4 exercise part. The exercise part is held as a laboratory course.

[4]: This course is held in German.

Course catalogue: Bachelor's Degree Programme Physics

Course	SSt.	Course Type	ECTS	Semester WS	Semester SS	Uni Graz[1]	TU Graz[1]
Moderne Kapitel der experimentellen Physik[2]	2	VO	3		X	X	
Moderne Kapitel der theoretischen Physik[2]	2	VO	3		X	X	
Physikalische Grundlagen der Materialkunde[2]	3	VO	4.5		X		X
Kontinuumsphysik[2]	2	VU[3]	3		X		X
Kryotechnik, Vakuumtechnik und Analysemethoden[2]	3	VO	4.5		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]: Assignment of the course to the participating universities. Both universities are named if the course is offered at both universities in combination, in parallel or alternately.

[2]: This course is held in German. Recommended for students who have not studied physics in the NAWI Bachelor's Degree Programme Physics.

[3]: 2/3 lecture part, 1/3 exercise part

§ 10. Free Electives

(1) The courses to be completed as part of the Free Electives in the Master's Degree Programme Physics are designed to provide individual strategic focus and further development of the students. They may be freely selected from the courses offered by any recognized national or international university and also recognized national post-secondary educational institutions. Appendix III contains recommendations for specific free-choice courses.

(2) If a free-choice subject does not have an allocation of ECTS credits, each semester course hour (SSt) of this course is counted as one ECTS credit point. However, if such courses are lecture-type courses (VO), they are assigned 1.5 ECTS credits for each semester course hour.

(3) Additionally, the possibility exists, in accordance with § 13, to take a professionally-oriented internship or short study periods in foreign countries as part of the Free Electives.

§ 11. Master's thesis

(1) The purpose of the master's thesis is to demonstrate the student's ability to work on scientific topics on their own, both with regard to content and methodology. The scope of the master's thesis must be determined in such a way that its completion can be reasonably and feasibly accomplished by the student within a period of six months.

(2) The topic of the master's thesis must belong to one of the compulsory or elective modules in the subject area of physics. Any exceptions are subject to approval by the dean of studies.

(3) The master's thesis must be registered before beginning work on it via the Dean's office. The subject, the field to which the subject is assigned, and the supervisor must be stated along with the name of the institute.

(4) 30 ECTS credits are allocated to the master's thesis.

(5) The master's thesis must be submitted for assessment in electronic form.

§ 12. Admission requirements for courses/examinations

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

(2) Students who have to complete additional and supplementary examinations in order to be able to study in the Master's Degree Programme Physics must have successfully completed these examinations before participating in laboratory exercises (LU) and lectures with integrated exercises (VU), which carry out part of the exercises as laboratory exercises.

§ 13. Stays abroad and internships

(1) Recommended stays abroad

It is recommended for students to spend one semester abroad in the course of their studies. In this master's degree programme, the 2nd or 3rd semesters are particularly suitable for this purpose. Courses taken during the study period abroad will be recognized by the dean of studies if they are equivalent. On the recognition of examinations taken during study periods abroad, we refer to § 78 (5) Universities Act 2002 (UG).

It is also possible to obtain recognition of work done in shorter study periods abroad, for example participation in summer or winter schools, as part of the Free Electives, by application to the dean of studies.

(2) Internships

It is possible to include professionally-oriented internships in Free Electives.

Each week of full employment corresponds to 1.5 ECTS credits. Active participation in an academic event may also count as an internship. This work experience must be relevant to the degree programme and must be approved by the dean of studies.

IV Examination Regulations and Completion of Studies

§ 14. Examination regulations

Courses are assessed individually.

(1) Examinations for courses held in the form of lectures (VO) must cover the entire contents of the course. Examinations can be oral-only, written-only or a combination of oral and written.

(2) In courses of the types lectures with integrated exercises (VU), exercises (UE), laboratory courses (LU), projects (PT), seminars (SE) and excursions (EX), students' performance is measured by continuous assessment of work done by the students and/or by ongoing tests. The assessment must be based on at least two evaluations of different aspects of the course.

(3) If a module is made up of multiple courses, the overall grade for the module is to be calculated as follows:

a. The grade of each course belonging to the module is multiplied by the corresponding ECTS credits.

b. The values calculated in point (a) are added together.

c. The result of the addition is divided by the sum of the ECTS credits of the courses.

d. The result of the division is rounded to a whole-numbered grade, if necessary. 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 may only be awarded if each individual course has been assessed as positive.

f. Courses whose assessment consists only of "successful/unsuccessful participation" are not included in the calculation under points (a) to (d).

(4) Regulations on repeating assessments for courses with continuous assessment are set out in the statues of TU Graz and Uni Graz.

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

- the presentation of the master's thesis (max. 20 minutes),
- the defence of the master's thesis (examination interview),
- an oral examination on topics from the module with which the master's thesis is associated, as well as from another module in accordance with § 8 and § 9 that does not thematically relate to the topic of the master's thesis.

The modules are determined by the dean of studies of the university of admission based on the candidate's suggestion. The total duration of the master's examination before a committee is usually 60 minutes and must not exceed 75 minutes.

(6) The examination committee for the master's examination includes the supervisor of the thesis and two other members who are nominated by the dean of studies, after considering suggestions from the candidate, if any. The examination committee must be chaired by one of the members who is not the supervisor of the thesis.

(7) The examination committee determines the grade of this oral examination.

§ 15. Completion of studies

(1) The master's degree programme is completed once the student has achieved positive grades for the courses of all compulsory and elective modules as well as for Free Electives, the master's thesis and the master's examination before the committee.

(2) A degree certificate is issued upon successful completion of the master's degree programme. The master's degree certificate is composed of:

a. a list of all the modules (examination subjects) as set out in § 4 (along with their ECTS credits) and their assessment results, but without the module ID, e.g., "General Physics" or "Stellar Astrophysics",

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

c. the assessment of the final master's examination before a committee,

d. the total of the ECTS credits in Free Electives as defined in § 10, and

e. the overall assessment.

V Validity and Transitional Regulations

§ 16. Legal validity

This Curriculum 2017 in the version of 2023 (UNIGRAZonline version 2023W, TUGRAZonline version 2023W) enters into force on 1 October 2023.

Curriculum	Version	UNIGRAZonline Version	TUGRAZonline Version	Published in the Uni Graz University Gazette	Published in the TU Graz University Gazette
2017	2023	2023W	2023W	31/05/2023	31/05/2023

§ 17. Transitional regulations

Students of the Master's Degree Programme Physics who are subject to the curriculum in the version from 2017 at the time when these changes to the curriculum come into force on 1 October 2023, will be subject to the 2023 version of the curriculum as of 1 October 2023.

Appendices to the curriculum of the Master's Degree Programme Physics

Appendix I Module Descriptions

Compulsory Module Descriptions

Module G:	General Physics
ECTS credits	15
Contents	♦ 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 successfully completing this module, students are able to • understand the basic principles of statistical physics and of general relativity and cosmology. • apply advanced methods in quantum theory. • perform successful standard-type calculations in these fields. After having completed this module, students have • a well-founded understanding of classical statistical physics. • profound knowledge of some aspects of quantum statistics. • an understanding of some of the more advanced techniques in quantum physics and of the most prominent physical effects in general relativity.
Teaching and learning activities and methods	Lectures, exercises
Recommended prerequisites for participation	Theory courses at a bachelor's degree level
Frequency in which the module is provided	Every year

Module M0	Preparation for the Master's Thesis
ECTS credits	14
Contents	♦ 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 students in the master's degree programme (and PhD students), complemented by recent and ongoing work of further presenters (e.g., of scientific guests).
Learning outcomes	After successfully completing this module, students are able to • solve problems in research-related topics. • present the results in short talks. • discuss recent advances in the research field connected to the master's thesis.
Teaching and learning activities and methods	Project, tutorial, seminar
Recommended prerequisites for participation	None
Frequency in which the module is provided	Every year

Module M1	**Preparation for the Master's Thesis in Astrophysics**
ECTS credits	14
Contents	♦ Tutorial and Seminars for Master's Students in Astrophysics: Discussions and guidance for ongoing master's thesis projects of the participating students in the master's degree programme; 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 successfully completing this 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. • process results to be presented in scientific talks. After having completed this module, students have • an understanding of data analysis and interpretation. • knowledge of numerical modelling of astrophysical processes. • a grasp of state-of-the-art astrophysics and major problems in astrophysics to be solved in future research.

	• knowledge of the fundamentals of astrophysics and research frontiers in astrophysics. • the skillset required for writing a thesis in accordance with good scientific practices.
Teaching and learning activities and methods	Lecture, course, seminars, tutorial
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years, tutorial and master's seminar every year

Module M2	**Preparation for the Master's Thesis in Atmospheric Physics and Climate**
ECTS credits	14
Contents	♦ Tutorial for Master's Students in Atmospheric Physics and Climate: The earth's climate system; physical climate mechanisms and geo-biochemical 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 students in the master's degree programme. ♦ 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 successfully completing this 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. • provide valuable contributions when working as a member of a scientific team. After having completed this module, students have • the ability to set up and calibrate instruments. • knowledge of the design and implementation of meteorological field campaigns. • an understanding of data analysis and interpretation. • a grasp of the climate system, future projections of climate change and research frontiers in climate and environmental research. • an understanding of the fundamentals of atmospheric and climate physics and research frontiers in atmospheric and climate physics. • the skillset required for writing a thesis in accordance with good scientific practices.

Teaching and learning activities and methods	Course, seminars, tutorial
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years, tutorial every year

Module M3	**Preparation for the Master's Thesis in Space Physics and Aeronomy**
ECTS credits	14
Contents	♦ Tutorial for Master's Students in 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 students in the master's degree programme (and PhD students), complemented by recent and ongoing work of further presenters (e.g., of scientific guests).
Learning outcomes	After successfully completing this module, students have • an understanding of the fundamental physics principles of in situ and remote measurements. • knowledge of the sequence of data acquisition, processing and analysis (calibration), modelling and simulation. • a grasp of the basics regarding selected topics in space physics and aeronomy. After successfully completing this module, students are able to • work in space science through knowledge of experiment performance, data acquisition, physical processes interpretation, modelling and simulation. • effectively search through scientific literature, hold oral presentations, and write scientific reports and papers. • work in various settings (single, teamwork with different roles of responsibility).
Teaching and learning activities and methods	Practical training, seminar, teamwork, tutorial, lecture
Recommended prerequisites for participation	Knowledge of astrophysics, astronomy, physics, geophysics, electromagnetism, hydrodynamics, electronics, plasma physics, elementary particle physics, waves theory at a bachelor's degree level
Frequency in which the module is provided	At least every two years, tutorial every year

Specialization Module Descriptions

Module A1	**Stellar Astrophysics**
ECTS credits	9
Contents	♦ 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 System: Composition and structure of the galaxy and extragalactic systems; galaxy clusters; galactic distance indicators.
Learning outcomes	After successfully completing this 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. • 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.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module A2	**Theoretical Astrophysics**
ECTS credits	9
Contents	♦ 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 successfully completing this module, 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. • 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.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module A3	**Physics of the Solar System**
ECTS credits	9
Contents	♦ 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 Tour: Excursion tour to Kanzelhöhe Observatory and practical 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 successfully completing this 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. • 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.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module A4	**Observation Techniques in Astrophysics**
ECTS credits	9
Contents	♦ 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 successfully completing this 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. • 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.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module A5	**Selected Topics in Astrophysics**
ECTS credits	9
Contents	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 courses must be selected. These can be lectures, advanced laboratories or seminars. A total of 9 ECTS credits must be completed.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module C1	**Principles of the Climate System**
ECTS credits	9
Contents	♦ 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 successfully completing this 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. • provide an overview of the field of oceanography and discuss relevant current events (e.g., the increased melting of sea ice). After having completed this module, students have • an understanding of the earth's physical climate system and anthropogenic climate change. • the skills required to engage with 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. • knowledge of physical oceanography and hydrology, and their relation to climate dynamics. • a grasp of the relations and interactions between the hydrosphere and the atmosphere. • an understanding of 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.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module C2	**Data Analysis and Simulation**
ECTS credits	9
Contents	♦ 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. ♦ <u>Time Series Analysis</u>: 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 successfully completing this 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. • analyse and interpret model/simulation results. After having completed this module, students have • knowledge of different methods of modelling/simulation in atmosphere, climate and environmental sciences. • knowledge of fundamental concepts and different methods of time series analysis. • critical thinking skills for practical modelling/simulation and data analysis problems.
Teaching and learning activities and methods	The module consists of one lecture and one lecture with integrated exercise. In the lectures, the material is presented theoretically and explained with selected examples. In the exercises, mainly computer-based practical training is provided for the topics covered by the associated lectures, supported by adequate software. The training covers both independent problem-solving (sup-ported by advice) and joint problem solving in a team.
Recommended prerequisites for participation	Fundamentals of a programming at a bachelor's degree level
Frequency in which the module is provided	Mandatory courses (♦) every year

Module C3	**Atmospheric Physics**
ECTS credits	9
Contents	♦ <u>Atmospheric Dynamics</u>: 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. ♦ <u>Atmospheric Composition and Chemistry</u>: 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. ♦ <u>Radiation and Energy Balance</u>: Radiative transfer in planetary atmospheres; radiative forcing; interaction of radiation (UV/VIS, IR) with gases and clouds; atmospheric energy budget.
Learning outcomes	After successfully completing this 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. • perform radiative transfer calculations. After having completed this module, students have • knowledge of the physical principles governing large-scale and mesoscale atmospheric flow and atmospheric thermodynamics. • an understanding of the composition and evolution of planetary atmospheres and fundamental chemical cycles. • an understanding of the principles of stratospheric and tropospheric chemistry and chemistry-climate connections. • a grasp of 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.
Recommended prerequisites for participation	None
Frequency in which the module is provided	At least every two years

Module C4	**Climate Physics**
ECTS credits	9
Contents	♦ 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 successfully completing this 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. • contribute to the debate on climate change on a global and regional scale. After having completed this module, students have • an understanding of the principles of climate modelling at an introductory level. • knowledge of a wide range of possibilities of using climate models. • a clear idea of the benefits and limitations of climate models. • an understanding of geophysical fluid dynamics and energy and momentum transport. • knowledge of large-scale climate modes, their underlying drivers and their role in the climate system. • an understanding of inter-annual to centennial climate variability. • a grasp of the current understanding of the climate system, future projections of climate change and research frontiers in climate and climate research.

Teaching and learning activities and methods	The module consists of two lectures. The relevant theoretical concepts are taught in detail and illustrated with many examples and applications.
Recommended prereq-uisites for participation	None
Frequency in which the module is provided	At least every two years

Module C5	**Atmosphere and Climate Measurement Methods**
ECTS credits	9
Contents	♦ <u>Atmosphere and Climate 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>Atmosphere and Climate 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 Atmosphere and Climate Measurement Methods</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 successfully completing this 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. • present a scientific topic. After having completed this module, students have • the skills to work with different atmospheric remote sensing measurement methods. • knowledge of different atmospheric in situ measurement methods. • an understanding of physical and chemical principles of individual measurement techniques. • scientific presentation skills.
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.
Recommended prereq-uisites for participation	None
Frequency in which the module is provided	At least every two years

Module E1	**Surface Science: Basic Principles**
ECTS credits	9
Contents	♦ Surface Science: Geometric and electronic structure of surfaces (theory and methods); adsorption; (thermodynamics, growth processes). ♦ Experimental Methods in Surface Science: The focus is on understanding the principles of modern experimental surface science techniques and gain-ing direct hands-on experience with the techniques available at the surface science groups at Uni Graz and TU Graz. Introductory experiments (surface cleaning, structure and composition analysis, adsorption and desorption) are followed by a small research project on a specific instrument and topic. ♦ Thin Film Science and Processing: Principles of thin film growth; thermo-dynamics and kinetics; adsorption; desorption; diffusion; techniques (PVD, CVD, LB, spin coating); nanostructure fabrication (etching, etc.).
Learning outcomes	After successfully completing this 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, 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. • understand the principles and methods of adsorption on surfaces, self-assembly, thin film growth and nanostructuring.
Teaching and learning activities and methods	Lectures, laboratory courses
Recommended prereq-uisites for participation	None
Frequency in which the module is provided	Every year

Module E2	**Surface Science: Advanced Topics**
ECTS credits	9
Contents	Molecular Interfaces: Bonding; orbitals; band structure; interfaces; angle-re-solved UPS; orbital tomography. Scanning Probe Techniques: Scanning tunnelling microscopy (theory; oper-ation; 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); spectro-microscopy: 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 cataly-sis; photocatalysis; electrochemistry). Vacuum Technology: Gas kinetics; pumps; pressure measurements; vac-uum 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
Recommended prerequisites for participation	None
Frequency in which the module is provided	Every year

Module E3	**Photon Science**
ECTS credits	9
Contents	Laser Spectroscopy: Laser spectroscopy techniques for atomic and molecular gasses, liquids, and solids; overview on optical spectroscopic diagnostic instrumentation; high-frequency and time-resolved spectroscopy and related diagnostic methods including most recent developments in optical spectroscopy, ranging from the x-ray to the infrared spectral region. Structured Light and Nanoscale Wave Phenomena: Introduction to the fascinating structure of light – from tall to small; discussion of various types of structured electromagnetic fields, generation methods and inherent properties; evanescent and propagating fields, polarization, angular momenta of light fields, optics of dielectric and metallic nanostructures, light-matter interactions at the nanoscale; exotic phenomena and intriguing effects in nanostructured fields; modern applications in nano-metrology, sensing, imaging, spectroscopy, polarimetry, photonic nanocircuitry, etc. Photonics: Light, Matter, and Time: Ultrafast time-domain perspective on optical properties of atoms and solids, dynamics of energy exchange between electric field and matter; refractive index and transition rates from quantum mechanical principles, optical control of charge and spin. Optical Waveguides, Photonic Circuitry and Applications: Introduction to various kinds of optical waveguides (integrated, dielectric, plasmonic, photonic crystal waveguides and fibres); discussion of photonic integrated circuits, corresponding components, and fascinating applications as well as recent developments. Optical Measurement Techniques: Introduction to optical spectroscopy methods for physics, chemistry and biological sciences with focus on providing knowledge for estimating applicability ranges of various methods, and on basics of spectroscopy instruments. Research Laboratory Photon Science: Practical training in advanced experimental optical techniques with a selection of intriguing topics related to photon sciences to be chosen in accordance with interests and lectures attended.
Learning outcomes	After successfully completing this module, students have • a concise theoretical knowledge base in photon science and related areas of physics (Optics, Electrodynamics, Quantum Mechanics, Physics of Semiconductors). • an understanding of fundamental laws of physics driving modern engineering areas including telecommunications, optoelectronics, photonics, nano- and microfabrication. • essential laboratory skills including experimental design, assembly of optical equipment, data acquisition and analysis. • training to communicate scientific and engineering ideas both orally and in written form.

Teaching and learning activities and methods	Lectures, laboratory courses
Recommended prerequisites for participation	Fundamentals of electrodynamics and optics as well as corresponding mathematical concepts at a bachelor's degree level
Frequency in which the module is provided	Every year

Module E4	**Nano and Laser-Optics**
ECTS credits	9
Contents	♦ Optics – A Photonics Perspective: 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 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 successfully completing this 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. • understand and apply the physical and technical principles of (ultrafast) lasers. After having completed this module, students have • the ability to design optical and laser setups. • the basis for a master's thesis in a research laboratory in the fields of modern optics and photonics.
Teaching and learning activities and methods	Lectures, laboratory courses
Recommended prerequisites for participation	Knowledge of experimental physics, quantum mechanics, electrodynamics and mathematical concepts at a bachelor's degree level
Frequency in which the module is provided	Every year

Module E5	**Quantum Optics and Molecular Physics**
ECTS credits	9
Contents	In this module, 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. ♦ Optics – A Spectroscopy Perspective: 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 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 successfully completing this 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. • 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 courses
Recommended prerequisites for participation	Knowledge of experimental physics, quantum mechanics, electrodynamics and mathematical concepts at a bachelor's degree level
Frequency in which the module is provided	Every year

Module E6	**Nano and Quantum Matter**
ECTS credits	9
Contents	♦ 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.

	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 micro-magnetism; magnetic domains. 2D Materials: Monoelemental (Xenes) and compound (MXenes, oxides, alloys) two-dimensional materials; freestanding, supported and stacked layers; physical, electrical, magnetic, chemical properties; characterization and applications.
Learning outcomes	After successfully completing this module, students have • understand modern physics based on size effects, dimensionality and quantum phenomena. • have gained an experimental and theoretical insight into methods of modern physics. • 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
Recommended prerequisites for participation	Knowledge of Solid-State physics, quantum mechanics, experimental and computational techniques at a bachelor's degree level
Frequency in which the module is provided	Mandatory courses (♦) every year; others at least every two years

Module E7	**Biological Applications**
ECTS credits	9
Contents	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. Theoretical Biophysics: Theory of soft and biological matter, focussing on the thermodynamics and kinetics of water, electrolytes, lipids, proteins and DNA. The course covers atomistic models as well as continuum and mean-field theory, spanning length scales from single atoms to membranes and vesicles. 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 successfully completing this module, students are able to • understand the hierarchical structure of biological systems. • specify methods for determining physical properties of biological materials. • use selected experimental methods for the characterisation of biological materials.
Teaching and learning activities and methods	Lectures, laboratory courses
Recommended prerequisites for participation	None
Frequency in which the module is provided	Mandatory course (♦) every year; others at least every two years

Module E8	**Industrial Applications**
ECTS credits	9
Contents	♦ 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. Excursion: An excursion to companies or external laboratory courses.
Learning outcomes	After successfully completing this module, students have • gained suitable knowledge of the concepts of how physical research is transferred to industrial applications and methods. • acquired some specific professional skills in management and legal aspects (protection of intellectual property rights, patent law).

	• the ability to use modern experimental equipment and methods in industry. After having completed this module, students are able to • use basic physical knowledge in industry. • utilise their experiences from industrial practice to assess industrial projects. • 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
Recommended prerequisites for participation	Knowledge of Solid-State physics, quantum mechanics, experimental and computational techniques at a bachelor's degree level
Frequency in which the module is provided	Mandatory courses (♦) every year; others at least every two years

Module S1	**Fundamentals of Space Physics and Aeronomy**
ECTS credits	9
Contents	♦ 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 successfully completing this 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. • explain the fundamentals of magnetohydrodynamics and electrodynamic waves in plasmas. After having completed this module, students have • knowledge of terrestrial planets, gas giants, moons, planetary ring systems, asteroids, and comets. • an understanding of the energy budget and dynamics of planets and tidal interactions. • a good grasp of the 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. • knowledge of the fundamentals of the motion of charged particles in electric and magnetic fields. • an understanding of 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.
Recommended prerequi-sites for participation	None
Frequency in which the module is provided	At least every two years

Module S2	**Solar and Heliospheric Physics**
ECTS credits	9
Contents	♦ <u>Introduction to Solar Physics</u>: 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. ♦ <u>Magnetohydrodynamics and Solar-Terrestrial Modelling</u>: Basic magnetohydrodynamics (MHD) equations; magnetic reconnection; interaction of the solar wind with planetary atmospheres; solar-terrestrial relations. ♦ <u>Exercises in Introduction to Solar Physics</u>: Training in the methods introduced in the associated lecture by solving problems related to Solar Physics. ♦ <u>Solar Physics Lab Tour</u>: Excursion tour to Kanzelhöhe Observatory and practical to obtain an insight into state-of-the-art methods of ground-based observations of the sun.
Learning outcomes	After successfully completing this 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. • give an overview of plasma physical phenomena and their applications in the solar system and astrophysical systems. After having completed this module, students have • an understanding of the solar interior structure and helioseismology. • well-founded knowledge of solar wind, flares, coronal mass ejections, and space weather. • the skills to understand basic magnetohydrodynamics. • an understanding of magnetic reconnection and interaction of the solar wind with planetary atmospheres. • a grasp of practical analysis methods for space plasmas (waves, shock waves, turbulence, reconnection). • knowledge of 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.
Recommended prerequi-sites for participation	None
Frequency in which the module is provided	At least every two years

Module S3	**Physics of Planetary Atmospheres and Magnetospheres**
ECTS credits	9

Contents	♦ 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; 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; palaeomagnetism; 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 successfully completing this module, students are able to • understand the fundamental physics principles of planetary atmospheres. • work with the concept of magnetic fields and their origin. • comprehend the basic plasma physics involved in particle and field interactions. After successfully completing this module, students have • an insight into complex interconnected areas of aeronomy and habitability. • competence in space science through magnetic fields. • profound knowledge of solar system plasma physics.
Teaching and learning activities and methods	Lectures
Recommended prerequisites for participation	Knowledge of astrophysics, astronomy, geophysics (earth's interior structure), chemistry, electromagnetism, hydrodynamics, plasma physics, electromagnetic and plasma waves at a bachelor's degree level
Frequency in which the module is provided	At least every two years

Module S4	**Measurement Methods and Observing Systems**
ECTS credits	9
Contents	♦ 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 successfully completing this module, students are able to • understand the fundamental physics principles of remote and in situ measurement methods. • work within the concept of space mission development, experiment performance, observation, and data acquisition. • make use of their basic skills regarding data quality, significance and error analysis. After successfully completing this module, students have • 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. • profound knowledge of measurement methods and techniques.
Teaching and learning activities and methods	Lectures, seminar
Recommended prerequisites for participation	Knowledge of astrophysics, astronomy, physics, geophysics, electromagnetism, hydrodynamics, electronics, plasma physics and waves theory at a bachelor's degree level
Frequency in which the module is provided	At least every two years

Module T1	**Advanced Theoretical Physics 1**
ECTS credits	9
Contents	♦ 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). ♦ Quantum Field Theory: Klein-Gordon, Dirac and Maxwell fields; canonical formalism, functional integrals, Feynman rules, renormalisation, leading order QED processes.
Learning outcomes	After successfully completing this 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. • perform successful standard-type calculations in quantum field theory. After having completed this module, students have • profound knowledge of group theory, complex analysis and the basics of quantum field theory.
Teaching and learning activities and methods	Lectures, exercise-based courses
Recommended prerequisites for participation	Theory courses at a bachelor's degree level and from the General Physics module

Frequency in which the module is provided	Every year

Module T2	**Advanced Theoretical Physics 2**
ECTS credits	9
Contents	♦ 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 successfully completing this module, students are able to • understand properties of physical systems from the thermodynamic limit in statistical physics. • apply further advanced methods in quantum theory. • perform successful standard-type calculations in these fields. After having completed this module, students have • 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. • basic knowledge of the underlying principles of Solid-State theory.
Teaching and learning activities and methods	Lectures
Recommended prerequisites for participation	Theory courses at a bachelor's degree level and from the General Physics module
Frequency in which the module is provided	Every year

Module T3	**Computational Physics**
ECTS credits	9
Contents	♦ 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 Nano 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. Quantum Computing: Qubit, Density matrix, quantum gates, quantum entanglement, teleportation and algorithms, Schor algorithm and RSA, Error

	correction, Quantum Cryptography, Simulation methods, Hardware implementations.
Learning outcomes	After successfully completing this 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. • 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 programmes. In a further lecture, either numerical methods specific to problems of Solid-State theory or particle physics are discussed.
Recommended prerequisites for participation	None
Frequency in which the module is provided	Every year

Module T4	**Theoretical Solid-State Physics**
ECTS credits	9
Contents	♦ Quantum Theory of Many-Body Systems: Correlation functions and linear response, Fermionic and Bosonic single-particle Green's functions, Perturbation theory and Feynman diagrams, Simple approximations: Hartree-Fock, Random Phase Approximation, Screening. 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 micro-magnetism; 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.
Learning outcomes	After successfully completing this module, students have a clear overview of the fundamental methods and open problems of modern theoretical Solid-State physics. They 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
Recommended prerequisites for participation	Knowledge of Solid-State physics, quantum mechanics and statistical physics at a master's degree level

Frequency in which the module is provided	Mandatory courses (♦) every year; others at least every two years

Module T5	**Theoretical Nano Physics**
ECTS credits	9
Contents	<u>Theoretical Nano- and Quantum Optics</u>: Quantisation of the electromagnetic field; basic concepts of quantum optics; Green's function; optical near fields; surface plasmons. <u>Quantum Computing</u>**:** Qubit, Density matrix, quantum gates, quantum entanglement, teleportation and algorithms, Schor algorithm and RSA, Error correction, Quantum Cryptography, Simulation methods, Hardware implementations. <u>Fundamentals of Electronic Structure Theory</u>: 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. <u>Computational Methods in Nano Physics</u>: 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 successfully completing this 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. • classify various quantum states of modern Solid-State physics.
Teaching and learning activities and methods	Lectures
Recommended prerequisites for participation	Knowledge of Solid-State physics, quantum mechanics and statistical physics at a master's degree level
Frequency in which the module is provided	Mandatory courses (♦) every year; others at least every two years

Module T6	**Modelling of Materials**
ECTS credits	9
Contents	Students are introduced to modern simulation techniques for electronic and nuclear motion in atoms, molecules and bulk structures. They are trained to solve topical problems inspired by current research and industrial needs. ♦ <u>Fundamentals of Electronic Structure Theory</u>: 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. ♦ <u>Simulating Materials Properties from First Principles</u>: Tutorial and scientific exercise; molecular properties, excitations, vibrations, visualisation, band-structure calculations, ab initio MD, interaction-driven Mott transition. <u>Advanced Electronic Structure Theory</u>**:** Advanced Electronic Structure Theory: Ab-initio electronic structure methods beyond ground state density functional theory; density functional perturbation theory for the calculation of phonon spectra; time-dependent density functional theory; quasi-particles within many-body perturbation theory.

	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 provides students with a solid methodical and computational background as well as practical knowledge regarding programme packages and libraries at the forefront of current research. After successful completion, students 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 courses
Recommended prerequisites for participation	Knowledge of quantum mechanics, electrodynamics, advanced quantum mechanics
Frequency in which the module is provided	Every year

Module T7	**Foundations of Particle Physics**
ECTS credits	9
Contents	♦ Quantum Field Theory 2: Gauge Theories: Classical non-Abelian gauge theories, instantons and topological field configurations; perturbative quantisation; BRST and anti-field formalism; Slavnov-Taylor identities; perturbative calculation at loop level and renormalisation; matter in gauge theories; global and local anomalies; quantization beyond perturbation theory; composite states; symmetries and symmetry breaking. Lattice Field theory: Regularisation of non-gauge and gauge theories on the lattice; scale setting and continuum limits; fermions and chiral symmetry; Markov chain and Monte Carlo; numerical algorithms (Metropolis, heatbath, fermion algorithms); transfer matrix; lattice perturbation theory; finite temperature and density; spectroscopy of bound states and resonances. Computational Methods in Particle: Numerical approaches to integrals; functional equations;(differntio-)integral equations; renormalisation; manipulation of large matrices; Monte Carlo methods; efficient numerical algorithms for linear algebra; machine learning. Special Topics in: Particle Physics Selected topics of current or emerging interest, which are not covered in other parts of T7 or T8. Advanced Mathematical Methods 2: Topology; differential geometry; category theory; operator algebras; integral equations.
Learning outcomes	After successfully completing this module, students are able to • understand the fundamental properties of gauge theories. • use their skills and understanding of tools required to do research in particle physics in the context of a master's thesis.
Teaching and learning activities and methods	Lectures, exercises, project

Recommended pre-requisites for partici-pation	Theory courses at a bachelor's degree level, from the General Physics mod-ule and module T1
Frequency in which the module is pro-vided	Lecture Quantum Field Theory II and project every year; other lectures and exercises every two years

Module T8	**Phenomenology of Particle Physics**
ECTS credits	9
Contents	♦ Standard Model: QCD; hadrons; chiral symmetry breaking; PDFs and frag-mentation; QED; electroweak physics and the Brout-Englert-Higgs effect; CKM and PMNS matrices and oscillation; precision tests; flavour physics; QCD and - electroweak phase diagram Beyond the Standard Model: Limits of the standard model; supersymmetry; composite Higgs; multi-Higgs models; grand-unified theories; supergravity; string theory; axions; other extensions of the SM; simplified models. Advanced General Relativity and Quantum Gravity: General relativity as a gauge theory; torsion; initial-value problem; black holes; cosmology; gravita-tional waves; foliation and Hamiltonian formulation; canonical quantum grav-ity; asymptotic Safety; dynamical triangulation; loop quantum gravity; string theory; other quantum and non-quantum theories of gravity. Astroparticle Physics: Astrophysical observations; cosmology and inflation; baryo-, lepto-, and nucleogenesis; dark matter indications and dark matter models; relic density and thermal history of the universe; dark energy; cosmic ray propagation and interactions; neutrinos in the cosmos; compact stellar objects. Experimental Particle Physics: Accelerators and enabling technologies; colli-sions and their interplay in understanding the shortest length scales; interac-tion of particles - with matter; detector technologies: gaseous detectors, sili-con detectors, calorimetry, particle ID, event reconstruction; trigger; principles of data analyses, and their statistical description. Collider Phenomenology: Fixed-order calculation of amplitudes and cross sections; PDFs and fragmentation functions; (QCD) coherence; jet cross sec-tions; event shapes and resummation; Monte Carlo event generators and phenomenological models; specific collider reactions with leptons, hadrons and heavy ions. Project in: Particle Physics: Small analytical or numerical projects motivated by current research; can be done in connection with a master's thesis.
Learning outcomes	After successfully completing this module, students are able to • understand several contemporary areas of particle physics. • use particle physics in general and in connection to neighbouring fields. • do research in particle physics in the context of a master thesis based on their knowledge of phenomenology.
Teaching and learning activities and meth-ods	Lectures, project
Recommended pre-requisites for partici-pation	Theory courses at a bachelor's degree level, from the General Physics mod-ule and module T1
Frequency in which the module is pro-vided	Lecture Hadron Physics and project every year; other lectures and exercises every two years

Appendix II Recommended Curriculum Timeline

1st semester	SSt.	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	
Specialization Modules	8		12	X	X
Free Electives	2		3	X	X
1st semester total	18		30		
2nd semester					
Specialization Modules	14		21	X	X
Elective Topics	4		6	X	X
Free Electives	2		3	X	X
2nd semester total	20		30		
3rd semester					
Specialization 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	
Elective Topics	2		3	X	X
3rd semester total	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		
4th semester total	2		33		
Total overall ECTS			120		

[1]: Assignment of the course to the participating universities. Both universities are named if the course is offered at both universities in combination, in parallel or alternately.

Appendix III Recommended Courses for the Free Electives

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

For students to broaden their knowledge in subjects relevant to the modules of this degree programme, courses in the fields of foreign languages, social competence, technological impacts assessment and women's and gender studies (especially the lecture “A doctoral programme at the Faculty of Mathematics, Physics and Geodesy – Information event for female master's students”) 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 at Treffpunkt Sprachen of the Uni Graz, the Centre for Social Competence of Uni Graz as well as the Inter-University Research Centre for Technology, Work and Culture (IFZ). The interdisciplinary master's degree modules “Master's Degree Plus” offered by the University of Graz are recommended in addition to the above.

Furthermore, to ensure that students are highly qualified for future management and leadership positions, the transfer initiative for management and entrepreneurship fundamentals, awareness, training and employability ("TIMEGATE") offered by the University of Graz is also recommended.

Other recommended courses for Free Electives:							
Course		Course		Semester		Uni Graz[1]	TU Graz[1]
	SSt.	**Type**	**ECTS**	**WS**	**SS**		
Praxiseinblick: Human Ressource Management[1]	1	KS	1	X	X	X	

[1]: This course is held in German.

Appendix IV Equivalence List

Courses whose equivalence or recognition is defined in this appendix to the curriculum no longer require individual recognition by the dean of studies. However, an individual recognition of a course is possible in accordance with § 78 Universities Act 2002 (UG). An equivalence list defines the equivalence of positively completed courses from this present curriculum and the previous curriculum. This equivalence is valid in both directions, i.e. positively completed courses of the previous curriculum are recognized under the current curriculum and positively completed courses of the current curriculum are recognized under the previous curriculum.
Courses that have the same title and are of the same type and have the same number of ECTS credits or the same number of semester hours, are equivalent per se and are not listed in the equivalence list.

Course from the expiring curriculum 2017 (2017W)				Courses from the current curriculum 2023 (2023W)			
Course	**Course Type**	**SSt.**	**ECTS**	**Course**	**Course Type**	**SSt.**	**ECTS**
Compulsory Module M							
Master's Seminar in Astrophysics	SE	2	2	Master's Seminar in Astro- and Space Physics	SE	2	2
Practical Training in Space Physics and Aeronomy	PT	3	6	Practical Training in Space Physics and Aeronomy	PT	3	7
Master's Seminar in Space Physics and Aeronomy	SE	2	3	Master's Seminar in Astro- and Space Physics	SE	2	2
Specialization Astrophysics							
Solar Physics Lab	PT	1	1	Solar Physics Lab Tour	EX	1	1
Astrophysics Lab	PT	2	3	Astrophysics Lab	LU	2	3
Astrophysics Lab 2	PT	2	3	Astrophysics Lab 2	LU	2	3
Specialization Experimental Physics							
Experimental Methods in Surface Science	VU	2	3	Research Laboratory Surface Science	LU	2	3
Research Laboratory Spectroscopy	LU	2	3	Research Laboratory Photon Science	LU	2	3
Spectroscopy	VO	2	3	Laser Spectroscopy	VO	2	3
Advanced Optics	VO	2	3	Optics – A Photonics Perspective	VO	2	3
Fundamental Optics	VO	2	3	Optics – A Spectroscopy Perspective	VO	2	3
Biomagnetism	VO	2	3	Theoretical Biophysics	VO	2	3
Specialization Atmospheric Physics and Climate							

Course from the expiring curriculum 2017 (2017W)				Courses from the current curriculum 2023 (2023W)			
Course	**Course Type**	**SSt.**	**ECTS**	**Course**	**Course Type**	**SSt.**	**ECTS**
Methods of Modeling and Simulation *and* Methods of Modeling and Simulation	VO *and* UE	2 *and* 2	3 *and* 3	Methods of Modeling and Simulation	VU	4	6
Atmospheric Measurement Methods: Remote Sensing	VO	2	3	Atmosphere and Climate Measurement Methods: Remote Sensing	VO	2	3
Atmospheric Measurement Methods: in situ	VO	2	3	Atmosphere and Climate Measurement Methods: in situ	VO	2	3
Seminar on Measurement Methods in Atmospheric Physics	SE	2	3	Seminar on Atmosphere and Climate Measurement Methods	SE	2	3
Specialization Space Physics and Aeronomy							
Solar Physics Lab	PT	1	1	Solar Physics Lab Tour	EX	1	1
Specialization Theoretical and Computational Physics							
Green's Function for Solid-State Physics	VU	2	3	Quantum Theory of Many-Body Systems	VU	2	3
Computational Methods in Solid-State Physics	VU	2	3	Computational Methods in Nano Physics	VU	2	3
Theoretical Nano- and Quantum Physics	VO	2	3	Theoretical Nano- and Quantum Optics	VO	2	3
Advanced Ab-Initio Techniques	VO	2	3	Advanced Electronic Structure Theory	VO	2	3
Special Topics in: Foundations of Particle Physics	VO	2	3	Special Topics in: Particle Physics	VO	2	3
Physics Beyond the Standard Model	VO	2	3	Beyond the Standard Model	VO	3	4.5

Courses from the previous curriculum version that have already been completed but are not included in any of the modules or in the equivalence list of the new curriculum can still be recognized for the module in which they originally appeared.

Any students who have already completed the course “Synchrotron Radiation Techniques” can still have this course recognized for Module E3. Any students who have already completed the course “Computational Methods in Solid-State Physics” can still have this course recognized either for Module T4 or as the course “Computational Methods in Nanophysics” in Module T5.

Appendix V Glossary

Glossary of the terms used that differently in the statutes and guidelines of the two universities:

Term used in this curriculum (NAWI GRAZ)	**Uni Graz terminology**	**TU Graz terminology**
SSt.	KStd.	SSt.
Elective Topics		Wahlfach
Free Electives	Freie Wahlfächer	Freie wählbare Lehrveranstaltung