Supplement to the curriculum for the

Master's degree program Digital Engineering

Curriculum 2022

This supplement was approved by the Senate of Graz University of Technology at its meeting on May 27, 2024

The change of the Bachelor's degree program Electrical Engineering in to the Bachelor's degree program Electrical and Electronics Engineering requires modifications to the Master's degree program Digital Engineering in the form of the following

equivalence list:

Curriculum Bachelor's degree program Electrical and Electronics Engineering 2024					Curriculum Master's degree program Digital Engineering 2022			
Course	**Type**	**Semester hours**	**ECTS**		**Course**	**Type**	**Semester hours**	**ECTS**
Sensorik	VO	2	3		Sensorsysteme	VO	2	3
Sensorik, Labor	LU	1	1,5		Sensorsysteme, Labor	LU	1	1,5
Prozessautomatisierung, Labor	LU	2	3		Prozessautomatisierung, Labor	LU	2	2,5
Digital Communications	VO	2	3		Fundamentals of Digital Communications	VO	2	3
Digital Communications	UE	1	1,5		Fundamentals of Digital Communications	UE	1	1

This amendment enters into force on October 1, 2024.

Curriculum for the Master's Degree Programme

Digital Engineering

Curriculum 2022

This curriculum was approved by the Senate of TU Graz in the meeting held on March 7, 2022.

The legal basis for this degree programme are the Universities Act (in German: *Universitätsgesetz* or UG) and the Excerpt of Statutes: Legal Regulations for Academic Affairs of TU Graz, as amended.

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I General Information

§ 1 Subject of the degree programme and qualification profile

The Master's Degree Programme Digital Engineering comprises four semesters. The total number of assigned credits is 120 ECTS credits according to § 54 (3) Universities Act 2002 (UG).

The Master's Degree Programme Digital Engineering is offered in English as a foreign language programme according to § 63a (8) UG.

Graduates of this programme are awarded the academic degree "Diplom-Ingenieur*in", which is abbreviated as "Dipl.-Ing." or "DI". This academic degree corresponds internationally to the "Master of Science", abbreviated as "MSc".

(1) Subject of the degree programme

Building on knowledge acquired in the associated bachelor's degree programme, the Master's Degree Programme Digital Engineering expands the skills and technical knowledge of the students in the areas of mathematical modelling, numerical simulation and the systematic design of control loops for complex interconnected dynamic systems. This programme combines aspects of electrical engineering, computer science and mechanical engineering. Students further enhance their skills by solving problems out of an individually chosen field of specialisation.

(2) Qualification profile and competences

Students who successfully complete the Master's Degree Programme Digital Engineering demonstrate an above-average level of competence which enables them to solve engineering problems independently and systematically as these arise in the design and creation of complex networked systems.

The graduates have knowledge enabling them to

- engage in and perform data-driven modelling of complex dynamic systems,
- understand algorithms used in numerical optimisation and simulation and
- design and create complex networked dynamic systems that are used in the fields of electrical engineering, computer science and mechanical engineering.

In addition, they have skills enabling them to

- apply their basic engineering knowledge to specific challenging problems,
- structure multidisciplinary, interconnected tasks by considering appropriate subproblems so that they can be solved successfully,
- design linear and non-linear control loops and realise them in embedded systems and
- implement given or self-designed algorithms applicable for control engineering, optimisation, or numerical simulation purposes.

Theirac

- ability to familiarise themselves independently with new areas of knowledge,
- interest in participating in international and interdisciplinary project groups and
- desire to integrate newly acquired knowledge into their field of activity and thereby develop it further,

enable them to enter many different technical sectors, both in science and in research and development departments in industrial companies.

(3) Need for and relevance of the degree programme to academia and the labour market

Digitalisation has resulted in a steady increase in networking among technical systems that interact closely with their physical environments. On the one hand, this networking makes a central contribution to fulfilling societal needs; on the other hand, the number of overall systems that need to be created are becoming increasingly complex in terms of their design and development. Without exception, this affects the entire population, since progression can only occur in areas like production, transportation, mobility, energy and environmental systems, but also medicine, if suitable technical systems and their networking are available and function effectively. Thus, the increasing demand for engineers with skills such as those who have successfully completed the Master's Degree Programme Digital Engineering is also apparent.

II General Provisions

§ 2 Admission requirements

(1) Admission to a master's degree programme requires the completion of a relevant bachelor's degree programme, a bachelor's degree programme completed at a university of applied sciences in a related (and deemed relevant) field of study, or another equivalent degree programme with at least 180 ECTS credits. These programmes need to have been completed at a recognised domestic or foreign post-secondary educational institution (§ 64 (3) Universities Act 2002 (UG)).

(2) The Master's Degree Programme Digital Engineering builds on knowledge acquired in the Bachelor's Degree Programme Digital Engineering offered at TU Graz. Graduates of this bachelor's degree programme or of the Bachelor's Degree Programme Mechatronics at the Johannes Kepler University Linz are admitted to the Master's Degree Programme Digital Engineering at TU Graz without any additional conditions.

(3) Other degree programmes that cover aspects of electrical engineering and information technology, computer science and mechanical engineering sufficiently are considered as relevant. In this case, up to 30 ECTS credits assigned to courses taken in the Bachelor's Degree Programme Digital Engineering at TU Graz can be recognised by the Dean of Studies in order to achieve full equivalence. The Bachelor’s Degree Programmes Information and Computer Engineering, Electrical Engineering and Mechanical Engineering of the TU Graz are basically considered as relevant for this purpose. The recognition of additional courses and achievements can also include up to 5 ECTS assigned to free-choice courses.

(4) In order to achieve a total of 300 ECTS credits in the postgraduate degree programme, the assignment of one and the same course is excluded both in the bachelor's degree programme that entitles the student to admission and in the master's degree programme in question.

§ 3 Allocation of ECTS credits

All study activities completed by the students are allocated certain ECTS credit points. The ECTS credits reflect the workload of each course or assignment relative to the workload of an academic year, which is intended to be 1500 actual hours, corresponding to 60 ECTS credits (i.e. 25 actual hours per 1 ECTS credit). The workload includes individual study time as well as the time in organised course activities. One semester course hour is equivalent to 45 minutes per week of the semester.

§ 4 Structure of the degree programme

The Master's Degree Programme Digital Engineering with a workload of 120 ECTS credits comprises four semesters. To complete the programme, students must complete the compulsory module A, module group B, a module group assigned to the areas of specialisation (C – H), as well as the free-choice courses and the master's thesis.

The structure of the degree programme is outlined in the following table.

	ECTS credit points		Total
Module Group A: Expansion of Mathematical Competence			
Compulsory Module A			11.5
Module Group B: Modeling, Simulation and Control of Cyberphysical Systems			
Compulsory Module B1: Modeling and Simulation	9		18
Compulsory Module B2: Signals and Systems	9		
Areas of specialisation			
Module Group C: Robotics			48
Compulsory Module C1: Robotics – Fundamentals	13	48	
Elective Module C2: Robotics – Electives	35		
Module group D: Production and Logistics			
Compulsory Module D1: Production and Logistics – Fundamentals	13.5	48	
Elective Module D2: Production and Logistics – Electives	34.5		
Module Group E: Mobility and Transportation			
Compulsory Module E1: Mobility and Transportation – Fundamentals	12	48	
Elective Module E2: Mobility and Transportation – Electives	36		
Module Group F: Internet of Things			
Compulsory Module F1: Internet of Things – Fundamentals	13	48	
Elective Module F2: Internet of Things – Electives	35		
Module Group G: Energy and Environmental Systems			
Compulsory Module G1: Energy and Environmental Systems – Fundamentals	13.5	48	
Elective Module G2: Energy and Environmental Systems – Electives	34.5		
Module Group H: Computational Science and Engineering			
Compulsory Module H1: Computational Science and Engineering – Fundamentals	13	48	
Elective Module H2: Computational Science and Engineering – Electives	35		
Free-choice courses			12.5
Master's thesis			30
Total			120

§ 5 Course types

The types of courses provided at TU Graz are set out in § 4 of the Excerpt of Statutes: Legal Regulations for Academic Affairs of TU Graz (see Appendix III).

§ 6 Group sizes

The following maximum numbers of participants (group sizes) have been established:

Lecture (VO: *Vorlesung*) Lecture part of VU (VU: *Vorlesung mit integrierter Übung*)	No restriction
Exercise (UE: *Übungseinheit*) Exercise part of VU Design exercise (KU: *Konstruktionsübung*)	25 25 30
Laboratory exercise (LU: *Laborübung*)	6
Project (PT: *Projekt*)	15

§ 7 Guidelines for the allocation of places in courses

(1) If more students register for a course than places are available, parallel courses will be provided and, if necessary, also during the lecture-free period.

(2) If enough parallel courses (groups) cannot be offered, students will be admitted to the course according to the following priority ranking:
   a. The course is compulsory for the student in the curriculum.
   b. The number of courses positively completed in the relevant degree programme (total ECTS credits).
   c. The date (priority given to the earlier date) that the participation requirement is fulfilled.
   d. Students who have already been deferred once or who are required to repeat the course will be given priority for the next course.
   e. The examination grade – or the grade average of the examinations (weighted according to ECTS credits) – for the course(s) serving as the basis of the participation requirement.
   f. Students for whom such courses are not listed as compulsory in their curriculum will be considered only on a place-available basis; their names, however, can be placed on a separate waiting list. The above provisions apply once necessary considerations have been made.

(3) Students who complete part of their studies at TU Graz as part of mobility programmes are given priority for up to 10% of the available places.

III Degree Programme Content and Structure

§ 8 Modules, courses and semester assignment

The individual courses of this master's degree programme and their assignment to compulsory and elective modules are listed below. The knowledge, methods, or skills that are taught in the modules are described in more detail in Appendix I. The assignment of the courses to specific semesters should be viewed in the light of a recommendation, made to ensure that courses are taken in a sequence that enables students to build optimally on previously acquired knowledge and to ensure that the workload for each academic year does not exceed 60 ECTS credits. The fourth semester is reserved for writing the master's thesis.

As described in § 4, the module groups A and B, one of the module groups of C to H listed under the areas of specialisation, as well as the free-choice courses and the master's thesis must be completed.

Master's Degree Programme Digital Engineering

Module	Course	SSt.	LV Type	ECTS	Semester credits I	II	with III	ECTS IV
Module Group A: Expansion of mathematical competence								
Compulsory Module A								
A.1	Numerische Optimierung[EN]	3	VO	4.5	4.5			
A.2	Numerische Optimierung[EN]	2	UE	2.5	2.5			
A.3	Stochastic Processes	3	VU[(2)]	4.5	4.5			
Subtotal Compulsory Module A		**8**		**11.5**	**11.5**	**0**	**0**	**0**
Module Group B: Modelling, Simulation and Control of Cyberphysical Systems								
Compulsory Module B1: Modelling and Simulation At least 9 ECTS must be completed from this compulsory module.								
B1.1	Computational Intelligence	2	VO	3		3		
B1.2	Computational Intelligence	1	UE	1.5		1.5		
B1.3	Foundations of Physics for DE	2	VO	3		3		
B1.4	Foundations of Physics for DE	1	UE	1.5		1.5		
B1.5	Multibody Dynamics	4	VU[(2)]	5	5			
Subtotal Compulsory Module B1				**9 ECTS out of the offered 14 ECTS**				
Compulsory Module B2: Signals and Systems At least 9 ECTS must be completed from this compulsory module.								
B2.1	Embedded Systems	2	VO	3		3		
B2.2	Embedded Systems, Laboratory	1	LU	1.5		1.5		
B2.3	Nonlinear Control Systems	2	VO	3	3			
B2.4	Nonlinear Control Systems	2	UE	3	3			
B2.5	Fundamentals of Digital Communications	2	VO	3	3			
B2.6	Fundamentals of Digital Communications	1	UE	1.5	1.5			
Subtotal Compulsory Module B2				**9 ECTS out of the 15 ECTS offered**				
Subtotal Module Group B		**18**						

Areas of specialisation: One of the following module groups must be completed.								
Module Group C: Robotics								
Compulsory Module C1: Robotics – Fundamentals								
C1.1	Advanced Robotics	2	VO	3		3		
C1.2	Advanced Robotics	1	LU	2		2		
C1.3	Construction of Mobile Robots	2	PT	5	5			
C1.4	Software Engineering for Autonomous Robots	2	VU(1)	3	3			
Subtotal Module Group C		**7**		**13**	**8**	**5**	**0**	**0**
Total Elective Module C2 according to § 9				**35**				
Total Compulsory ECTS Module Group C				**48**				

Module Group D: Production and Logistics								
Compulsory Module D1: Production and Logistics – Fundamentals								
D1.1	Robotics and Automation	2	VO	3		3		
D1.2	Design of Production Systems	2	VO	3		3		
D1.3	Prozessautomatisierung[EN]	2	VO	3		3		
D1.4	Prozessautomatisierung, Labor[EN]	2	LU	2.5		2.5		
D1.5	Modelling and Optimisation in Production and Logistic Systems	2	VU(1)	2		2		
Subtotal Module Group D		**10**		**13.5**	0	**13.5**	**0**	**0**
Total Elective Module D2 according to § 9				**34,5**				
Total Compulsory ECTS Module Group D				**48**				

Module Group E: Mobility and Transportation								
Compulsory Module E1: Mobility and Transportation – Fundamentals								
E1.1	Automotive Engineering 1	2	VO	3	3			
E1.2	Electric Vehicles and E-Mobility Systems	2	VO	3		3		
E1.3	Vehicle Dynamics	3	VU(1)	3	3			
E1.4	Embedded Mechatronic Architectures	2	VO	3	3			
Subtotal Module Group E		**9**		**12**	**9**	**3**	**0**	**0**
Total Elective Module E2 according to § 9				**36**				
Total Compulsory ECTS Module Group E				**48**				

Module Group F: Internet of Things								
Compulsory Module F1: Internet of Things – Fundamentals								
F1.1	Information Security	2.5	VO	4	4			
F1.2	Information Security	2.5	KU	3	3			
F1.3	Sensor Networks	2	VU(2)	3		3		
F1.4	Sensor Networks, Laboratory	2	LU	3		3		
Subtotal Module Group F		**9**		**13**	**7**	**6**	**0**	**0**
Total Elective Module F2 according to § 9				**35**				
Total Compulsory ECTS Module Group F				**48**				

Module Group G: Energy and Environmental Systems								
Compulsory Module G1: Energy and Environmental Systems – Fundamentals								
G1.1	Energy Storage Systems	2	VO	3		3		

G1.2	Energy Storage Systems, Laboratory	1	LU	1.5		1.5		
G1.3	Environmental Sensing	2	VO	3	3			
G1.4	Thermal Conversion Routes for Energetic Biomass Utilisation I	2	VO	3	3			
G1.5	Angewandte Energieplanung[EN]	2	VU[(1)]	3		3		
Subtotal Module Group G		**9**		**13.5**	**6**	**7.5**	**0**	**0**
Total Elective Module G2 according to § 9				**34.5**				
Total Compulsory ECTS Module Group G				**48**				

Module Group H: Computational Science and Engineering								
Compulsory Module H1: Computational Science and Engineering – Fundamentals								
H1.1	Multiphysical Simulation I	2	VO	3	3			
H1.2	Multiphysical Simulation I	1	UE	1,5	1.5			
H1.3	Technische Numerik 2[EN]	2	VO	3		3		
H1.4	Technische Numerik 2[EN]	1	UE	1		1		
H1.5	Continuum Mechanics	3	VU[(1)]	4,5	4.5			
Subtotal Module Group H		**9**		**13**	**9**	**4**	**0**	**0**
Total Elective Module H2 according to § 9				**35**				
Total Compulsory ECTS Module Group H				**48**				

Master's thesis								**30**
Free-choice courses according to § 10				**12.5**				
Overall Total				**120**	**30**	**30**	**30**	**30**

EN These courses are conducted in English although they have a German course title.

(1).....1/2 lecture part, 1/2 exercise part
(2).....2/3 lecture part, 1/3 exercise part

§ 9 Elective modules

In the course of the Master's Degree Programme Digital Engineering, an area of specialisation must be completed in the form of a module group (C – H). A module group listed under the area of specialisations is considered as 'completed' when all parts of the compulsory module have been completed in full and when at least the number of ECTS credits assigned to the associated elective module, as specified in the table in § 4, have been achieved.

For the Robotics elective module , at least 35 ECTS credit of courses from the following elective module catalogue must be completed.

Elective Module C2: Robotics – Electives					
Course		Course		Semester Assignment	
	SSt.	**Type**	**ECTS**	**WS**	**SS**
Context-Aware Computing	2	VO	3	3	
Context-Aware Computing	1	UE	1.5	1.5	
Industrieroboter[EN/DE]	2	VU[(2)]	2	2	
Smart Factory	3	LU	3	3	
State Estimation and Filtering	2	VO	3	3	
State Estimation and Filtering	1	UE	1.5	1.5	
Designing Interactive Systems	2	VU[(1)]	3		3

Elective Module C2: Robotics – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Grundlagen der Artificial Intelligence und Logik[DE]	2	VU[(1)]	3		3
Intelligent User Interfaces	3	VU[(2)]	5	5	
Autonomously Learning Systems	2	VO	3	3	
Autonomously Learning Systems	1	KU	2	2	
Intelligent Systems	2	VO	3		3
Intelligent Systems	1	KU	2		2
Computer Vision[DE]	2	VU[(1)]	2.5		2.5
Sensorsysteme[DE]	2	VO	3		3
Sensorsysteme, Labor[DE]	1	LU	1.5		1.5
Robot Vision	2	VO	3		3
Robot Vision	1	KU	2		2
Control of Electric Drives and Machines	2	VO	3	3	
Control of Electric Drives and Machines, Laboratory	2	LU	3	3	
Camera Drones	3	VU[(3)]	5	5	
Selected Topics of Robotics	2	VO	3	3	3

For the Production and Logistics elective module , at least 34.5 ECTS credits of courses from the following elective module catalogue must be completed.

Elective Module D2: Production and Logistics – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Industrielle Logistiksysteme[EN/DE]	2	VO	3		3
Engineering and Automation Technologies in Intralogistics	3	VU[(2)]	3	3	
Mechatronik Systems Engineering[EN/DE]	3	VU[(1)]	3	3	
Material Flow Planning and System Design	3	VU[(2)]	3	3	
Hydraulische Steuerungen und geregelte Antriebe[EN/DE]	2	VU[(2)]	2	2	
Control of Electric Drives and Machines	2	VO	3	3	
Control of Electric Drives and Machines, Laboratory	2	LU	3	3	
Produktion im Automobilbau[EN/DE]	2	VU[(2)]	2	2	
Computer Aided Manufacturing (CAM)[EN/DE]	3	VU[(3)]	3		3
Modellbildung und Simulation in der Produktionstechnik[EN]	2	VU[(2)]	2		2
Modellbildung und Simulation i.d. Materialflusstechnik[EN/DE]	2	VU[(1)]	2		2
Introduction to Materials Science	2	VO	3	3	
Basic Laboratory for Advanced Materials Science	2.67	LU	2	2	
Laboratory Logistics Engineering	3	LU	3	3	
Smart Factory	3	LU	3	3	
CAD[DE]	2	VU[(3)]	3		3
Mechatronic Systems Modelling	2	VO	3		3
Mechatronic Systems Modelling	1	UE	1.5		1.5
Optimal Feedback Design	2	VO	3		3
Optimal Feedback Design	1	UE	1.5		1.5
Embedded Internet	2	VU[(2)]	3	3	
Embedded Internet, Laboratory	2	LU	3	3	
Selected Topics of Production and Logistics	2	VO	3	3	3

For the Mobility and Transportation elective module , 36 ECTS credits of courses from the following elective module catalogue must be completed.

Elective Module E2: Mobility and Transportation – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Verkehrsplanung[DE]	3.5	VO	5	5	
Transport Modelling	4	VU[(1)]	6		6
Navigation Systems	2	VU[(2)]	3	3	
Schienenfahrzeugtechnik[DE]	2	VO	3	3	
Kolbenmaschinen[DE]	2	VO	3	3	
Automotive Engineering 2	2	VO	3		3
Antriebssysteme mit VKM[DE]	3	VO	4.5		4.5
Modelling and MBS Simulation in Vehicle Dynamics	3	VU[(3)]	3		3
Integrale Fahrzeugsicherheit[EN/DE]	2	VO	3	3	
Automated Driving	2	VO	3	3	
Embedded Mechatronic Architectures II	2	VO	3		3
Automotive Electronics	2	VO	3	3	
Real-Time Bus Systems	1	VO	1.5	1.5	
Real-Time Bus Systems, Laboratory	1	LU	1.5	1.5	
Embedded Automotive Software	2	VU[(2)]	3	3	
User interfaces	1,5	VU[(2)]	2		2
Laborübungen Fahrzeugtechnik[EN/DE]	3	LU	3		3
Laborübungen zur passiven Fahrzeugsicherheit[EN/DE]	2	LU	2	2	
Laborübungen zur aktiven Fahrzeugsicherheit[EN/DE]	1	LU	1		1
Sensor Fusion for Automated Driving, Laboratory	2	LU	3	3	
Selected Topics of Mobility and Transportation	2	VO	3	3	3

For the Internet of Things elective module , 35 ECTS credits of courses from the following elective module catalogue must be completed.

Elective Module F2: Internet of Things – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Embedded Internet	2	VU[(2)]	3	3	
Embedded Internet, Laboratory	2	LU	3	3	
Context-Aware Computing	2	VO	3	3	
Context-Aware Computing	1	UE	1.5	1.5	
Mobile Radio Systems	2	VO	3	3	
Secure Application Design	2	VO	3		3
Secure Application Design	1	KU	2		2
Digitale Automatisierungs- und Messtechnik in der Hochspannungstechnik[DE]	2	VU[(1)]	3	3	
Structural Health Monitoring	2	VO	3	3	
Structural Health Monitoring	2	FU	3	3	
Model Based Optimisation of Water Distribution Systems	2	VU[(1)]	3	3	
Automated Driving	2	VO	3	3	
Modelling of Networks	3	VU[(1)]	4.5	4.5	
Transport Modelling	4	VU[(1)]	6		6
Straßenverkehrstechnik und Telematik[DE]	2	VO	3	3	
Navigation Systems	2	VU[(2)]	3	3	
Location-Based services	3	VU[(2)]	4.5	4.5	

Elective Module F2: Internet of Things – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Smart Factory	3	LU	3	3	
Selected Topics of Internet of Things	2	VO	3	3	3

For the Energy and Environmental Systems elective module , 34.5 ECTS credits of courses from the following elective module catalogue must be completed.

Elective Module G2: Energy and Environmental Systems – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Control of Electric Drives and Machines	2	VO	3	3	
Control of Electric Drives and Machines, Laboratory	2	LU	3	3	
Traffic and Air Quality	2	VU[(1)]	2		2
Environmental Technologies	3	VO	4	4	
Energy Systems Analysis	2	VO	3		3
Leistungselektronik[DE]	2	VO	3		3
Power Electronics for Power Engineering	2	VO	3	3	
Power Electronics 2	2	VO	3		3
Elektrische Energiesysteme 1[DE]	2	VO	3	3	
Modelling of Networks	3	VU[(1)]	4.5	4.5	
Erneuerbare Energien[EN/DE]	2	VO	3		3
Gasanwendungs- und Brennstoffzellentechnik[DE]	2	VO	3		3
CFD Applications for Energy Systems	2	VO	3	3	
Solar Energy Use[DE]	2	VO	3	3	
Sonnenenergienutzung[DE]	1	VO	1.5		1.5
Windenergiekonversion[DE]	2	VO	3	3	
Wärmepumpentechnik[EN/DE]	2	VO	3	3	
Environmental Impact of Road Traffic	3	VO	4.5		4.5
Selected Topics of Energy and Environmental Systems	2	VO	3	3	3

For the Computational Science and Engineering elective module, 35 ECTS credits of courses from the following elective module catalogue must be completed.

Elective Module H2: Computational Science and Engineering – Electives					
Course		Course		Semester Assignment	
	SSt.	Type	ECTS	WS	SS
Structural Dynamics	2	VU(1)	3		3
Boundary Element Methods	2	VU(1)	3		3
Plates and Shells	3	VU(1)	4		4
Höhere Festigkeitslehre und FE-Methoden[DE]	2	VO	3		3
Höhere Festigkeitslehre und Finite Elemente Methoden[DE]	1	UE	1		1
Numerical Simulation of Strongly Correlated Many-Body Models	2	VU(1)	3	3	
Numerical Simulation and Modelling of Incompressible Flow	2	VO	3	3	
Numerical Simulation and Modelling of Incompressible Flow	1	UE	1	1	
Laborübung Strömungslehre und Wärmeübertragung[EN/DE]	3	LU	3		3
Laborübung FE-Methoden[EN/DE]	3	LU	3	3	
Multiphysical Simulation II	2	VO	3		3
Multiphysical Simulation II	1	UE	1.5		1.5
Aeroacoustics	2	VO	3	3	
Aeroacoustics	1	UE	1.5	1.5	
Convex Optimisation	3	VU(2)	5		5
GPU Programming	3	VU(2)	5		5
Computational Biomechanics	4	VU(1)	5.5		5.5
Numerics and Simulation	3	VO	4		4
Numerics and Simulation	1	UE	1.5		1.5
Selected Topics of Computational Science and Engineering	2	VO	3	3	3

EN These courses are conducted in English, although they have a German course title.
DE These courses are conducted in German.
EN/DE These courses are conducted in English if they are attended by students in the Master's Degree Programme Digital Engineering. Otherwise, these courses may be conducted in German.

(1).....1/2 lecture part, 1/2 exercise part

(2).....2/3 lecture part, 1/3 exercise part

(3).....1/3 lecture part, 2/3 exercise part

Up to 3 ECTS credits of courses that enable the in-depth study of a foreign language (English or German) can be completed.

Courses with the title "Selected Topics of [module group name] (subtitle)" are assigned to the elective module catalogue, whereby one semester course hour is usually equivalent to 1.5 ECTS credits. 2 SSt. VO of these courses are offered with characteristic subtitles. Courses with different subtitles should be counted as different courses, whereby at most one of these courses can be credited for the respective elective module.

§ 10 Free-choice courses

(1) The courses that need to be completed among the free-choice courses in the Master's Degree Programme Digital Engineering help the student to refine their

individual focus and support further development. These can be freely selected from among the courses offered at recognised domestic and foreign universities as well as at recognised domestic and foreign post-secondary educational institutions. Appendix II contains recommendations for free-choice courses.

(2) If no ECTS credits are assigned to a free-choice course, each semester course hour (SSt.) assigned to this course will be allotted one ECTS credit. However, if such courses are defined as the lecture (VO) type, they are allotted 1.5 ECTS credits per SSt.

(3) Furthermore, according to § 13, students have the possibility to take a professionally-oriented internship or to spend short study periods abroad, achieving up to 4 ECTS within the framework of the free-choice courses.

§ 11 Master's thesis

(1) The master's thesis serves as proof of the student's ability of the student to work on scientific topics independently and must also be acceptable in terms of content and methodology. Care should be taken in choosing the topic of the master's thesis to ensure that the thesis can be completed by the student within six months with a reasonable workload.

(2) The topic of the master's thesis is assigned to a module group (A-H). Any exceptions are subject to approval by the officer responsible for study matters.

(3) The master's thesis must be registered before beginning work on it via the Dean's office with consultation of the respective officer responsible for study matters. The details that should be registered are the topic, the module group (A-H, see table in § 4) that the topic belongs to and the supervisor, stating their institute.

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

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

§ 12 Registration requirements for courses/examinations

In order to be admitted to the master's thesis examination, the student must submit proof of positive completion of all examinations, as described in § 8 to § 10, as well as submit a positively assessed master's thesis.

§ 13 Stays abroad and internships

(1) Recommended stays abroad

Students are recommended to complete a semester abroad during the period of their studies. In this master's degree programme, the 3rd or 4th semester is particularly suitable for this stay abroad. Modules or courses completed during the stay abroad will be recognised by the officer responsible for study matters if they are considered as equivalent. To learn more about how examinations taken during stays abroad are recognised, please refer to § 78 (6) Universities Act 2002 (UG) Recognition of examinations, other academic achievements, activities and qualifications.

Furthermore, once the student has applied to the officer responsible for study matters, achievements made during shorter periods of study abroad – such as active participation in international summer or winter schools – may also be recognised within the framework of the free-choice courses.

(2) Internships

Within the framework of the free-choice courses, it is possible to complete professionally-oriented internships/work experience.

In this context, 1.5 ECTS credits are assigned to each working week under conditions of full employment. Active participation in a scientific event is also considered as professionally-oriented work experience. Any internship has to be approved by the officer responsible for study matters for the degree programme and has to complement the degree programme in a meaningful way.

IV Examination Regulations and Completion of Studies

§ 14 Examination regulations

Courses are assessed individually.

(1) Regarding courses held in the form of lectures (VO: *Vorlesung*), the examination covers the entire course content. Examinations can be held in exclusively oral, exclusively written, or combined written and oral formats.

(2) Regarding courses held in the form of lectures with integrated exercises (VU: *Vorlesung mit integrierter Übung*), exercises (UE: *Übung*), laboratory exercises (LU: *Laborübung*), construction exercises (KU: *Konstruktionsübung*), field exercises (FU: *Feldübung*), projects (PT: *Projekt*), seminars (SE: *Seminar*), seminar projects (SP: *Seminarprojekt*) and excursions (EX: *Exkursion*), the assessment is carried out continuously and based on the students' contributions and/or by the examinations that are held. In any case, the assessment must be based on at least two evaluations of different aspects of the course.

(3) If a module/module group comprises several examinations, the module grade/module group grade will be determined by
   a. the grade of each examination associated with the module/module group is multiplied by the number of ECTS credits assigned to the corresponding course,
   b. the values calculated according to point (a) are added,
   c. the result of this calculation is divided by the sum of the ECTS credits assigned to the courses and,
   d. if necessary, the result of this division is rounded up or down to a whole number. Decimal values greater than 0.5 must be rounded up and, otherwise, rounded down.
   e. A positive module grade/module group grade can only be given if each individual examination has been positively assessed.
   f. Courses where the assessment only confirms successful/unsuccessful participation will not be included in this calculation according to point (a) through (d).

(4) Regulations on repeating parts of assessments for courses with continuous assessment are set out in the Excerpt of Statutes: Legal Regulations for Academic Affairs of TU Graz.

(5) The master's examination before a committee includes
   - the presentation of the master's thesis by the student (maximum 25 minutes),

- the defence of the master's thesis with the members of the examination committee (approx. 15 minutes) and
- the examination discussion with the members of the examination committee on topics from the module group to which the master's thesis is assigned in terms of subject/content.

(6) The total time of the master's examination before a committee is usually 60 minutes and must not exceed 75 minutes.

(7) The examination committee created for the purpose of the master's examination consists of the supervisor of the master's thesis and two additional members, who are nominated by the officer responsible for study matters of the degree programme after hearing the candidate. The examination committee is chaired by a member who is not the supervisor of the master's thesis.

(8) The assessment of this examination is determined by the examination committee on the basis of the performance achieved during the master's examination, in accordance with § 24 (6) of the Excerpt of Statutes: Legal Regulations for Academic Affairs.

§ 15 Completion of studies

(1) The master's degree programme is considered as completed if the courses for all compulsory and elective modules, the free-choice courses, the master's thesis and the master's examination by the examination committee have been the assessed positively.

(2) A graduation certificate will be issued upon the successful completion of the programme. The graduation certificate that signifies completion of the Master's Degree Programme Digital Engineering includes

a. a list of the completed module groups (i.e. module group A, B and the module group for the chosen area of specialisation) according to § 4 (including ECTS credits) and their assessments,
b. the title and assessment of the master's thesis,
c. the assessment of the final examination before a committee,
d. the total number of ECTS credits assigned to the free-choice courses according to § 10, as well as
e. the overall assessment as described in § 11 of the Excerpt of Statutes: Legal Regulations for Academic Affairs.

V Entry Into Force and Transitional Provisions

§ 16 Entry into force

This 2022 curriculum (TUGRAZonline abbreviation 2022W) shall enter into force on October 1, 2022.

Appendices to the Curriculum of the Master's Degree Programme Digital Engineering

Appendix I

Module descriptions and method of performance assessment

Unless otherwise specified in the module description, the assessment of performance in a module is based in each case on the completion of all course examinations and courses with continuous assessment that are included in the module.

Compulsory Module A	**Expansion of Mathematical Competence**
ECTS credits	11.5
Content	This compulsory module enables the student to enhance their mathematical competence in the field of numerical optimisation and offers a basic education in probability, statistics and stochastic processes. Content is taught such as the fundamentals of numerical optimisation, linear, non-linear optimisation, convex optimisation, optimality conditions, the least squares method, gradient method, Gauss-Newton and optimisation over convex sets. In addition, basic concepts are taught of probability theory, such as probability spaces, Laplace experiments, important elementary distributions, random variables, expected value, conditional probabilities, independence, convergence concepts, the law of large numbers and the central limit theorem. Based on these concepts, fundamental knowledge of stochastic processes is presented.
Learning outcomes	Once they have completed the module, students will be able to solve simple statistical problems. They can represent data graphically and describe them numerically. They can determine certain estimators and formulate and test hypotheses independently. They can apply their knowledge to practical problems. They will understand how to correctly interpret and critically question the corresponding results. Furthermore, after completing the module, they will be able to understand and use the most important numerical optimisation terms and methods as well as to solve "large" optimisation problems. Another goal in this module is to be able to use optimisation algorithms independently and to apply the methods learned to practical problems.
Teaching and learning activities and methods	Lectures, exercises in groups, independent use of optimisation algorithms
Recommended prerequisites for participation	-
Frequency in which the module is provided	Every winter semester

Module Group B: Modelling, Simulation and Control of Cyberphysical Systems

Compulsory Module B1	Modelling and Simulation
ECTS credits	9
Content	This compulsory module enables the student to improve their ability to mathematically model complex dynamical systems by taking different approaches. So-called data-driven and physically motivated methods will be presented as learning material. The students will be able to apply and use interdisciplinary methods of physically motivated modelling (e.g. based on mechanical systems). Concepts and methods from the fields of machine learning and pattern recognition will be discussed. In particular, the theoretical foundations of machine learning, linear data transformations, neural networks, support vector machines, hidden Markov models used with sequential data and unsupervised learning methods will be discussed. Additional content in this module extends the student's basic knowledge of physically motivated model building, covering the fundamentals of optics, selected elements of quantum mechanics, thermal radiation and selected topics in solid-state physics.
Learning outcomes	Once they have completed the module, students will understand the fundamentals and key concepts of machine learning. Students will understand the most important learning algorithms (e.g. neural networks, support vector machines, k-nearest neighbour, regression, Bayes and maximum likelihood estimation, linear transformations), be able to identify the respective advantages and disadvantages, and be able to select and apply appropriate methods in practical applications. Furthermore, the students will understand the most important concepts related to statistical data analysis (e.g. regularisation, data splitting) and be able to deal with probabilistic and sequential models. They can apply their knowledge, e.g. from the fields of optics, thermal radiation and quantum mechanics, to the mathematical modelling of specific problems. Based on mechanical systems, their modelling ability will be increased, meaning that they can formulate equations of motion for multi-body systems by applying various methods (e.g. Newton-Euler equations of motion, Lagrangian equations of motion of the 1st and 2nd kind).
Teaching and learning activities and methods	Lectures, lectures with integrated exercises, exercises in groups, independent execution or preparation of numerical simulation examples.
Recommended prerequisites for participation	-
Frequency in which the module is provided	Each academic year

Compulsory Module B2	Signal and Systems
ECTS credits	9
Content	This compulsory module offers the student, on the one hand, the chance to improve their ability to understand a complex overall system composed of networking subsystems – specifically with regard to digital data exchange and the embedded systems

	used, and, on the other hand, to influence the overall system behaviour as desired. Fundamental information about embedded systems, target architectures and hardware platforms, software and real-time requirements, distributed embedded systems and internet-enabled embedded systems will be discussed. Example applications and case studies will be presented to deepen the knowledge shared. Control algorithms that can be systematically derived based on a nonlinear mathematical model will be discussed as algorithms that can be used in the embedded systems. For example, the method of Exact Linearisation for single and multivariable systems will be taught. To support the design of robust control loops, the so-called "adaptive backstepping" and the "sliding-mode control" schemes will be discussed. Topics such as the fundamentals of digital transmission systems, modulators and demodulators, and ways in which signal and transmission channel representations shape the content regarding how the networked subsystems digitally communicate with each other.
Learning outcomes	After completing the module, students will have gained deeper insights into the problems related to embedded systems. They will be able to analyse problems in this area and be able to apply the acquired methods to solve simple problems. They will also be able to design robust control algorithms for nonlinear systems and understand basic aspects of digital communication, as well as be able to use several methods to classify and describe signals.
Teaching and learning activities and methods	Lecture with media support, laboratory exercises, exercises in groups, calculation exercises
Recommended prerequisites for participation	Attendance of courses in module group A
Frequency in which the module is provided	Each academic year

Module Group C: Robotics

Compulsory Module C1	**Robotics – Fundamentals**
ECTS credits	13
Content	This compulsory module enables the student to improve their fundamental knowledge of mobile robots. In addition to selected architectures of autonomous intelligent systems and robots, methods for self-localisation, world modelling and multi-agent systems will be discussed. Additionally, decision-making using artificial intelligence as well as the required or most common software architectures of mobile robots will be discussed. As an essential part of this module, students will design a mobile robot, selecting or creating both the hardware and the software in order to enable the robot to perform a specific task.
Learning outcomes	After completing this module, students will have basic knowledge about relevant methods used for the world modelling, control and decision-making of mobile robots. They will be able to design and use an appropriate mobile robot to perform a given task.
Teaching and learning activities and methods	Hands-on lab work, working in small groups, Implementation of algorithms, lectures

Recommended prerequisites for participation	-
Frequency in which the module is provided	Each academic year

Elective Module C2	**Robotics – Electives**
ECTS credits	35
Content	This elective module offers advanced training in the field of robotics. Methods for behaviour control adapted to the robot's environment play a central role in this training. To achieve this purpose, different method variants used to evaluate the robot state as well as to enable the robot to recognise and perceive the environment will be discussed. Machine learning methods as well as algorithms for path planning with precise robot kinematics will be discussed as possible algorithms for behaviour control. Some of the courses that can be selected in this module address the possibility of using sensor technology for environmental perception and known method variants for controlling commonly used electric drives.
Learning outcomes	After successfully completing the module, students will know how to enable a robot to perceive its environment. They will be able to train the robot to generate automated decisions, enabling them to control the robot based on the perceived environment. In addition, they will know precisely how to control the robot actuators.
Teaching and learning activities and methods	Lectures, courses with continuous assessment, laboratory exercises
Recommended prerequisites for participation	-
Frequency in which the module is provided	Each academic year

Module Group D: Production and Logistics

Compulsory Module D1	**Production and Logistics – Fundamentals**
ECTS credits	12.5
Content	This compulsory module introduces digitalised production techniques and logistical processes. To this end, the topics of automated production machines and transport means will be covered. The training includes aspects of virtual factory planning, networked and individualised production and optimised material flows and goods transports (e.g. route planning). In addition, methods for modelling motion sequences in industrial robots will be covered, and methods used to design controllers and observers (also for systems with limited input

	variables) will be discussed. Selected methods will be practically tested in laboratory exercises.
Learning outcomes	After completing the module, students will be familiar with linear programming models, understand their properties and limitations, and know how to solve the developed models. In addition, they will have gained experience with solving mixing, scheduling, transport and network problems. They will learn simulation techniques (e.g. Monte Carlo simulation) and understand relevant relationships between simulation and real systems. In addition, they will have a better understanding of how to solve practically relevant control engineering problems and significantly more knowledge about how to use modelling methods based on industrial robots.
Teaching and learning activities and methods	Lecture with integrated exercises, lecture with media support, laboratory exercises
Recommended prerequisites for participation	-
Frequency in which the module is provided	Each academic year

Elective Module D2	**Production and Logistics – Electives**
ECTS credits	35.5
Content	This elective module offers advanced training in the modelling, simulation, optimisation and design of modern production and logistics systems. In addition to reviewing basic logistics concepts, topics such as the design and planning of logistics distribution centres, warehousing and order picking systems, and driverless transportation systems will be discussed. In addition, courses can be chosen that cover topics such as electrical, mechanical, or hydraulic system modelling or basic knowledge about integrating the Internet to ensure the reliable operation of networked systems.
Learning outcomes	After completing the module, students will have a basic understanding of modelling, simulation and optimisation in networked production and logistics systems. They will be able to model and design drive and control components (mechanical, electrical, or hydraulic) and they understand various computer-aided manufacturing options.
Teaching and learning activities and methods	Lectures with audio-visual support, exercises and laboratory exercises, lectures with media support, lectures with integrated exercises
Recommended prerequisites for participation	Previous knowledge of production engineering and mechanical engineering is helpful
Frequency in which the module is provided	Each academic year

Module Group E: Mobility and Transportation

Compulsory Module E1	**Mobility and Transportation – Fundamentals**
ECTS credits	12

Content	This compulsory module addresses fundamental aspects of automotive engineering and mobility systems necessary for transporting goods and people. Vehicular system functions and embedded components and subsystems (such as the powertrain, steering, or the chassis with a braking system and their interactions) will be discussed. The dynamic behaviour of complete vehicles will be modelled and simulated. Electromobility (including applications, vehicle architectures and charging technologies) will be covered in addition to fundamental knowledge about vehicle modelling, enabling students to assess driving behaviour, driving stability and interactions among the mechanics, sensors, actuators, software and driver. How modern transportation systems are developed using established mechatronic development processes and the development standards relevant to this field are also discussion topics in this module.
Learning outcomes	After completing the module, students will be familiar with the main structures or components of motor vehicles and will be able to create initial rough designs, e.g. of spring-damper systems. They will have a basic knowledge of how mechatronic automotive components and systems and various drive technologies operate and function. They will be able to understand and model dynamic vehicular behaviour. In addition, upon completing the module, students will understand how mechatronic systems and the corresponding development standards are developed, as well as guidelines and methods used for quality assurance.
Teaching and learning activities and methods	Lecture with media support, lecture with audio-visual aids and PC simulations
Recommended prerequisites for participation	-
Frequency in which the module is provided	Each academic year

Elective Module E2	**Mobility and Transportation – Electives**
ECTS credits	36
Content	This elective module offers advanced education in the field of transportation and mobility. This covers, for example, fundamental knowledge of transportation planning, ways to simulate transportation networks, and methods that can be used to improve navigation and the integral safety of vehicles in transportation systems. The student's knowledge of automotive systems (i.e. drive systems and vehicle physics) will be deepened. The topics of mechatronic and automated driving functions, software and data communication, sensor technology and data fusion, and human-machine interfaces will be discussed. The theoretical knowledge will be complemented and applied in practical laboratory exercises.
Learning outcomes	After completing the module, students will be able to use digital technologies to develop sustainable vehicle and mobility systems. They will be able to use traffic planning and traffic simulation software to solve problems in public and individual transport. They will also be able to assess safety and accident risks in transportation systems. Students will be able to understand, model and optimise complex mechanical-digital vehicle systems. They acquire knowledge of the integrated

	development processes for software, hardware, mechanics and infrastructure. This knowledge can then be practically applied using design methods, simulation and experimental investigations and implemented in real hardware.
Teaching and learning activities, methods	Lectures with audio-visual support, laboratory exercises, lectures with media support, lectures with integrated exercises, interaction between teachers and students
Recommended prerequisites for participation	Knowledge of vehicle measurement technology, "Passive Safety – Injury Mitigation", "Active Safety – Accident Mitigation" and "Trauma Biomechanics"
Frequency in which the module is provided	Each academic year

Module Group F: Internet of Things

Compulsory Module F1	**Internet of Things – Fundamentals**
ECTS credits	13
Content	This compulsory module introduces computer systems that are embedded in physical environments and networked with both each other and with the Internet. These systems can perceive the physical environment by means of sensors and influence it with actuators. An emphasis is placed on systems where the requirements regarding reliability and security are particularly relevant. Sensor networks represent part of the content of this module, consisting of hundreds of sensor nodes ("minicomputers" equipped with sensors and radio modules), which are battery-powered and collect sensor data over long periods of time, and transmit these data to other nodes or to a base station, respectively. For this purpose, topics such as energy-efficient wireless networking, time synchronisation, position determination and distributed sensor data processing are discussed. As another part of the content, an introduction to the central topic of information security will be given in order to establish a basis for reliability and security. Cryptography and computer security are emphasised, i.e. topics like cryptographic algorithms, digital signatures, secure communication protocols, threat scenarios for IT systems, isolation techniques, runtime security, side channel attacks and protection mechanisms are covered.
Learning outcomes	After completing the module, students will understand the basic concepts of cryptography and computer security. They will be familiar with the central challenges and corresponding solution approaches. They will also understand the basic concepts, as well as the possibilities and limitations, of wireless sensor networks and can understand and further evaluate scientific literature on the subject of wireless sensor networks. Students will have acquired the ability to independently develop and evaluate sensor network applications.
Teaching and learning activities and methods	Lectures, courses with continuous assessment; in the exercise part, students address specific topics, summarise concepts independently, and present them in short lectures, laboratory exercises

Recommended prerequisites for participation	Attendance of the courses “Embedded Systems” and “Embedded Systems, Laboratory” from Compulsory Module B2
Frequency in which the module is provided	Each academic year

Elective Module F2	**Internet of Things – Electives**
ECTS credits	35
Contents	This elective module enables the student to deepen their knowledge in the area of networked and internet-connected embedded systems as well as to assess their reliability and security. Based on specific applications, such as automated determination and monitoring of the status of bridges, railroad systems, water supply systems, intelligent factories, energy systems and traffic control systems, the basic knowledge acquired is broadened to include aspects specific to particular applications.
Learning outcomes	The students will understand the challenges presented by the "Internet of Things", especially in combination with safety-critical requirements. They will also become familiar with the most important standard forms of communication between individual devices and basic concepts and technologies used in the technical design of networked and safety-critical applications.
Teaching and learning activities and methods	Lectures, lectures with media support, lectures with integrated exercises, laboratory exercises
Recommended prerequisites for participation	Attendance of the courses “Embedded Systems” and “Embedded Systems, Laboratory” from Compulsory Module B2
Frequency in which the module is provided	Each academic year

Module Group G: Energy and Environmental Systems

Compulsory Module G1	**Energy and Environmental Systems – Fundamentals**
ECTS credits	13.5
Content	In this compulsory module, fundamental knowledge about energy use based on renewable energy sources and biomass combustion is taught. In addition, the topic of modelling biomass combustion for thermal energy production will also be addressed. Methods for emission, immission, and particulate measurement, storage of energy, and the "optimal" use of energy sources will be discussed. Regarding energy storage, applications of mobile energy storage will specifically be addressed. Laboratory exercises will include the measurement of various energy storage devices, modelling using equivalent circuit diagrams, and simulation.
Learning outcomes	After successfully completing the module, students will be able to name the types and origins of air pollutants, and understand and evaluate sensor concepts for emission and immission. They will be familiar with basic concepts related to the production of e.g. heat and biofuels from biomass and can suggest possible production variants, depending on the biomass availability. They will know and understand the functional principles of selected energy storage systems and be able to determine their relevant

	parameters experimentally in the laboratory, as well as to perform simulations based on them.
Teaching and learning activities, methods	Lectures with media support, laboratory exercises
Recommended prerequisites for participation	Basic knowledge of chemistry (school leaving exam level)
Frequency in which the module is provided	Each academic year

Elective Module G2	**Energy and Environmental Systems – Electives**
ECTS credits	34.5
Content	This elective module addresses topics related to sustainable energy generation, conversion, storage and distribution. The estimation, modelling and measurement of the partially associated impacts of these processes on nature and the environment are also addressed in this module. The energy sources considered are mainly renewable energy sources. Ways of converting energy into electrical energy will be discussed, including discussions of both mechanical aspects (e.g. wind turbine and wind wheel designs, solar collector designs and their hydraulic interconnections) and electrotechnical aspects (e.g. power electronics required for energy conversion). The environmental effects of energy production and energy conversion will be discussed, e.g. exhaust air systems are discussed and calculations are performed or the emission behaviour of vehicles is addressed. Discussions on the impacts, modelling and simulation of pollutant emissions, and especially from the transportation sector, are also included in this module.
Learning outcomes	The students will become familiar with different methods used to conserve and store energy, as well as to understand the entire chain of effects from generation to storage. They will be made aware of the energy sector affects the environment and learn procedures used for modelling, simulating but also reducing these effects. The students will gain an in-depth knowledge on renewable energy topics.
Teaching and learning activities and methods	Lectures with media support, lectures with integrated exercises
Recommended prerequisites for participation	Basic knowledge of chemistry (school leaving exam level)
Frequency in which the module is provided	Each academic year

Module Group H: Computational Science and Engineering

Compulsory Module H1	**Computational Science and Engineering – Fundamentals**
ECTS credits	13
Content	This compulsory module addresses the modelling and simulation of multiphysics problems. In general, the quantities used to describe physical effects in coupled field problems are a function of location and time. This description yields a system of partial differential equations (e.g. electromagnetics-mechanics-acoustics). In this module, numerical methods, such

	as the finite element method, will be explained in detail. Properties but also limitations of various numerical methods will be discussed and applied to concrete examples (e.g. the mechanics of electric field heat transfers or mechanical-acoustic couplings). Students will independently perform simulations of practically relevant coupled field problems.
Learning outcomes	After completing the module, students will understand essential aspects of how to model multiphysical systems as well as basic mathematical considerations for using different numerical methods to simulate these systems. They will be able to create the models themselves and to set up and run simulations.
Teaching and learning activities and methods	Calculation exercises, lectures with media support, lectures with integrated exercises
Recommended prerequisites for participation	-
Frequency in which the module is provided	Each academic year

Elective Module H2	**Computational Science and Engineering – Electives**
ECTS credits	35
Content	This elective module enables the student to deepen their knowledge in the area of modelling and simulating multiphysics problems. Additional solution algorithms will be discussed and demonstrated by presenting practical examples. Insofar as possible, analytical solutions will be derived and compared with the independently determined numerical solutions. More detailed discussions of the methods presented will be supported, for example, by applications taken from the fields of fluid acoustics, electromagnetics-mechanics, electromagnetics-thermics, plane structures, or from applications relevant to modelling and simulating biological materials.
Learning outcomes	After successfully completing the module, students will be able to explain fundamental physical aspects of mechanical, electro-magnetic, fluidic, thermal and acoustic fields as well as their couplings, to formulate the finite element method mathematically and to apply it in a program. They will also be able to independently carry out all of the necessary steps to perform a successful finite element analysis, from the modelling to the pre-processing stage. They will then be able to perform the actual finite element simulation up to the post-processing stage, interpret the simulation results while considering physical aspects so that they can take appropriate steps to improve the existing systems and develop new ones, and to identify and further investigate research-relevant topics.
Teaching and learning activities and methods	Lectures with integrated exercises, lectures with media support, laboratory exercises
Recommended prerequisites for participation	Fundamentals of acoustics
Frequency in which the module is provided	Each academic year

Appendix II

Recommended free-choice courses

Free-choice courses can be freely chosen from among the courses offered at recognised domestic and foreign universities as well as at recognised domestic and foreign post-secondary educational institutions according to § 10 of this curriculum.

To broaden the knowledge base in the module subject areas in this degree programme, students are recommended to take courses offered in the fields of foreign languages, social competence, technological impact assessment as well as women's and gender studies. In particular, the student’s attention is directed toward offers provided by the service department Languages, Key Competencies and In-House Training at TU Graz, by treffpunkt sprachen at the University of Graz, by the Center for Social Competence at the University of Graz, and by the Science, Technology and Society Unit.

Appendix III

Course types

At TU Graz, the following types of courses are offered as described in § 4 (1) in the Excerpt of Statutes: Legal Regulations for Academic Affairs. The courses mentioned in number 2) through number 12) are courses with continuous assessment.

(1) VO ... (*Vorlesung*) Lecture: Lectures introduce students to the subject and its methods in a didactically systematic manner. The subject content and methods are presented.
(2) UE ... (*Übung*) Exercise: Exercises develop the students' skills in applying the subject to specific problems.
(3) KU ... (*Konstruktionsübung*) Design exercise: In design exercises, skills and abilities are taught as part of scientific pre-vocational training, deepening and/or complementing the material taught in the associated lectures in design work. Special equipment or spatial facilities are required.
(4) LU ... (*Laborübung*) Laboratory exercise: In laboratory exercises, skills and abilities are taught in the course of practical, experimental and/or constructive work as part of scientific pre-vocational training. Particularly intensive supervision is provided during these exercises, deepening and/or complementing the material taught in the associated lectures. As an essential component, laboratory exercises require the student to prepare protocols on the work that is carried out.
(5) PT ... (*Projekt*) Project: In projects, experimental, theoretical and/or constructive, applied work or small research projects are carried out, taking into account all of the necessary steps to perform this work. Projects result in a written paper that forms part of the assessment. Projects can be carried out as teamwork or as individual work; if the work is performed in a team, it must still be possible to assess the individual performance.
(6) VU ... (*Vorlesung mit integrierter Übung*) Lecture with integrated exercises: Lectures with integrated exercises (VU) offer not only an introduction to subtopics within the field and methods used in this field, but also instructions that enable the student to independently acquire knowledge or independently apply this knowledge through examples.
(7) SE ... Seminar: Seminars present scientific methods, teach students how to develop and critically evaluate results of their own work, present special chapters of scientific literature and enable them to practice leading and participating in technical discussions. Written work is prepared, presented and discussed.
(8) SP ... (*Seminarprojekt*) Seminar project: In seminar projects, scientific methods are used to solve experimental, theoretical and/or constructive applied problems. Alternatively, small research projects are carried out, taking into account all of the necessary work steps. Seminar projects culminate in a written paper and an oral presentation that forms part of the assessment. Seminar projects can be carried out as teamwork or as individual work; if the work is performed in a team, it must still be possible to assess the individual performance.
(9) EX ... (*Exkursion*) Excursion: Excursions serve to illustrate content developed in other course types by demonstrating the practical relevance of this content beyond the studies.

(10) OL ... (*Orientierungslehrveranstaltung*) Orientation course: Orientation courses provide students with opportunities to gain further information and have been designed to provide an overview of the programme.
(11) PV ... (*Privatissimum*) Exclusive tutorial: The exclusive tutorial is a research seminar that is part of the doctoral programme.
(12) FU ... (*Feldübung*) Field exercise: Field exercises are held away from the TU Graz campuses, i.e. in the field, for example, near a road, at construction sites, in alpine terrain, in a forest, in a tunnel) and partly also under inhospitable weather conditions. After receiving appropriate preparation, the students essentially carry out the exercise tasks on their own.