Curriculum for the master's degree programme in

Technical Physics

Curriculum 2017

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

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

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

Table of contents:

I General provisions

§ 1. Object of degree programme and qualification profile

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

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

Graduates of this programme are awarded the university degree of "Diplom-Ingenieurin"/"Diplom-Ingenieur", abbreviated: "Dipl.-Ing." or "DI". The international equivalent of this university degree is "Master of Science", abbreviated: "MSc".

(1) Object of degree programme

The English-language master's degree programme in Technical Physics offered jointly by TU Graz and Uni Graz provides students with a postgraduate degree in the subject area of physics as part of further education in natural sciences and technology.

Physics shapes our modern world view decisively and forms the basis for other sciences and for technology. The degree programme in Technical Physics is therefore dedicated to researching fundamental relationships, finding answers to essential questions in the world of physics and applying methods of physics to technical problems. The key objectives of this education include training logical thinking and learning problem-solving methods. It is typical for the degree programme in Technical Physics that practice-oriented, technology-related subjects and application-oriented computer methods are offered, in addition to a sound education in physics and mathematics. The teaching of business and social competencies rounds off the degree programme in terms of content and provides students with key qualifications that are crucial in professional life.

For successful work in professional practice, the use of spoken and written English as the lingua franca in science, technology and business is of fundamental importance. For this reason, the degree programme is held completely in English.

(2) Qualification profile and competencies

Knowledge and understanding

After completing the master's degree programme in Technical Physics, graduates have become familiar with and learnt to apply complex scientific methods. They are able to define and interpret characteristics, limits, terminologies and schools of thought of their subject area.

Graduates have deepened their subject-specific knowledge in the areas of

- Statistical and Computational Physics;
- Advanced Quantum Mechanics and Atom Physics, and
- Advanced Solid State Physics and Radiation Physics

and have dealt with the basics of Business and Entrepreneurship.

Optionally, they have acquired and applied specialist knowledge in several of the following 13 topics:

- Applied Materials Physics, Semiconductor Devices, Surface Science;
- Computational Condensed Matter Physics, Modelling of Materials, Theoretical Solid State Physics, Quantum Many-Body Physics;
- Nanoscience, Nano and Laser Optics, Quantum Optics and Molecular Physics, and
- Radiation and Plasma Physics, Laboratory Technology and Instrumentation, Microscopy and Nanoanalysis.

Knowledge-based application and assessment

The master's degree programme in Technical Physics enables graduates to

- specialise in a field of Technical Physics in such a way that they can find connections to current international research;
- work independently on the tasks in natural sciences and engineering sciences that they are set;
- apply modern scientific methods and analyse complex processes with current methods of computer simulation;
- also work professionally in a field far removed from the specialist field in which they deepened their knowledge in the master's degree programme and apply their basic knowledge of physics, together with the scientific methods and problem-solving strategies learnt, including in new and unfamiliar situations, and
- work on problems, including in other branches of science (e.g. mathematics, chemistry, medicine and environmental systems sciences).

Communicative, organisational and social competencies

Graduates are equipped with basic skills that enable them to further develop critical and analytical approaches, acquire new knowledge independently, and work on research-oriented and application-oriented tasks in a targeted manner on the basis of their specialist competence.

They possess the necessary perseverance to handle difficulties in projects and to nevertheless achieve their goal, possibly with a modified strategy.

In addition, they are able to document their results and solution strategies comprehensively in the context of current international research and to portray them using modern communication and presentation techniques.

Through the interdisciplinary education, graduates acquire the ability to cooperate and communicate in project teams across the disciplines.

They are aware of their responsibility regarding science and the possible consequences of their actions on the environment and society.

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

Physicists have excellent specialist qualifications and the valuable core competency often described as a physicist's mindset, which results from a combination of sound knowledge of natural sciences, familiarity with practical methods (experimental, theoretical and computer-oriented), a strong capacity for analytical thought and well-developed problem-solving abilities. They are therefore considered to be universal problem-solvers, particularly in innovative sectors, are distinguished by a high level of flexibility professionally and between industries, and can work as exceptionally qualified experts in a wide variety of fields, from industry to business and science.

Physicists work in the following sectors, in particular:

- universities and colleges as well as other educational and research institutions;
- data processing;
- electronics and electrical engineering;
- precision mechanics and optics;
- mechanical engineering and vehicle construction;
- the healthcare sector and public services, and
- the services sector and other services for companies.

The master's degree programme also provides the prerequisites for independent scientific work as part of a doctoral programme.

II General requirements

§ 2. Admission requirements:

(1) Admission to a master's degree programme requires a subject-related bachelor's degree of a university or university of applied sciences or another equivalent degree of a recognised Austrian or foreign post-secondary educational institution (§ 64 para. 5 UG).

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

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

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

§ 3. Allocation of ECTS credit points

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

§ 4. Organisation of the degree programme

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

	ECTS
Compulsory module A: Statistical and Computational Physics	10
Compulsory module B: Advanced Quantum Mechanics and Atom Physics	10
Compulsory module C: Advanced Solid State Physics and Radiation Physics	10
Compulsory module D: Business and Entrepreneurship	4.5
3 physics specialisation modules (each 9 ECTS credit points)	27
General elective module	15.5
Free-choice subject	10
Master's seminar	2
Master's thesis	30
Master's examination	1
Total	120

§ 5. Types of courses

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

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

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

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

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

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

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

§ 6. Group sizes

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

(1) The maximum group size for exercise-based courses (UE) and exercise components of lectures with integrated exercises (VU) is 25 students. For integrated laboratory courses of VU-type courses, the maximum group size is 6 students.

(2) The maximum group size for laboratory courses (LU) is 6 students.

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

§ 7. Guidelines for the allocation of places on courses

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

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

a. Students are required to complete the course according to their curriculum.

b. The sum of the successfully completed courses of the respective study programme (total ECTS credit points).

c. The date (early date has priority) of the fulfilment of the participation requirement.

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

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

III Course content and curriculum

§ 8. Modules, courses and semester allocation

The individual courses of this master's degree programme and their grouping into compulsory and elective modules are indicated hereinafter. The knowledge, methods or skills to be provided in the modules are described in more detail in Annex I. The semester allocation is a recommendation and ensures that the sequence of courses builds optimally on previous knowledge and that the workload of an academic year does not exceed 60 ECTS credit points. Annex II and § 9 below contain the allocation of the courses to the participating universities.

Master's degree programme in Technical Physics								
Module	**Course**	**SSt**	**LV type**	**ECTS**	**Semester incl. ECTS I**	**II**	**III**	**IV**
Compulsory module A: Statistical and Computational Physics								
	Statistical Physics [1]	2	VO	4	4			
	Statistical Physics [1]	1	UE	2	2			
	Computer Simulations	3	VU [2]	4		4		
Subtotal for compulsory module A		**6**		**10**	**6**	**4**	**0**	**0**
Compulsory module B: Advanced Quantum Mechanics and Atom Physics								
	Advanced Quantum Mechanics [1]	2	VO	4	4			
	Advanced Quantum Mechanics [1]	1	UE	2	2			
	Advanced Atomic and Molecular Physics	2	VO	4		4		
Subtotal for compulsory module B		**5**		**10**	**6**	**4**	**0**	**0**
Compulsory module C: Advanced Solid State Physics and Radiation Physics								
	Advanced Solid State Physics	2	VO	4	4			
	Advanced Solid State Physics	1	UE	2	2			
	Radiation Physics	2	VO	4		4		
Subtotal for compulsory module C		**5**		**10**	**6**	**4**	**0**	**0**

Compulsory module D: Business and Entrepreneurship								
Either D.1 or D.2 together with D.3 must be completed.								
D.1	Encyclopedia Business Economics	3	VO	4.5		4.5		
D.2	Enabling Innovation	1	VO	1.5		1.5		
D.3	Enabling Innovation	2	UE	3		3		
Subtotal for compulsory module D				**4.5**		**4.5**		
Total for the compulsory modules				**34.5**	**18**	**16.5**	**0**	**0**
3 physics specialisation modules (each 9 ECTS, according to § 9a below)				27				0
General elective module according to § 9b below				15.5				0
Total for the elective modules according to § 9 below				**42.5**	**9**	**9**	**24.5**	**0**
Master's seminar [3, 4]				**2**				2
Master's thesis				**30**				30
Master's examination				**1**				1
Free-choice subject according to § 10 below				**10**	**3**	**4.5**	**2.5**	0
Overall total				**120**	**30**	**30**	**27**	**33**

[1]: Held jointly with the master's degree programme in Physics

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

[3]: This course is assessed as "successful participation" or "unsuccessful participation".

[4]: Students who complete the master's seminar at TU Graz must complete one of the following institute seminars: Seminar on Experimental Physics, Seminar on Theoretical Physics and Computational Physics, Seminar on Solid State Physics, Seminar on Materials Physics, or Seminar on Electron Microscopy and Nanoanalysis.

§ 9. Elective modules: catalogues of courses

A. Physics specialisation modules

Three physics specialisation modules must be completed. From each specialisation module chosen, exactly three courses must be completed. The courses marked (◆) in a chosen module must be completed. Courses of the type LU may only be completed as part of the chosen module[I, II] – the courses “Measurement Techniques and Probe Analysis” and “Computer Supported Measurement Techniques” (module G) are excluded therefrom, and may also be used in the general elective module.

Physics specialisation modules (alphabetical order)							
Module/course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Module E: **Applied Materials Physics**							
◆ Research Laboratory Applied Materials Physics	2	LU	3	X	X		X
Functional Materials	2	VO	3	X			X
Soft Matter Physics	2	VO	3		X		X
Structurally Complex Materials	2	VO	3	X			X
Structural Transformations and Diffusion in Materials	3	VU [2]	3		X		X
Module F: **Computational Condensed Matter Physics**							
◆ Research Laboratory Advanced Computational Physics	2	UE	3	X	X		X
Numerical Simulation of Strongly Correlated Many-Body Models	2	VU [3]	3	X			X
Quantum Dynamics	2	VU [2]	3	X			X
Ab-initio Methods for Correlated Materials	2	VO	3	X			X
Module G: **Laboratory Technology and Instrumentation**							
One of the two laboratory courses (LU) must be completed:							
◆ Measurement Techniques and Probe Analysis	2	LU	3	X	X		X
◆ Computer Supported Measurement Techniques	2	LU	3	X			X
Vacuum Technology	2	VO	3	X		X	X
X-ray and Neutron Scattering	2	VO	3		X		X
Light Engineering	2	VO	3	X			X
Temperature Measurements	2	VO	3	X			X
Ultrasound Methods	2	VO	3		X	X	
Signal Theory and Signal Processing	2	VU [2]	3		X	X	X

[I] This also applies for the laboratory course with the course type VU in the specialisation module Surface Science.

[II] If the associated specialisation module has not yet been chosen bindingly at the time of registration for the laboratory course, admission to the laboratory course shall only be carried out according to § 7 (2) f subject to the availability of free places as part of the free-choice subject.

Module H: **Microscopy and Nanoanalysis**								
◆	Electron Microscopy 1	2	VO	3	X			X
◆	Advanced 2D and 3D Nanoanalysis	2	VU [2]	3		X		X
	Electron Microscopy 2	2	VO	3		X		X
	X-ray and Neutron Scattering	2	VO	3		X		X
	Research Laboratory Microscopy and Nanoanalysis	2	LU	3	X	X		X
Module I: **Modelling of Materials** [4]								
◆	Fundamentals of Electronic Structure Theory	2	VO	3		X	X	X
◆	Simulating Materials Properties from First Principles	2	UE	3		X	X	X
	Applications of Electronic Structure Methods	2	VO	3		X		X
	Ab-initio Methods for Correlated Mate-rials	2	VO	3	X			X
	Advanced Ab-initio Techniques	2	VO	3	X		X	X
	Modelling of Molecular Systems	2	VO	3	X			X
Module J: **Nano and Laser Optics** [4]								
◆	Advanced Optics	2	VO	3	X		X	
◆	Research Laboratory Nano and La-seroptics	2	LU	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 K: **Nanoscience**								
◆	Nanostructures and Nanotechnology	2	VO	3		X		X
◆	Research Laboratory Nanoscience	2	LU	3	X	X		X
	Chemical Fundamentals of Nanosci-ence	2	VO	3	X			X
	Theory of Magnetism and Collective Phenomena	2	VO	3	X			X
	Quantum Transport Theory	2	VO	3		X	X	X
	Structuring of Material Surfaces and Functional Nanofabrication	2	VO	3				X
Module L: **Quantum Many-Body Physics**								
◆	Green's Functions in Many-Particle Physics	2	VU [2]	3		X		X
	Introduction to Correlated Many-Body Systems	2	VU [2]	3	X			X
	Many-Body Systems out of Equilib-rium	2	VU [2]	3	X			X
	Open Quantum Systems	2	VU [2]	3	X			X
	Strongly Correlated Systems in Ex-periment	2	VO	3		X	X	X
Module M: **Quantum Optics and Molecular Physics** [4]								
◆	Fundamental Optics	2	VO	3	X	X		X
◆	Research Laboratory Quantum Optics and Molecular Physics	2	LU	3	X	X	X	X
	Laser Physics	2	VO	3			X	

	Ultrafast Laser Physics	2	VO	3		X		X
	Quantum Optics	2	VO	3	X			X
	Modelling of Molecular Systems	2	VO	3	X			X
Module N: **Radiation and Plasma Physics**								
◆	Applied Radiation Physics	2	VO	3	X			X
◆	Research Laboratory Radiation and Plasma Physics	2	LU	3	X			X
	Plasma Physics	2	VO	3	X			X
	Fusion Physics	2	VO	3	X			X
	Kinetic Theory in Plasma Physics	2	VO	3		X		X
Module O: **Semiconductor Devices**								
◆	Physics of Semiconductor Devices	2	VO	3	X			X
◆	Research Laboratory Semiconductor Devices	2	LU	3	X	X		X
	Microelectronics and Micromechanics	2	VO	3		X		X
	Organic Semiconductors	2	VO	3		X		X
	Modelling and Simulation of Semicon-ductors	2	VO	3		X		X
Module P: **Surface Science**								
◆	Surface Science	2	VO	3	X		X	
◆	Experimental Methods in Surface Sci-ence	2	VU [5]	3		X	X	X
	Molecular Interfaces	2	VO	3		X	X	
	Scanning Probe Techniques	2	VO	3		X	X	
	Synchrotron Radiation Techniques	2	VO	3	X		X	
	Thin Film Science and Processing	2	VO	3		X		X
	Surface Chemistry	2	VO	3		X		X
	Vacuum Technology	2	VO	3	X		X	X
Module Q: **Theoretical Solid State Physics [4]**								
◆	Green's Functions for Solid State Physics	2	VU [2]	3		X	X	
	Fundamentals of Electronic Structure Theory	2	VO	3		X	X	X
	Theory of Magnetism and Collective Phenomena	2	VO	3	X			X
	Theory of Superconductivity	2	VO	3	X			X
	Phase Transitions and Critical Phe-nomena	2	VO	3	X			X
	Exotic States in Solids	2	VO	3	X		X	
	Quantum Transport Theory	2	VO	3		X	X	X
	Computational Methods in Solid State Physics	2	VU [2]	3	X		X	

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

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

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

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

[5]: 1/4 SSt/lecture component, 3/4 SSt/exercise component

Students who study for at least one semester at a university abroad are entitled to replace specialisation modules according to § 9 with physics-oriented modules that they complete there, provided that these examinations are recognised by the officer responsible for study matters. This does not affect the recognition of further examinations according to UG § 78 (1), insofar as they are equivalent to the examinations prescribed in the curriculum.

B. General elective module

As part of the general elective module, courses with a scope of 15.5 ECTS credit points must be completed.

The following courses may be chosen:

- Courses from the catalogue of the abovementioned specialisation modules that are not completed in the chosen specialisation module; the laboratory courses are excluded herefrom (see explanations under item A Specialisation modules)
- Compulsory and elective courses of the NAWI Graz master's degree programme in Physics, taking into consideration the relevant admission requirements
- Courses to deepen knowledge of a foreign language (English or German) with a scope of max. 3 ECTS credit points
- Courses from the following catalogue "General elective module"
- German-language courses from the following catalogue "Bachelor's specialisation Technical Physics" of the NAWI Graz bachelor's degree programme in Physics in consideration of § 2 (4)

Catalogue of courses: General elective module							
Course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Master's Project [2]	0.5	PT	6	X	X	X	X
Special Topics of Technical Physics: [subheading] [3]							X
Programming in Physics: Advanced MATLAB	4	VU [4]	4	X			X
MATHEMATICA for Theoretical Physics: Symbolic and Numerical Computation	4	VU [4]	4		X		X
Kinetic Equations for Classical and Quantum Mechanical Systems	2	VO	3	X			X
Quantum Information Theory	2	VO	3	X		X	X
Advanced Statistical Physics	2	VO	3	X		X	X
Functional Materials II	0.66	VO	1		X		X
Business and Entrepreneurship:							
Encyclopedia Business Economics	2	UE	2		X		X
Industrial Management and Innovation	2	VO	3	X			X
Product Innovation Project [5]	3	PT	5	X			
Product Innovation Project 2	2	PT	3		X		
Implementation Innovation Strategy Through Merger & Acquisition – Essential for Engineers	2	SE	3	X			X

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

[2] Project for preparation of the master's thesis, which may only be completed with the supervisor of the master's thesis

[3] Courses with the title "Special Topics of Technical Physics (subheading)" may be assigned to the general elective module, whereby one semester hour generally corresponds to 1.5 ECTS credit points. These courses have descriptive subtitles and are offered with a total scope of 1-3 SSt for lectures and/or 1-2 SSt for exercises. Courses with different subtitles shall be classified as different courses.

[4]: 1/3 SSt/lecture component, 2/3 SSt/exercise component

[5]: Upon application, this course is recognised for compulsory module D: "Business and Entrepreneurship".

Catalogue of courses: Bachelor's specialisation Technical Physics							
Course		LV		Semester allocation		Uni Graz[1]	TU Graz[1]
	SSt	type	ECTS	WS	SS		
Physikalische Grundlagen der Materialkunde [2]	3	VO	4.5		X		X
Kontinuums- und Fluidmechanik [2]	1.5	VU [3]	3		X		X

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

[2]: Held in German. Recommended for students who have not completed the specialisation Technical Physics in the NAWI bachelor's degree programme in Physics.

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

§ 10. Free-choice subject

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

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

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

§ 11. Master's thesis

(1) The master's thesis is proof of the student's capability to perform scientific research and development tasks independently and which are academically grounded as far as content and methodology are concerned. The scope of work of the master's thesis must enable students to finish their thesis within a period of six months.

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

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

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

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

§ 12. Registration requirements for courses/examinations

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

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

§ 13. Study periods abroad and internship

(1) Recommended studies abroad

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

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

(2) Internship

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

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

IV Examination regulations and degree certificate

§ 14. Examination regulations

Courses are evaluated individually.

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

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

(3) Examinations with positive results are to be assessed as "very good" (1), "good" (2), "satisfactory" (3) or "sufficient" (4); those with negative results are to be assessed as "insufficient" (5). The master's seminar is assessed as "successful participation" or "unsuccessful participation".

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

a. multiplying the grade of each examination result in connection with the module with the ECTS credit points of the corresponding course;

b. adding the values calculated according to lit. a.;

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

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

- the presentation of the master's thesis (maximum duration: 20 minutes);
- the defence of the master's thesis (oral examination), and
- an oral examination on topics from an experiment-oriented module and a theory-oriented module according to § 8 above, whereby the master's thesis is assigned to one of the two modules.

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

(6) The master's examination senate consists of the supervisor of the master's thesis and two further members nominated by the officer responsible for study matters after the hearing of the candidates. The senate is chaired by a member of the examination senate who is not the supervisor of the master's thesis. The chairperson and the other member may not belong to the Institute of Physics (TU Graz) or the subject area of the Institute of Physics (Uni Graz) at which the master's thesis was completed.

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

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

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

§ 15. Degree certificate

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

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

a. a list of all modules (examination subjects) according to § 4 above (including the ECTS credit points, without module code letters) and their assessments;
b. the title and the assessment of the master's thesis;
c. the assessment of the final examination before a committee;
d. the entirety of the ECTS credit points for the free-choice subject according to § 10 above, and
e. the overall assessment of the degree programme.

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

V Legal validity and transitional provisions

§ 16. Legal validity

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

§ 17. Transitional provisions

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

Students who have completed the TU Graz bachelor's degree programme in Technical Physics according to the curriculum 2009 or an older curriculum and who begin the NAWI master's degree programme in Technical Physics according to this curriculum

2017 or opt for this curriculum must complete the courses Electrodynamics, VO (2 SSt, 4 ECTS credit points) and Electrodynamics, UE (1 SSt, 2 ECTS credit points) instead of the courses Statistical Physics, VO (2 SSt, 4 ECTS credit points) and Statistical Physics, UE (1 SSt, 2 ECTS credit points).

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

Annex I

Module descriptions

Compulsory module	**Statistical and Computational Physics**
ECTS credit points	10
Subject content	Statistical Physics: Introduction; probability; classical statistical physics (microcanonical, canonical and grand canonical ensembles, ideal gas, etc.); quantum statistics (density operator, ensembles, Bose-Einstein and Fermi-Dirac statistics, ideal Bose gas, black-body radiation, etc.) Exercises Statistical Physics: Addressing and working out explicit examples of the topics discussed in class Computational Simulations: Introduction to modern techniques of computer simulations e.g. Markov chain Monte Carlo, optimisations, molecular dynamics, finite element methods
Learning outcomes	After having participated successfully in the module, students are able to ● understand the basic principles of statistical physics and computational physics; ● apply advanced methods in quantum theory, and ● perform successful standard-type calculations in these fields. After having completed the module, students have gained ● profound knowledge of classical statistical physics and some aspects of quantum statistics, and ● they are familiar with some of the most important methods of computer simulations and their range of applicability.
Teaching and learning activities and methods: Lectures, exercise courses with problem sets	
Previous knowledge expected	Theory courses at bachelor's level and programming knowledge
Frequency of offer: Every year	

Compulsory module	**Advanced Quantum Mechanics and Atom Physics**
ECTS credit points	10
Subject content	Advanced Quantum Mechanics ● Extension beyond the hydrogen atoms: covalent bond and LCAO, Born-Oppenheimer approximation, van der Waals interaction ● Advanced aspects of angular momentum theory: ○ addition of angular momentum ○ the Wigner-Eckart theorem and selection rules ● Identical particles ● Particle in a classical electromagnetic field, gauge invariance, Landau levels ● Second quantisation (fermions, bosons, electromagnetic field) ● Matter/radiation interaction: transition rates, etc. ● Scattering theory in one and three dimensions (introductory) ● Path integral Exercises Advanced Quantum Mechanics Addressing and working out explicit examples of the topics discussed in class Advanced Atomic and Molecular Physics Interference, laser and high-frequency spectroscopy: principles and experimental setup. Basics of theoretical molecular physics: molecular formation, molecular binding, interaction with light, molecular symmetry. Rotational, vibrational, and electronic excitations in polyatomic systems. Theoretical molecular spectroscopy. Short introduction to selected topics of quantum chemistry and cluster physics
Learning outcomes	After having participated successfully in the module, students are able to ● understand the principles of advanced quantum mechanics, including the composition of angular momenta, identical particles, matter/radiation interaction and scattering theory; ● address and solve problems in these fields, and ● link abstract knowledge to concrete problems in atomic and molecular physics. After having completed the module, students have gained ● an understanding of advanced aspects of quantum mechanics: angular momentum, identical particles and second quantisation, matter/radiation interaction and scattering theory; ● knowledge of classical as well as modern spectroscopic setups and their application to measurements of rotational, vibrational or electronic transitions, and ● deeper insights into abstract concepts of quantum mechanics through concrete applications in atomic and molecular physics.
Teaching and learning activities and methods: Lectures, exercise classes	
Previous knowledge expected	Quantum mechanics and electrodynamics at bachelor's level
Frequency of offer:	Every year

Compulsory module	Advanced Solid State Physics and Radiation Physics
ECTS credit points	10
Subject content	Advanced Solid State Physics: The calculation and interpretation of photon, phonon and electron dispersion relations and densities of states, photoemission; determination of the equilibrium thermodynamic properties from the densities of states; electrons in a magnetic field: the quantum Hall effect, the Shubnikov-de Haas effect and the de Haas-van Alphen effect; phase transitions: structural, magnetism, ferroelectricity, piezoelectricity, superconductivity, Peierls transition, Landau theory; optical properties of materials: linear response theory, Kramers-Kronig relations, optical absorption, ellipsometry; electrical and thermal transport: Boltzmann equation; crystal symmetries; quasiparticles: plasmons, polarons, polaritons, excitons, magnons, Raman spectroscopy, EELS; electron-electron interactions: Fermi liquid theory, screening, Mott transition, single-electron effects, Hubbard model Exercises Advanced Solid State Physics: Students are asked to design and complete a project that will help other students to pass the course. Radiation Physics: Basic experimental and theoretical concepts of nuclear physics (scattering of particles by nuclei, nuclear models, nuclear fission); types of ionising radiation (photons, charged and neutral particles), their detection and measurement and their specific interaction with matter; natural radiation sources; effects of ionising radiation on biological systems, dosimetry; concepts of radiation protection and its legal aspects; application of ionising radiation in medicine for diagnosis and therapy; application of nuclear methods in materials science
Learning outcomes	After having participated successfully in the module, students are able to ● calculate any property of any crystal starting from the microscopic arrangement of the atoms, and ● understand the principles of radiation physics, incl. radiation detection and dosimetry, radiation protection and application of ionising radiation. After having completed the module, students have gained ● a fundamental understanding of crystalline solids, and ● basic knowledge of radiation physics and its application.
Teaching and learning activities and methods: Lectures, laboratory course, independent project	
Previous knowledge expected	Knowledge of solid state physics, thermodynamics, electrodynamics, quantum mechanics and experimental physics at bachelor's level
Frequency of offer:	Every year

Compulsory module	**Business and Entrepreneurship**
ECTS credit points	4.5
Subject content	The compulsory module Business and Entrepreneurship is an essential element of the master's programme in Technical Physics, providing students with basic business knowledge that is important for their professional career. Students must take one of the lecture courses Encyclopaedia Business Economics or Enabling Innovation. In the course Encyclopaedia Business Economics, students are introduced to business economics, including topics such as financial accounting, marketing, purchasing, human resource management, capital investment and financial management. Moreover, the enterprise is illustrated as a process-orientated value chain. The course Enabling Innovation provides students with basic knowledge of industrial innovation. The following topics are covered: Basics of Innovation, Models of Innovation Management, Idea Generation, Idea Acceptance, Idea Implementation, Innovation Marketing, Intellectual Property Rights (IPR), Entrepreneurship. There is the option of taking further courses related to this module within the General Elective Module.
Learning outcomes	After successful completion of the course Encyclopaedia Business Economics, students have a basic understanding of the principles of business economics. Furthermore, students are able to apply the discussed tools as efficient controlling instruments in enterprises. After successful completion of the course Enabling Innovation, the students have acquired a general understanding of product innovation management and the innovation process. The students know the basic tasks of product innovation management. They are familiar with methods related to the innovation process and are able to choose and apply the learned methods in different situations.
Teaching and learning activities and methods: Lectures, exercises, seminars	
Previous knowledge expected	None
Frequency of offer:	Every year

Specialisation module	**Applied Materials Physics**
ECTS credit points	9
Subject content	◆ Research Laboratory Applied Materials Physics: Characterisation and analysis of basic structural and functional materials with a focus on current developments in the field of applied materials physics Functional Materials: Physics and applications of electroceramics, energy materials (batteries, fuel cells, hydrogen storage) and superconductors Soft Matter Physics: Introduction to colloids, gels, liquid crystals, polymers and some biological systems regarding structural, mechanical and optical properties; hierarchical structures and self-assembly processes Structurally Complex Materials: Specific, structure-related physical properties of e.g. intermetallic compounds, quasicrystals, amorphous and nanocrystalline materials Structural Transformations and Diffusion in Materials: Fundamentals of diffusion in e.g. metals, semiconductors, ceramics and ionic conductors in relation to technologically relevant processes
Learning outcomes	After having participated successfully in the module, students are able to ● understand the foundations of the different materials classes such as metals, ceramics, polymers and composites; ● assess the relation between the atomic structure, microstructure, kinetic processes and the resulting properties of functional and structural materials, and ● use modern experimental equipment and methods for the characterisation of materials and the analysis of materials processes. After having completed the module, students have gained ● profound knowledge of different classes of materials and their application as functional and structural materials, and ● an insight into the application potentials of materials.
Teaching and learning activities and methods: Lectures, laboratory course	
Previous knowledge expected	Experimental physics, solid state physics
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	Computational Condensed Matter Physics
ECTS credit points	9
Subject content	Numerical simulations play a major role in the theoretical treatment of condensed matter problems as well as in quantum chemistry. The module provides an overview of most of the common numerical algorithms and how they are applied to realistic problems. Guided by several examples, results for static and dynamical observables in and out of equilibrium are discussed. The course focuses on the challenging problems encountered in novel materials with an emphasis on correlation effects, which are the driving force for many interesting physical properties such as collective magnetism, Mott insulators, the Kondo effect, giant magnetoresistance, and many more. ◆ Research Laboratory Advanced Computational Physics: Addressing and working out explicit examples of the topics discussed in the lectures described below Numerical Simulations of Strongly Correlated Many-body Models: The lecture provides an introduction to the models used to describe correlation effects in novel materials and to the numerical approaches to handling the corresponding challenging numerical tasks. The focus in the lecture is on equilibrium properties of models such as the Hubbard, Holstein, Anderson impurity, Kondo and Heisenberg models used to study electronic, phononic and spin degrees of freedom and their mutual interactions. Quantum Dynamics: Introduction to the time evolution of highly entangled many-body quantum systems. Discussion of quantum phenomena and applications. Integrability and analytical approaches, mostly in one space dimension. Highly efficient representations, numerical techniques. Programming and investigation of examples Ab Initio Methods for Correlated Materials: Introduction to correlations and correlated materials; localised basis sets (Wannier functions); Hubbard model and calculation of interaction parameters; (non-)Fermi liquids; the dynamical mean field theory and the Mott-Hubbard transition
Learning outcomes	After having participated successfully in the module, students have acquired profound knowledge of how to model the key features of realistic materials. They have obtained an overview of the various numerical simulation techniques and they have learned how to develop large-scale computer codes. Based on the content of the courses in the module, students are able to join international research groups immediately and to collaborate at the forefront of research in condensed matter physics.
Teaching and learning activities and methods: Lectures, exercise courses and laboratory courses	
Previous knowledge expected	Theory courses at bachelor's level, plus advanced quantum mechanics
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	**Laboratory Technology and Instrumentation**
ECTS credit points	9
Subject content	◆ <u>Measurement Techniques and Probe Analysis</u>: Selection of advanced laboratory courses in the fields of optics, interferometry, spectrography, physics of lasers, solid state and surface physics ◆ <u>Computer-supported Measurement Techniques</u>: Laboratory course on the structure, function and programming of a microcontroller in combination with hardware control for automated measurement tasks and process controlling (assembler codes, C-codes, LabVIEW codes) <u>Vacuum Technology</u>: Gas kinetics, pumps, pressure measurements, vacuum chambers, safety <u>X-ray and Neutron Scattering</u>: Basic principles of elastic and inelastic scattering techniques to study the structure and dynamics of materials at an atomic and molecular level <u>Light Engineering</u>: Photometry, colorimetry; radiation flux and intensity, radiance, irradiance; visual measurements; physical and visual photometry, spectral luminous efficiency; the CIE chromaticity of black-body radiation <u>Temperature Measurements</u>: Temperature measurements by fixed points, expansion of liquids and metals, electrical resistance, thermoelectric effects; optical temperature measurement: pyrometry, emissivity, black-body radiation <u>Ultrasound Methods</u>: Ultrasound generation, propagation, and behaviour in various media and across interfaces. Ultrasound as an analysis tool incl. imaging <u>Signal Theory</u>: Introduction to concepts of digital signal processing (spectral analysis and digital filtering, fast transforms, physics of noise, correlation measurement techniques) incl. a laboratory course with practical examples and test programs for real-time data analysis
Learning outcomes	After having participated successfully in the module, students are able to • understand how physical principles and phenomena can be examined and characterised experimentally, and • use and apply modern experimental equipment and methods. After having completed the module, students have gained • experience of working scientifically by using experimental equipment or connecting experimental hardware for control and analysis by a computer, and • competence and practical knowledge for the application of various measurement techniques.
Teaching and learning activities and methods: Lectures, lecture/practical, laboratory course	
Previous knowledge expected	Knowledge of solid state physics, experimental and computational techniques at bachelor's level
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	**Microscopy and Nanoanalysis**
ECTS credit points	9
Subject content	Correlating the atomic and nanoscale structure of condensed matter with physical properties and functionality lies at the heart of a wide range of critical technologies. Electron scattering and diffraction instruments are uniquely positioned to address technological challenges with simultaneous spatial, reciprocal and spectroscopic information of a material in two and three dimensions. ◆ Electron Microscopy 1: Overview of electron microscopic instrumentation and techniques. Principles of image formation, contrast mechanisms, resolution. ◆ Advanced 2D and 3D Nanoanalysis: Advanced imaging and spectroscopic methods and 3D techniques. Aberration-corrected TEM/STEM, electron tomography, electron beam monochromation and applications, EELS data processing and MLLS fitting based mapping. Practical exercises Electron Microscopy 2: Fundamentals of nanoanalytical methods. Special chapters about in-situ and atomic resolution applications. Industrial applications. X-ray and Neutron Scattering: Basic principles of elastic and inelastic scattering techniques to study the structure and dynamics of materials at the atomic and molecular level Research Laboratory Microscopy and Nanoanalysis: Practical training in the laboratory applying advanced experimental techniques related to current research topics in nanoscience
Learning outcomes	After having participated successfully in the module, students are able to ● understand the functionalities of electron microscopes and spectrometers for SEM and (S)TEM as well as other diffraction techniques; ● interpret variations in image contrast, intensity and signal-to-noise ratio that result from electron specimen interactions; ● understand diffraction effects and patterns and relate information to the crystallography of the specimen; ● assess what microscopy and/or spectroscopy techniques in 2D or 3D are adequate for particular research and formulate a strategy for specimen preparation, microscopy observation and analysis, and ● use modern experimental equipment and methods of nanoscience. After having completed the module, students have gained ● profound knowledge of microscopy and nanoanalysis techniques; ● an insight into the potential of electron scattering and diffraction instruments, and ● specialised competence for material characterisation.
Teaching and learning activities and methods: Lectures, lecture/practical, laboratory course	
Previous knowledge expected	Basics in solid state physics, experimental and computational techniques at bachelor's level
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	Modelling of Materials
ECTS credit points	9
Subject content	Students are introduced to modern simulation techniques for electronic and nuclear motion in atoms, molecules and bulk structures. They are trained to solve topical problems inspired by current research and industrial needs. ◆ Fundamentals of Electronic Structure Theory: Electronic band structure, free-electron bands and tight-binding approximation. SCF approximation; DFT; basis functions; full-potential and pseudopotential approach; advanced topics ◆ Simulating Materials Properties from First Principles: Tutorial and scientific exercise. Molecular properties, excitations, vibrations, visualisation, band-structure calculations, ab initio MD, interaction-driven Mott transition 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; Mott-Hubbard model Advanced Ab Initio Techniques: Going beyond semi-local functionals. Perturbative approaches beyond DFT – G0W0 and GW. Dispersion corrections; RPA; the Bethe-Salpeter equation for simulating excitations; time-dependent DFT Modelling of Molecular Systems: Non-Born-Oppenheimer effects; rovibronic interactions; group theory; excited states; post-Hartree-Fock techniques; solvation, QM/MM embedding; reaction dynamics and transition state theory
Learning outcomes	The module offers a solid methodical and computational background as well as practical knowledge regarding programme packages and libraries at the edge of current research. Participants are equipped with substantial knowledge in the field of materials modelling and electronic structure theory, which makes them valuable job candidates at materials research facilities.
Teaching and learning activities and methods: Lectures, laboratory course	
Previous knowledge expected	Quantum mechanics, electrodynamics, advanced quantum mechanics
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

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

<table>
<tr><th>Specialisation module</th><th>Nanoscience</th></tr>
<tr><td>ECTS credit points</td><td>9</td></tr>
<tr><td>Subject content</td><td>◆ <u>Nanostructures and Nanotechnology</u>: Overview of physical nanoscience: physics of low-dimensional systems. Electronic transport and magnetic properties on the nanoscale. Nanoparticles, nanocrystalline and nanoporous materials. Lateral nanostructuring. Nanowires, nanotubes and nanodots. Scanning probe techniques

◆ <u>Research Laboratory Nanoscience</u>: Practical training in the laboratory with advanced experimental techniques related to current research topics of nanoscience

<u>Chemical Fundamentals of Nanoscience</u>: Chemical fundamentals of making nanoparticles. Precipitation; sol-gel processes; dendrimers; supramolecular structures; carbon-based nanoparticles; toxicity of nanoparticles

<u>Theory of Magnetism and Collective Phenomena</u>: Magnetic exchange mechanisms; models for magnetic materials; response functions and phase transitions, Brown theory of micromagnetism; magnetic domains

<u>Quantum Transport Theory</u>: Introduction to basic approaches to quantum transport theory e.g. semiclassical Boltzmann equation; Wigner function approach; Green’s function techniques. Selected applications in nanophysics

<u>Structuring of Material Surfaces and Functional Nanofabrication</u>: Overview of technologies that allow the defined fabrication of (functional) surface structures on the microscale and nanoscale</td></tr>
<tr><td>Learning outcomes</td><td>After having participated successfully in the module, students are able to
● understand the basic principles of low-dimensional systems and the methods of the interdisciplinary research field of nanoscience;
● assess the relation between the structure and the properties of nanoscale materials, and
● use modern experimental equipment and methods of nanoscience.
After having completed the module, students have gained
● profound knowledge of nanoscience, allowing them to make use of specialist literature;
● an insight into the application potentials of nanotechnology, and
● specialised competence in the field of one of the elective courses e.g. in the application of theoretical concepts in nanoscience.</td></tr>
<tr><td colspan="2">Teaching and learning activities and methods: Lectures, laboratory course</td></tr>
<tr><td>Previous knowledge expected</td><td>Knowledge of solid state physics, quantum mechanics, experimental and computational techniques at bachelor’s level</td></tr>
<tr><td>Frequency of offer:</td><td>Mandatory courses (◆) every year; others at least every two years</td></tr>
</table>

Specialisation module	**Quantum Many-body Physics**
ECTS credit points	9
Subject content	◆ Green's Functions in Many-particle Physics Correlation functions and linear response. Definition of Green's functions for fermions and bosons. Matsubara, retarded and time-ordered Green's functions. Spectral representation. Perturbation theory and Feynman diagrams. Self-energy. Approximation methods. Introduction to Correlated Many-body Systems Introduction to topical problems in strongly correlated many-body physics. Models such as the Hubbard, Heisenberg, tJ and Kondo model are derived in second quantisation. In the framework of the Green's function formalism, electronic, magnetic, and optical properties are studied. Many-body Systems out of Equilibrium Non-equilibrium Green's functions and Keldysh contour. Perturbation theory and diagrams. Steady state. Quantum transport. Derivation of Boltzmann equations. Impurity scattering. Electron-electron and electron-phonon interactions. Time-dependent phenomena Open Quantum Systems Classical master equation: time evolution of probabilities. Reduced density matrix of an open system. Elimination of degrees of freedom. Lindblad equation. Microscopic derivation. Solution methods. Applications to quantum computer, decoherence and quantum measurement, quantum optics, quantum dots
Learning outcomes	After having participated successfully in the module, students ● have gained an overview of modern aspects of many-body physics; ● have acquired a deeper understanding of many-body quantum systems in and out of equilibrium, especially in connection with solid state physics, and ● have learned several theoretical approaches to evaluate their properties, which are used for the research carried out at the Institute of Theoretical and Computational Physics.
Teaching and learning activities and methods: Interactive classes with alternating lectures, tasks and exercises	
Previous knowledge expected	Quantum mechanics at master's level. Elements of quantum statistics
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	**Quantum Optics and Molecular Physics**
ECTS credit points	9
Subject content	Concepts of light-matter interaction are introduced and described with semi-classical and quantum physics. Topics ranging from light propagation in solids to femtosecond processes in isolated molecules are covered. ◆ Fundamental Optics: Basics of optics for research and industrial applications: light propagation in isotropic materials and birefringent crystals; polarisation optics; nonlinear optics; Fraunhofer and Fresnel diffraction, Fresnel zone plates; coherence and interference; 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. Laser Physics: Emission and absorption; Einstein coefficients; laser theory and rate equations; optical resonators and modes; laser types; laser safety Ultrafast Laser Physics: Introduction to the state-of-the-art research field of femtosecond time-resolved molecular spectroscopy: generation and amplification of femtosecond laser pulses; pulse propagation in media, dispersion compensation; pulse characterisation; methods and examples of femtosecond time-resolved spectroscopy; strong field effects; applications Quantum Optics: Correlated photons; theory of light-pressure force; laser cooling, trapped atomic ensembles; atom interferometry; quantum interference; atomic clocks, optical magnetometers (foundations and 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
Learning outcomes	After having participated successfully in the module, students are able to ● solve optics-related tasks in research and industry, equipped with a substantial fundamental and practical basis; ● understand light-induced molecular processes, their investigation with (femtosecond) laser radiation, as well as their modelling; ● design and construct optical setups for laser applications, and ● carry out a master's thesis in a research laboratory in the field of modern optics or laser spectroscopy.
Teaching and learning activities and methods: Lectures, laboratory course	
Previous knowledge expected	Experimental physics, quantum mechanics, electrodynamics and mathematical concepts at bachelor's level
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	**Radiation and Plasma Physics**
ECTS credit points	9
Subject content	◆ Applied Radiation Physics: Introduction to ionising radiation sources, interaction of radiation with matter; human exposure to natural and man-made radiation sources, their biological effects, risks and tolerance limits; basics of dosimetry and activity measurements; applied radiation protection ◆ Research Laboratory Radiation and Plasma Physics: Exercises on radiation detection, dosimetry and activity measurements, gamma-spectrometric identification of radionuclides and determination of radon concentration in air. Computer simulations on topics of plasma or fusion physics Plasma Physics: Collective effects in plasmas and conducting fluids; drift motions of charged particles in electromagnetic fields; plasma models; linear response of electric media; plasma waves Fusion Physics: Introduction to nuclear fusion; magnetic confinement; inertial confinement; fusion concepts (tokamak, stellarator, mirror, field-reversed configuration) and related experiments; fusion fuels; power balance in fusion plasmas; technological aspects; safety aspects; comparison to nuclear fission; nuclear fusion in the sun and in stars (creation of elements in the universe) Kinetic Theory in Plasma Physics: Concepts of kinetic theory in plasma physics; comparison to single particle and fluid description; derivation of Liouville equation, Lenard-Balescu equation, Fokker-Planck equation and Vlasov equation; Coulomb collisions in plasmas; applications of kinetic theory
Learning outcomes	After having participated successfully in the module, students are able to ● understand the basic physical principles of ionising radiation, plasma and fusion processes. After having completed the module, students have gained ● profound knowledge of ionising radiation and radiation protection; ● an insight into the basic physics of ionised gases, and ● practical skills and specialised competence in radiation and plasma physics.
Teaching and learning activities and methods: Lectures, laboratory course	
Previous knowledge expected	Basic courses in theoretical mechanics and electrodynamics
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	Semiconductor Devices
ECTS credit points	9
Subject content	◆ Physics of Semiconductor Devices: Introduction to the band structures of semiconductors; intrinsic and extrinsic semiconductors; drift and diffusion of electrons and holes; p-n junctions; Schottky diodes; Ohmic contacts; JFETs, MESFETs; MOSFETs; CMOS; memories; bipolar transistors; solar cells; light-emitting diodes; laser diodes ◆ Research Laboratory Semiconductor Devices: Characterisation of transistors; noise measurements; voltage-capacitance; the Hall effect; charge pumping; EBIC; EDMR; fabrication of organic devices; e-beam lithography; ellipsometry and pyrometry; SEM; TEM; FIB; IR spectroscopy; simulation laboratory Microelectronics and Micromechanics: Basic processes of Si-planar technology; oxidation; thin film deposition; lithography; etching; fabrication of semiconductor devices; micromechanics; LIGA; micro-optics; microfluidics; EBID Organic Semiconductors: Molecular and crystalline structures; liquid crystals; self-assembly processes; charge transport in organic semiconductors; photophysical and non-linear optical properties; organic light-emitting devices; lighting applications and displays; organic thin-film transistors; modelling of organic devices; fabrication of organic devices 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
Learning outcomes	After having participated successfully in the module, students are able to ● describe the fabrication and operation of semiconductor devices; ● understand how the choice of materials changes the properties of the devices, and ● use modern experimental equipment and methods for the characterisation of semiconducting materials and devices.
Teaching and learning activities and methods: Lectures, laboratory course, independent project	
Previous knowledge expected	Knowledge of solid state physics, electrodynamics, computer programming, and experimental physics at bachelor's level
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

Specialisation module	Surface Science
ECTS credit points	9
Subject content	◆ Surface Science: Geometric and electronic structure of surfaces (theory and methods); adsorption (thermodynamics, growth processes) ◆ Experimental Methods in Surface Science: Combination of lectures and laboratory courses; the focus is on understanding the principles of modern experimental surface science techniques (morning lectures) and gaining direct hands-on experience (afternoon laboratory course) with the techniques available at the surface science groups at Uni Graz and TU Graz. Molecular Interfaces: Bonding; orbitals; band structure; interfaces; angle-resolved UPS; orbital tomography Scanning Probe Techniques: Scanning tunnelling microscopy (theory, operation, measurement modes, spectroscopy, applications, spin-polarised STM, inelastic STM/STS, manipulation). Atomic force microscopy (theory, interaction forces, modes (static, dynamic), force-distance curves, Kelvin probe, magnetic force; spectromicroscopy: PEEM, LEEM, µ-XPS Synchrotron Radiation Techniques: Synchrotron light generation (history, accelerators, etc.); synchrotron XPS (time-resolved, data analysis, line shapes, curve fitting, etc.); X-ray absorption spectroscopy (EXAFS, XANES) 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.) Surface Chemistry: Chemical reactions on surfaces (heterogeneous catalysis; photocatalysis; electrochemistry) Vacuum Technology: Gas kinetics, pumps, pressure measurements, vacuum chambers, safety
Learning outcomes	After having participated successfully in the module, students are able to ● understand the fundamental (geometric and electronic) properties of surfaces as a representation of a truncated crystalline bulk material; ● understand the principles, operate and interpret the results obtained with state-of-the-art ultra-high vacuum-based surface science methods and standard surface analytical methods for industry, and ● understand the principles and methods of adsorption on surfaces, self-assembly, thin film growth and nanostructuring. ● The optional courses provide students with deeper knowledge of the systems and techniques of surface physics and surface chemistry.
Teaching and learning activities and methods: Lectures, laboratory course	
Previous knowledge expected	Knowledge of solid state physics
Frequency of offer:	Mandatory courses (◆) every year; others at least every two years

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

Annex II

Curriculum

1st semester	SSt	LV type	ECTS	Uni Graz[1]	TU Graz[1]
Statistical Physics	2	VO	4	X	X
Statistical Physics	1	UE	2	X	X
Advanced Quantum Mechanics	2	VO	4	X	X
Advanced Quantum Mechanics	1	UE	2	X	X
Advanced Solid State Physics	2	VO	4	X	X
Advanced Solid State Physics	1	UE	2	X	X
Elective modules			9	X	X
Free-choice subject			3	X	X
Total for the 1st semester			30		
2nd semester					
Computer Simulations	3	VU	4		X
Advanced Atomic and Molecular Physics	2	VO	4		X
Radiation Physics	2	VO	4		X
Compulsory module Business and Entrepreneurship			4.5		X
Elective modules			9	X	X
Free-choice subject			4.5	X	X
Total for the 2nd semester			30		
3rd semester					
Elective modules			24.5	X	X
Free-choice subject			2.5	X	X
Total for the 3rd semester			27		
4th semester					
Master’s seminar	2	SE	2	X	X
Master’s thesis			30	X	X
Master’s examination			1	X	X
Total for the 4th semester			33		
Total ECTS			120		

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

Annex III

Recommended courses for the free-choice subject

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

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

As part of the free-choice subject, an exclusive tutorial with a scope of 2 ECTS credit points may be completed that is offered by the supervisor of the master's thesis with a "venia docendi" teaching qualification.

Annex VI

Equivalence list and recognition list

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

For students of the master's degree programme in Technical Physics, curriculum 2013, at TU Graz, the following table regulates the recognition of courses between the expiring master's degree programme in Technical Physics, curriculum 2013, and this curriculum.

a. Students of TU Graz who do not opt for this curriculum may replace courses of the curriculum for the master's degree programme in Technical Physics in the version 2013, with courses of this curriculum according to the following table if these courses are linked with "↔" or "←". In the table, "↔" means the equivalence of both courses and "←" means that the course in the left-hand column of the table may be replaced by the course in the right-hand column.

   If the replacement of courses according to the table leads to an increase or decrease in the scope of ECTS credit points of a compulsory subject or the General Physics elective subject of the curriculum 2013, the scope to be completed for the Physics specialisation subject is decreased or increased by the same number of ECTS credit points.

   Courses from the catalogue of the Physics specialisation modules (§ 9A) and from the catalogue "General elective subject" (§ 9B) of this curriculum that are not listed in the table below may also be used as a course for Catalogue of electives VI of the curriculum 2013[III]. The officer responsible for study matters may prohibit this if the teaching content of the course concerned does not differ considerably from the other courses that are chosen for the General Physics elective subject and the physics specialisation subject.

Students of TU Graz who opt for this curriculum may replace courses of this curriculum with courses of the curriculum for the master's degree programme in Technical Physics in the version 2013 according to the following table if these courses are linked with "↔" or "→". In the table, "↔" means the equivalence of both courses and "→" means that the course in the right-hand column of the table may be replaced by the course in the left-hand column.

The recognition of courses from the curriculum 2013 for a specialisation module shall also apply in the same way for the general elective module.

If the replacement of courses according to the table leads to an increase or decrease in the scope of ECTS credit points of a physics specialisation module, the scope to be completed for the general elective module is decreased or increased by the same number of ECTS credit points.

Course from the expiring curriculum 2013					Course from this curriculum 2017			
Course	**LV type**	**SSt**	**ECTS**		**Course**	**LV type**	**SSt**	**ECTS**
Statistische Physik								
Statistische Physik	VO	2	4	↔	Statistical Physics	VO	2	4
Statistische Physik	UE	1	2	↔	Statistical Physics	UE	1	2
Advanced Quantum Mechanics								
Fortgeschrittene Quantenmechanik	VO	2	4	↔	Advanced Quantum Mechanics	VO	2	4
Fortgeschrittene Quantenmechanik	UE	1	2	↔	Advanced Quantum Mechanics	UE	1	2
Computer Simulations and Mathematical Methods								
Computersimulationen	VU	3	4	↔	Computer Simulations	VU	3	4
Analytische Funktionen	VO	1	2	→ ←	Green's Functions for Solid State Physics	VU	2	3
Analytische Funktionen	UE	1	1					
Advanced Computational Physics								
Advanced Computational Physics	VO	2	3	→ ←	Complete Module: Computational Condensed Matter Physics			
Advanced Computational Physics	UE	4	5					
Research Laboratory								

[III] Apart from the laboratory courses of the module "Laboratory Technology and Instrumentation", the courses of the type LU of the specialisation module (or VU in the specialisation module Surface Science) are excluded herefrom.

Course from the expiring curriculum 2013					Course from this curriculum 2017			
Course	**LV type**	**SSt**	**ECTS**		**Course**	**LV type**	**SSt**	**ECTS**
Forschungslabor 1	LU	3	4	→ ←	Research Laboratory of a Module or Experimental Methods in Surface Science of Module Surface Science	LU VU	2 2	3 3
Forschungslabor 2	LU	3	4	→ ←	Research Laboratory of a Module or Experimental Methods in Surface Science of Module Surface Science	LU VU	2 2	3 3
Advanced Experimental Physics								
Experimentelles Praktikum	LU	3	4	→ ←	Research Laboratory of a Module or Experimental Methods in Surface Science of Module Surface Science	LU VU	2 2	3 3
Strahlenphysik	VO	2	4	↔	Radiation Physics	VO	2	4
Experimentelle Methoden der Spektroskopie, Quantenoptik und Quantenmesstechnik	VO	2	4	↔	Advanced Atomic and Molecular Physics	VO	2	4
Advanced Solid State Physics								
Fortgeschrittene Festkörperphysik	VO	2	5	↔	Advanced Solid State Physics	VO	2	4
Fortgeschrittene Festkörperphysik	UE	1	1	↔	Advanced Solid State Physics	UE	1	2
Fundamentals for Business Economics								
Grundlagen der Betriebswirtschaftslehre	VO	2	4	↔	Encyclopedia Business Economics	VO	3	4.5
Grundlagen der Betriebswirtschaftslehre	UE	1	2	↔	Encyclopedia Business Economics	UE	2	2
Catalogue of electives II (Experimental Physics)								
Atom- und Molekülphysik	VO	2	3	→ ←	Modelling of Molecular Systems	VO	2	3
Optik	VO	2	3	↔	Fundamental Optics	VO	2	3
Physik des Lasers	VO	2	3	↔	Laser Physics	VO	2	3
Transmissionselektronenmikroskopie	VO	2	3	→ ←	Electron Microscopy 1	VO	2	3
Rasterelektronenmikroskopie	VO	2	3	→ ←	Electron Microscopy 1	VO	2	3
Catalogue of electives III (Solid State Physics and Material Physics)								
Oberflächen- und Dünnschichtphysik	VO	2	3	↔	Thin Film Science and Processing	VO	2	3
Physics of semiconductor devices	VO	2	3	↔	Physics of Semiconductor Devices	VO	2	3
Soft-Matter-Physik	VO	2	3	↔	Soft Matter Physics	VO	2	3

Course from the expiring curriculum 2013					Course from this curriculum 2017			
Course	**LV type**	**SSt**	**ECTS**		**Course**	**LV type**	**SSt**	**ECTS**
Funktionswerkstoffe	VO	2	3	↔	Functional Materials	VO	2	3
Nanostrukturen und Nanotechnologie	VO	2	3	↔	Nanostructures and Nanotechnology	VO	2	3
Catalogue of electives IV (Theoretical Physics)								
Plasmaphysik	VO	2	3	↔	Plasma Physics	VO	2	3
Theoretische Festkörperphysik	VO	2	3	→ ←	Fundamentals of Electronic Structure Theory	VO	2	3
Transport in Nanostrukturen und mesoskopischen Systemen	VO	2	3	↔	Quantum Transport Theory	VO	2	3
Quanten und Felder	VO	2	3	→ ←	Non-compulsory course of Module Quantum Many-Body Physics	VU	2	3
Catalogue of electives V (seminar)								
Seminar Experimentalphysik 1	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Experimentalphysik 2	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Festkörperphysik 1	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Festkörperphysik 2	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Materialphysik 1	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Materialphysik 2	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Theoretische Physik – Computational Physics 1	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Theoretische Physik – Computational Physics 2	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Elektronenmikroskopie und Nanoanalytik 1	SE	2	2	↔	Masterseminar	SE	2	2
Seminar Elektronenmikroskopie und Nanoanalytik 2	SE	2	2	↔	Masterseminar	SE	2	2
Catalogue of electives VI								
Partial catalogue: Experimental Physics								
Special Topics of Molecular Physics	VO	2	3	→	Non-compulsory course of Module Quantum Optics and Molecular Physics	VO	2	3
Experimentelle Plasmaphysik	VO	2	3	→	Non-compulsory course of Module Radiation and Plasma Physics	VO	2	3
Feinwerktechnik	VO	2	3	→	Lecture course of Module Laboratory Technology and Instrumentation	VO	2	3

Course from the expiring curriculum 2013					Course from this curriculum 2017			
Course	**LV type**	**SSt**	**ECTS**		**Course**	**LV type**	**SSt**	**ECTS**
Special Topics of Coherent Optics	VO	2	3	→	Non-compulsory course of Module Quantum Optics and Molecular Physics	VO	2	3
Lichttechnik	VO	3	4	↔	Light Engineering	VO	2	3
Quantenoptik	VO	2	3	↔	Quantum Optics	VO	2	3
Praktikum aus kohärenter Optik, Atom- und Molekülspektroskopie 1	LU	5	5	→	Research Laboratory of Module Nano and Laser Optics or of Module Quantum Optics and Molecular Physics	LU	2	3
Praktikum aus kohärenter Optik, Atom- und Molekülspektroskopie 2	LU	5	5	→	Research Laboratory of Module Nano and Laser Optics or of Module Quantum Optics and Molecular Physics	LU	2	3
Temperaturmessungen	VO	2	3	↔	Temperature Measurements	VO	2	3
Partial catalogue: Solid State Physics								
Dünnschichttechnologie	VO	2	3	→	Non-compulsory course of Module Semiconductor Devices or of Module Surface Science	VO	2	3
Topics in surface science	VO	2	3	→	Non-compulsory course of Module Surface Science	VO	2	3
Polymers in electronics	LU	2	3	→	Non-compulsory course of Module Semiconductor Devices	VO	2	3
Festkörperspektroskopie	VO	2	3	→	Non-compulsory course of Module of Module Surface Science or of Module Laboratory Technology and Instrumentation	VO	2	3
Chemische Grundlagen der Nanowissenshaften	VO	2	3	↔	Chemical Fundamentals of Nanoscience	VO	2	3
Lichterzeugung und Displaytechnologie in Theorie und Praxis	VO	2	3	→	Lecture course of Module Laboratory Technology and Instrumentation	VO	2	3
Mikroelektronik und Mikromechanik	VO	2	3	↔	Microelectronics and Micromechanics	VO	2	3
Oberflächenchemie	VO	2	3	↔	Surface Chemistry	VO	2	3
Topics in semiconductors	VO	2	3	→	Non-compulsory course of Module Semiconductor Devices	VO	2	3
Organic Semiconductors – Fundamentals and Applications	VO	3	4	→ ←	Organic Semiconductors	VO	2	3
Praktikum Festkörperphysik	LU	3	3	→ ←	Research Laboratory of Module Semiconductor Devices	LU	3	3
X-ray physics	VO	2	3	↔	X-ray and Neutron scattering	VO	2	3

Course from the expiring curriculum 2013					Course from this curriculum 2017			
Course	**LV type**	**SSt**	**ECTS**		**Course**	**LV type**	**SSt**	**ECTS**
Vakuumtechnologie	VO	2	3	↔	Vacuum Technology	VO	2	3
Partial catalogue: Material Physics								
Topics in Materials Physics	VO	2	3	→	Lecture course of Module Applied Materials Physics	VO	2	3
Ausgewählte Themen der Technischen Physik	VO	2	3	→	Lecture course of Module Applied Materials Physics	VO	2	3
Biologische und biobasierte Materialien	VO	2	3	→	Lecture course of Module General Elective	VO	2	3
Nukleare Festkörperphysik	VO	2	3	→	Lecture course of Module Applied Materials Physics	VO	2	3
Experimentelle Methoden der Materialforschung	VO	2	3	→	Lecture course of Module Applied Materials Physics	VO	2	3
Praktikum computerunter-stützte Messtechnik	LU	3	3	→ ←	Computer Supported Measurement Tech-niques	LU	2	3
Praktikum Materialphysik	LU	3	3	↔	Research Laboratory Ap-plied Materials Physics	VO	2	3
Strahlenschutz für ionisierende Strahlung	VU	2	3	→ ←	Applied Radiation Phys-ics	VO	2	3
Strukturbildung und Diffusion in Materie	VU	3	4	→ ←	Structural Transfor-mations and Diffusion in Materials	VU	3	3
Structurally complex materials	VO	2	3	↔	Structurally Complex ma-terials	VO	2	3
Partial catalogue: Theoreti-cal Physics – Computational Physics								
Allgemeine Relativitätstheorie	VO	2	3	→	Lecture course of Module General Elective	VO	2	3
Analytische Methoden in der angewandten theoretischen Physik	VO	2	3	→	Lecture course of Module General Elective	VO	2	3
Applikationssoftware für Fort-geschrittene	VU	4	5	→ ←	Programming in Physics: Advanced MATLAB	VU	4	4
Ausgewählte Kapitel der theo-retischen Vielteilchenphysik	VO	2	3	→	Non-compulsory course of Module Quantum Many-Body Physics <u>or</u> of Module Computational Condensed Matter Phys-ics	VO	2	3
Festkörpertheorie	VO	2	3	→	Non-compulsory course of Module Theoretical Solid State Physics	VO	2	3
Einführung in das symbolische Rechnen	VO	2	3	→	Lecture course of Module General Elective	VO	2	3
Fundamentale Effekte von Vielteilchenproblemen	VO	2	3	↔	Introduction to Correlated Many-Body Systems	VU	2	3
Fusionsphysik	VO	2	3	↔	Fusion Physics	VO	2	3
Kinetische Gleichungen für klassische und quantenmecha-nische Systeme	VO	2	3	↔	Kinetic Equations for Classical and Quantum Mechanical Systems	VO	2	3
Kinetic Theory in Plasma Physics	VO	2	3	↔	Kinetic Theory in Plasma Physics	VO	2	3

Course from the expiring curriculum 2013					Course from this curriculum 2017			
Course	**LV type**	**SSt**	**ECTS**		**Course**	**LV type**	**SSt**	**ECTS**
Correlation Phenomena in Solid State Physics	VU	3	4	→	Non-compulsory course of Module Theoretical Solid State Physics or of Module Quantum Many-Body Physics	VU	3	4
Mathematische Methoden der Theoretischen Physik	VO	2	3	→	Lecture course of Module General Elective	VO	2	3
Computational Many-Body Physics	VU	3	4	→ ←	Numerical Simulation of strongly Correlated Many-Body Models	VU	2	3
Phasenübergänge und kritische Phänomene	VU	4	5	→ ←	Phase Transitions and Critical Phenomena	VO	2	3
Plasmaelektrodynamik	VO	2	3	→	Non-compulsory course of Module Radiation and Plasma Physics	VO	2	3
Quanten und Felder	UE	2	2	→	Non-compulsory course of Module Quantum Many-Body Physics	UE	2	2
Theoretische Physik mit MA-THEMATICA: symbolisches und numerisches Rechnen	VU	4	4	↔	MATHEMATICA for Theoretical Physics: Symbolic and Numerical Computation	VU	4	4
Partial catalogue: Electron Microscopy and Nanoanalytics								
Materials characterization by electron microscopy	LU	2	2	→ ←	Research Laboratory Microscopy and Nanoanalysis	LU	2	3
Microscopy and structuring of materials surfaces	VU	2	3	→	Advanced 2D and 3D Nanoanalysis	VU	2	3
Strukturaufklärung mittels Hochauflösungselektronen-mikroskopie	VO	2	3	→	Lecture course of Module General Elective	VO	2	3

Annex V

Glossary

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

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

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