

Appendix to the examination regulations

Modules of the degree program

# Sustainable Engineering of Products and Processes (Bachelor) PO 1

Date: 10.03.2025

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Bachelor Sustainable Engineering of Products and Processes	
ECTS	180

Compulsory Modules: Fundamentals of Mathematical Science and Information Technology	
ECTS	31

Title	Digital Tools
Number	2515300
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written examination+ (135 min)
Course achievement	<ul> <li>2 optional course achivements:</li> <li>a) Creation and documentation of computer programmes in the winter semester.</li> <li>(on application, the result of the course achievement is taken into account in the assessment of the written examination+. The course achievement can account for up to 10 % of the grade of the written examination+.)</li> <li>b) Creation and documentation of computer programmes in the summer semester</li> <li>(on application, the result of the course achievement is taken into account in the assessment of the written examination+.)</li> <li>b) Creation and documentation of computer programmes in the summer semester</li> <li>(on application, the result of the course achievement is taken into account in the assessment of the written examination+. The course achievement can account for up to 10 % of the grade of the written examination+.)</li> <li>In the case of a) and b), the application must be submitted to the examiner before the start of the written examination+.</li> </ul>
Module grade composition	
Objective qualification	
After completing the module, students are able to use object-oriented programming languages (Python, C ++) and their environment (development environments, expansion modules) in a goal-oriented manner. The skills learned include	

After completing the module, students are able to use object-oriented programming tanguages (Fython, C ++) and then environment (development environments, expansion modules) in a goal-oriented manner. The skills learned include working effectively with vectors, matrices and their algebra, visualizing and analyzing data, performing simple simulations and working with symbolic mathematics. The students are able to combine and link efficiently and problem-oriented the various digital tools. Furthermore, the students are able to perform object-oriented software engineering for new problems and to design algorithms on the basis of design patterns and to develop and use corresponding data structures. The students also have initial theoretical and practical knowledge in the areas of optimization and machine learning.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fascination Mechanical Engineering
Number	2516510
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam+ (90 min) or oral examination (30 min)
Course achievement	course achievement: Term paper in the form of a video presentation on the project accompa- nying the lecture (on application, the result of the course achievement is taken into account in the assessment of the written examination+. The course achievement can account for up to 20% of the grade of the written examination+)
Module grade composition	
Objective qualification	
The students are able to identify and apply by	: asic engineering methods

- recognize knowledge gaps and fill them through their own research,
- identify and apply the fundamentals of systematic problem-solving in engineering,
- describe and abstract technical solutions as systems,
- grasp simple technical problems using basic physical principles and effects, and translate them into technical solutions,
- describe their own ideas and proposed solutions, and present them to an audience using digital media formats.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Mathematics for Engineers A
Number	1294250
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 written exam (180 minutes) After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination.
Course achievement	
Module grade composition	

#### **Objective qualification**

The students combine the learnt mathematical methods of univariate calculus and linear algebra in the description and investigation of applied problems in the engineering

sciences. They choose appropriate calculation techniques and appropriate methods of proof for the discussion of the mathematical fundamentals in the applied and engineering sciences,

and they apply these techniques and methods. The students explain the formation of mathematical concepts and they derive the motivation of these concepts from applications and from the mathematical specification and delimitation of terms and definitions. The students reproduce and explain basic proofs and ideas of proofs in univariate calculus and linear algebra. They are able to identify and to test relations between the learnt concepts. The students are able to analyse mathematical problems occurring in applications and engineering lectures,

to extract and to solve treatable sub-problems and to identify continuative difficulties. Finally, students use constructively modern tools for the treatment of computational problems.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Mathematics for Engineers B
Number	1294260
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 written exam (180 min) After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination.
Course achievement	
Module grade composition	
Objective qualification	
The students combine the learnt mathematical methods of multivariate calculus and differential equations in the descrip- tion and investigation of applied problems in the engineering sciences. They use constructively the mathematical forma-	

tion and investigation of applied problems in the engineering sciences. They use constructively the mathematical formalism of scalar and vector fields, of differential operators, of different integral concepts and of Fourier analysis to model and analyse mechanical applications. The students describe time-dependent processes by means of ordinary differential equations and explain the close relation to dynamics and to oscillations. They analyse the quantitative and qualitative behaviour of ordinary differential equations and explicate the basic existence and uniqueness theorems. The students model fundamental applications, derive the behaviour of the trajectories and calculate solutions of systems of differential equations manually as well as by use of modern computational tools. The students combine their competences in technical mechanics with those in mathematics and they transfer their detailed insight of the one-mass oscillator to more general oscillating systems and their motion. They identify the system response and transient parts of the oscillations, and they explain resonance phenomena.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Control Theory
Number	2599460
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 Examination element: written exam (120 min)
Course achievement	
Module grade composition	
Objective qualification	
Students know the basic	c structures, terms and methods of control engineering and can apply them to all simple tech-

Students know the basic structures, terms and methods of control engineering and can apply them to all simple technical or physical systems. With Laplace transformation, transfer function, frequency response, stability criteria, state space concept and the description of mathematical systems, students learn how to set up equations for unknown dynamic systems. Furthermore, control loop elements, the analysis of linear systems in the time and frequency domain as well as controller design for unknown systems can be applied. By means of theoretical and illustrative examples, the students can abstract and deal with control engineering problems from various disciplines. The control engineering methods and requirements are placed in the context of the design of production processes, process optimization and process control and can be transferred by the students to corresponding unknown systems.

Compulsory Modules: Fundamentals of Engineering	
ECTS	23

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fundamentals of Fluid Mechanics
Number	2512190
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (150 min) or oral exam (45 min)
Course achievement	
Module grade composition	
Objective qualification	
The students can deline	ate the characteristics of continuum analysis in fluids. The students can state and explain the

The students can delineate the characteristics of continuum analysis in fluids. The students can state and explain the axioms of moving fluids. They can derive useful simplifications of the equations of motion of fluids and explain the corresponding physical content. The students are able to relate application oriented problems of fluid mechanics to analytical or empirical mathematical models and to solve the associated mathematical relations.

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Title	Engineering Mechanics 1
Number	2544040
ECTS	8,0
Compulsory requirements	none
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam of 120 min
Course achievement	
Module grade composition	
Objective qualification	
After completing this co	ourse attendees are familiar with the basic concepts and methods of statics and mechanics of

After completing this course attendees are familiar with the basic concepts and methods of statics and mechanics of materials. The course enables the attendees to model, design and assess elastostatic components and systems.

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Title	Engineering Mechanics 2
Number	2540460
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam, 90 minutes
Course achievement	
Module grade composition	
Objective qualification	
<b>T</b>	

The students can name the basic concepts and can apply methods of kinematics and kinetics. They can model simple dynamic components and systems, formulate the associated equations of motion and solve them if necessary. Students are able to use an energy and working principle to analyse specific solutions. Students should independently formulate, solve and evaluate mechanical problems in engineering problems.

# ↑

Title	Thermodynamics 1
Number	2519180
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam, 90 minutes
Course achievement	
Module grade composition	
Objective qualification	

Students are able to name the basic terms and laws of thermodynamics and to list their most important consequences for energy conversion processes. The students can explain relevant characteristic numbers of technical systems on the bases of thermodynamic fundamentals. The students are able to apply scientific statements and processes in the field of thermodynamics to specific and practical problems. Students can analyze technical systems using balance equations of energy, mass, momentum and entropy. The students decide which of two processes is better suited to solve a problem of thermodynamics.

# Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Compulsory Modules: Engineering Applications	
ECTS	14

Title	Fundamentals of Engineering Design
Number	2516520
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min) or oral exam (30 min)
Course achievement	1 course achievement: homework, during the semester
Module grade composition	
Objective qualification	

The student is capable of:

- interpreting and creating standards-compliant and technical drawings that follow the current rules and standards for technical drawing
- discussing a question for the display of technical objects in a team and find a solution together
- laying out of the stationary strained component with the help of the given computation methods
- developing technical constructions of low complexity with the principles and rules of the design and construction technical components and componentry, and being able to assess their operativeness
- knowing the functional usage of springs and suspension elements and being able to explain those with the help of current standards and computation methods
- knowing the functional usage and design of shafts and axle, and being able to explain those with the help of current standards and computation methods
- knowing the functional usage of detachable (screws, bolts, pins) and inseparable (weldings, soldering, adhesive) connections based on technical requirements and being able to design and interpret according to stress
- naming and explaining the functioning and usage of pipes and tanks based on examples
- naming and explaining the structure, functioning and usage of static and dynamic sealing elements based on the construction-examples and being able to use the sealing elements in the technical componentry following the technical requirements
- apply basic functions of a CAD program using simple design examples

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Materials Science	
Number	2524370	
ECTS	6,0	
Compulsory requirements		
Compulsory attendance		
Expected performance/ Type of examination	written exam, 120 minutes	
Course achievement		
Module grade composition		
Objective qualification		
Students understand the mechanisms in metals. This nical engineering in a metals. The shape. They are able to can read phase diagrams of motion for vacancies corrosion and can evalue and the design of compo- metals, ceramics, polym components. The studer cally explain the capacity most important principle able to discuss the influe Moreover, they can outfle	relationship between material structure and material properties as well as the strengthening This enables them to select and use metals, ceramics and polymers for applications in mecha- heaningful way. For simple load cases they can calculate stresses, elastic strains and changes in analyze stress-strain diagrams and determine material properties based on these diagrams. They s. They are able to classify steels based on their designation. They comprehend the background and atoms at elevated temperatures. They understand essential mechanisms of oxidation and ate simple oxidation and corrosion processes on this basis. They learn how to assess materials onents by using different test methods. The course treats important methods of processing of hers and fibre reinforced composites, as well as the influence of these processes on properties of fits learn different application cases on basis of various examples. The students are able to basi- ty to withstand stresses of materials with regard to different test methods. They can describe the es of the processing of metals, polymers and fiber reinforced composites. Furthermore, they are ence of the processes on the properties of the component part with regard to the process chain. tine the scope of application with descriptive examples.	

Compulsory Modules: Sustainability	
ECTS	17

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Energy Systems
Number	252000000
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	

#### **Objective qualification**

Energy Systems provides a thorough understanding of key topics in energy science and engineering. The stu-dents will explore various energy carriers and the principles of chemical reactions and combustion systems in energy production. The course covers mass and energy balance to ensure a solid foundation in analysing and optimizing energy processes. Students will study chemical and electrochemical reactions, focusing on their roles in electrochemical energy conversions and storage systems such as electrolysers, fuel cells, and batteries.

The students get basic knowledge on heat transfer and thermodynamic cycles, emphasizing energy efficiency and the fundamental principles governing these processes. A significant portion is dedicated to solar and photo-voltaic systems, highlighting the latest advancements and applications in renewable energy technologies. Mechanical energy systems and nuclear energy systems are briefly examined to generate a comprehensive understanding of both traditional and innovative energy sources.

Additionally, the course addresses critical aspects of energy storage, distribution, and management, preparing students to tackle the challenges and complexities of modern energy infrastructure. To enhance theoretical knowledge with practical experience, lab visits to institutions e.g., the Institute for Energy Systems (InES) and the Battery Lab Factory Braunschweig (BLB) are integrated into the curriculum. These visits allow students to gain practical insights into real-world energy systems and technologies.

This comprehensive approach equips students with the knowledge and skills necessary to innovate, manage, and lead in the evolving international energy landscape. By combining theoretical foundations with practical applications, the course prepares graduates to become proficient in developing sustainable energy solutions and advancing the field of energy systems engineering.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Environmental and Social Sustainability in Engineering
Number	2513350
ECTS	6,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	Written examination+ (120 min) or oral examination (30 min)
Course achievement	Report on the lecture-accompanying team project and presentation (On application, the result of the course achievement is taken into account in the assessment of the written examination+. The course achievement can account for up to a maximum 10 % of the grade of the written examination+.)
Module grade composition	
Objective qualification	1

With regard to environmental sustainability students are # able to name the global challenges on environmental sustainability and describe the levers of product and process engineering on those impacts based on the IPAT equation. Furthermore, the students can reflect on each of the terms of the equation and their complex interactions # able to explain the concepts of relative and absolute sustainability. In this regard, the students are able to describe the concept of planetary boundaries regarding the earth#s carrying capacity. The students are furthermore able to reflect on the challenges related to the allocation of safe operating spaces. # able to describe different environmental impact categories including the impact pathway of the emissions causing this impact and name their end-point indicators. # able to apply systems thinking to critically analyze on the life cycle of technical products and processes. # able to critically reflect on the influence exerted by the surrounding background systems to a technology with regard to its environmental impact. # able to describe the scope and fields of action of Life Cycle Engineering (LCE). # are able to name methods and tools in LCE, from qualitative to quantitative approaches, and are able to discuss their application potentials within engineering activities. # able to explain the core life cycle assessment (LCA) method, including key terms (e.g. environmental impact, functional unit, system boundary). Furthermore, the students are able to understand the challenges of LCA-based Life Cycle Engineering and can name strategies to address those challenges. With regard to social sustainability students are # able to identify how local and global inequalities are inscribed in engineering practices and understand the social impact of engineering products on the basis of fundamental concepts of inequality (e.g. subjective, structural and symbolic dimensions of inequality, intersectionality and diversity, gender studies). # aware of the mutual influence society, engineering and scientific knowledge production have on each other and can explain basic approaches and concepts of social and cultural studies of technology (SST, SCOT, ANT etc.), which theoretically grasp this relation of mutual construction. Furthermore, they can apply these concepts to different fields of engineering and technological products. # able to identify social actors/stakeholders who are involved in engineering practices, overseen, affected by their outcomes or intended to use the respective product of these practices in the future. They know suitable methods (e.g. PD, VSD, OD) to communicate and work with these social actors/stakeholders and can employ them in different contexts. # able to recognize and analyze conflicts of interests and dilemma situations in engineering processes, which might result from taking into account a) marginalized, vulnerable or so far overseen social actors/stakeholders, b) different dimensions of sustainability (e.g. social, economic, ecological) or c) ethical considerations. # able to reflect on their own perspectives, interests and responsibilities as future engineers, in order to make conscious and socially responsible design decisions.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Sustainable Business Economics
Number	2542010
ECTS	6,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	<ul> <li>2 examination elements:</li> <li>a) written exam, 60 minutes or oral exam, 20 minutes (according to Production Systems and Supply Chains)</li> <li>b) term paper (according to Entrepreneurship and Business Model Generation)</li> </ul>
Course achievement	
Module grade composition	
<b>Objective qualification</b>	1

Part A Students...

- can explain the challenges of global production and sustainable development

- can describe production processes and systems using mathematical models

- have a basic understanding of economic assessment concepts and methods

- understand the importance of considering production systems in the context of supply chains

- know the pertinent approaches for life-cycle oriented sustainability assessment

- can apply life-cycle oriented assessment methods to analyze simple production systems and supply chains

- are able to transfer the individual assessment methods into an integrated assessment approach

- are familiar with the key concepts of decision theory and capable to apply simple multi-criteria decision-making models

Part B Students...

- have a general understanding of entrepreneurship and high-tech entrepreneurship

- can differentiate between invention and innovation and is able to explain disruptive innovation

- have a basic understanding of business model generation

- can analyze and develop appropriate value propositions for specific market targets

- can explain the characteristics of entrepreneurial mindset

- are familiar with the Lean Startup Approach

- can apply different tools that facilitate starting a business

- know how to validate the business models

- can describe the key stakeholders of an entrepreneurial ecosystem

- understand the sustainable business concept

- have a basic understanding of venture capital and high-tech startup grants

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Specialisation: Sustainable Mobility

Specialisation Sustainable Mobility - Compulsory Modules	
ECTS	43

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Aircraft Design
Number	2515320
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: term paper according to examiner's specifications
Course achievement	
Module grade composition	
Objective qualification	1
In this course students will learn, how to design a transport aircraft from scratch based on the given top-level require- ments. Such a procedure includes initially developing the aircraft geometry. For this purpose, students will learn the theoretical background required to initiate the aircraft configuration, as well as practical skills to use state of the art software for aircraft configuration development. In addition to that, the students will be able to determine the aircraft geometrical parameters, such as the required wing area and the dimensions of the wing, tail, fuselage, landing gears, etc. After developing the initial configuration, the students will learn how to perform more detailed analysis to evaluate the performance of their aircraft. This evaluation includes, weight estimation of the aircraft, aerodynamic assessment of the aircraft, stability and control analysis of the aircraft, etc. In-house tools as well as additional open source soft- ware will be distributed to the students and in-depth tutorials are offered to them to train the student using those tools to support their design activity. At the end of the course students will be able to simulate their aircraft in a flight simu-	

lator software offered to them during the course and digitally fly it!

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Title	Collaborative Work Sustainable Mobility
Number	2598130
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	<ul><li>2 examination elements (project work):</li><li>a) written elaboration of project work (to be weighted 5/6 in the calculation of module mark)</li><li>b) oral exam as a presentation on the project work (to be weighted 1/6 in the calculation of module mark)</li></ul>
Course achievement	1 course achievement (laboratory): Colloquium, laboratory report
Module grade composition	
Objective qualification	

Project work: After successful completion of the project work, students are able to: - structure open, research-oriented tasks into subtasks and objectives, - apply knowledge acquisition techniques to unfamiliar topics, - develop interdisciplinary approaches and concepts for institute-specific, research-related tasks, - organise, solve and document research-oriented tasks, preferably in teamwork, - present referenced and self-developed results using common forms of presentation

Laboratory: After successful completion of this module, students are able to - carry out experiments either independently or under supervision, depending on the experimental set-up, - record measurement data and - evaluate these within the framework of scientific work with a concluding discussion of the experiments.

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Title	Aeroplane Performance
Number	2514580
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
The students will acquire knowledge about the fundamental mathematical and physical laws which are required for investigations of the flight performance of aircraft under different flight conditions. They will learn to evaluate different types of aircraft based on their performance. They will receive an insight into different factors influencing the	

flight performance.

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Title	Fundamentals of Sustainable Product Development and Engineering Design
Number	2516500
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	

The students are capable of:

- · describing the development process of technical systems using product examples
- planning, carrying out and review a development project using the general approaches and selected methods
- naming principle methods used for task explanation and development fundamental solutions and by applying them for the development of new products
- explaining the basics of systems thinking and apply them to any system
- describing the importance of a holistic approach in the context of product development, especially for aspects of sustainability
- describing the Systems Engineering (SE) approach and apply it using selected SE methods
- naming and applying methods for the consideration of costs and the planning of projects
- · planning a development task independently and apply individual methods in a targeted manner

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fundamentals of Drive Systems
Number	2517290
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	

After successful completion of this module, students are able to:

• explain the structure and functionality of basic drive systems using stationary and mobile machines as examples.

• explain the power transmission within drive systems and calculate and interpret common performance quantities.

• name and explain the function and design of mechanical, combustion engine, electrical and fluid drive components using design examples.

• interpret and evaluate the performance of selected components using common characteristic curves and diagrams.

• interpret symbol images for circuit diagram representation and to name, explain and design the structure and function of simple overall drive systems using circuit diagrams.

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Title	Multimodal Transport Systems
Number	2539000000
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 Examination: written exam+ (90 min) or oral exam+ (30 min)
Course achievement	1 course achievement (facultative): Implementation and dokumentation of the project accom- panying the lecture (on application, the result of the course achievement can account for up to 20% of the grade of the written exam+/oral exam+) The application must be submitted to the examiner before the start of the exam+.
Module grade composition	
Objective qualification	

The aim of the module is to provide an overview on intermodal transport and logistics systems with a particular focus on methods for planning, design and coordination of such systems. In particular, students shall be able to describe, explain, apply and analyze modes and systems in transport and logistics. Moreover, students can recall, interpret and evaluate key performance indicators for unimodal and intermodal systems. Regarding planning and design, students are able to characterize, apply and differentiate methods with respect to the area of application and assess suitability of these methods. Last, students are able to describe, categorize and evaluate methods of coordination regarding intermodality.

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Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Numerical Methods for Mobility Applications
Number	2512390
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	Either 1 examination element in "Calculation Methods in Aerodynamics": written exam (90 min), or or oral exam (45 min) or 1 examination element in "Numerical Methods in Automotive Engineering": written exam, (120 min), or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
The students are able to understand the mathematical fundamentals of numerical methods for solving the motion equa-	

tions of either multi-body simulations in automotive engineering or of aerodynamics. Furthermore, the students can explain the relationships of these methods for systems of a ground-based or flying means of transport. The students are able to apply numerical methods, including computer-aided methods, for given system examples, as well as to indicate possible analytical procedures. Furthermore, the students are able to discuss the suitability of different numerical differential equation solvers. Finally, the students can evaluate the generated results and present them for professionals.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Vehicle Design
Number	2534380
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 Examination element: written exam, 90 minutes
Course achievement	
Module grade composition	
Objective qualification	
After completing the module, students are able to identify trends in future vehicle concept development and pre- sent them in the form of application scenarios. Furthermore, they will be able to list basic requirements for the entire vehicle, systems and components and to derive them from given specifications and/or application scenarios. Students will be able to define and describe functions and designs (package) of future vehicle concepts using usage scenarios. In addition, they are able to classify and assess vehicle concepts in the context of sustainable mobility applications in a holistic way, e.g. taking into account changing production and usage requirements. Furthermore, students can name	

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and describe measures for energy optimisation.

Specialisation Sustainable Mobility - Elective Modules	
ECTS	20

various drive topologies and energy storage concepts, explain their basic functionality and describe their integration into the vehicle. Finally, the students can draw up overall energy balances for a vehicle concept in its basic features

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Introduction to Metrology
Number	2511360
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam, 150 minutes
Course achievement	
Module grade composition	
Objective qualification	
The students are familia	ar with the basics of measurement technology. That contains issues concerning preparations of

the measurement and its realization as well as the evaluation and interpretation of the measured data. The students are able to recognize and avoid or at least minimize possible error sources by understanding the interactions between measuring device, measuring object, environment and user. Beyond that, they can handle the measured data, in particular statistic methods enabling them to test the validity of data and to estimate a measurement uncertainty. Furthermore, the students get an overview of state-of-the-art metrology techniques determining variables in process monitoring and quality control.

# $\uparrow$

Title	Basic Concepts of Lightweight Structural Design
Number	2515180
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
Students gain an overview of issues, phenomena, modeling and concepts of lightweight design. They are thus able to apply lightweight materials (mainly fiber composites) and their modeling, stability calculation methods, damage tole-	

rance calculations with the necessary caution.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Future Propulsion Technologies for Sustainable Aviation
Number	2518000020
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
By attending the course, students develop a comprehensive understanding of the challenges and opportunities asso- ciated with innovative propulsion technologies designed for sustainable aviation. They are able to analyze the impact of aviation on the climate and environment and evaluate the emerging types of propulsion systems and alternative sustainable energy earliers, including sustainable fuels, bettering and fuel calls. Students clear asia language for the sustainable	

sustainable energy carriers, including sustainable fuels, batteries and fuel cells. Students also gain knowledge of effective strategies for performance improvement and insights into new propulsion technologies. Through hands-on exercises with advanced digital tools, the students learn to critically evaluate the performance and the emissions of future propulsion systems.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Basics of Automotive Engineering
Number	2534250
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min)
Course achievement	
Module grade composition	
Objective qualification	
The students are capable to analyse independently the longitudinal, lateral and vertical dynamic vehicle behavior in various driving situations. With the help of different calculation approaches they are able to analyse and evaluate the vehicle behavior. The students can recall automotive engineering terms and can explain their peculiarities. They are capable of classifying and analyzing the influences of typical vehicle parameters in a comprehensive survey of the vehicle's dynamic behavior. The students can interpret the basics of computer-aided modelling of the dynamic behavior of motor vehicles and can implement the methodical knowledge to optimize complex products. Based on various vehicle models they are able to check and argument independently when to use which model for each complex problem. Due to this, the students can communicate in technical discussions with specialists from the automotive sector and independently evaluate statements based on their learned knowledge in the area of longitudinal, lateral and vertical dynamic vehicle behavior.	

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fundamentals of Flight Guidance
Number	2513240
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min)
Course achievement	
Module grade composition	
Objective qualification	
Students are able to apply their basic mathematical, physical and mechanical knowledge to the technical implementa- tion of aircraft guidance systems. The students master the mathematical and scientific methods to analyse and abstract the various aeronautical measurement and substitute variables such as e.g. static pressure, dynamic pressure and tem-	

the various aeronautical measurement and substitute variables such as e.g. static pressure, dynamic pressure and temperature and to calculate the relevant display variables that can be derived from them such as e.g. barometric altitude, airspeed and rate of descent. The students understand the individual systems for guiding an aircraft. The students acquire a basic knowledge of the organisation of airspace and know the political, economic and ecological boundary conditions in the organisation of European air traffic.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Intelligent and Connected Vehicles	
Number	2534390	
ECTS	5,0	
Compulsory requirements		
Compulsory attendance		
Expected performance/ Type of examination	1 examination element: written exam (60 min)	
Course achievement	1 course achievement: protocol and/ or colloquium of the completed laboratory experiments	
Module grade composition		
Objective qualification	1	
After completing the me lications and explain the able to derive future use the students become fan mated driving (vehicle a connected driving, stude	bdule, students can explain the motivations for using automated vehicles in future mobility appears basic principle of the automation levels. Depending on the degree of automation, students are e-cases or mobility applications and discuss the resulting technical requirements. Furthermore, niliar with the tasks and challenges as well as the elements of the vehicle architecture for auto-actuators, sensors, environmental perception and interpretation). In the context of cooperative, ents will also be able to analyze the potential of Car2X communication to broaden the horizon	

of perception and explain the advantages and disadvantages of various communication to broaden the horizon in the laboratory (implementation of own applications and experimental tests with automated vehicle demonstrators on a test track), students are able to apply and implement what they have learned in the lectures by solving selected practical questions.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Air Traffic Simulation - Fundamentals of Flight Guidance
Number	2513250
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	Written exam (90 min)
Course achievement	
Module grade composition	
Objective qualification	1

The students learn the basics of simulation technology in the field of air traffic control. They understand the motivation of air traffic and workplace simulation and can describe the application in teaching, research and development operations. They can describe procedural models for the validation and verification of simulation systems and procedures in their structure and classify and explain them on the basis of examples. The students are able to apply the process steps of a model for a given simulation scenario and to interpret and compare the resulting development process.

# $\uparrow$

Title	Mechanical Behaviour of Materials
Number	2524310
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	

Through lectures, exercises and self-study, the students have in-depth knowledge of the mechanical behavior of all materials groups and the underlying deformation mechanisms. They understand the mechanical behaviour under multiaxial elastic and plastic loading, in the presence of notches and cracks as well as under cyclic and high temperature loading. They know the tools to calculate the material behavior under these loading conditions. As a result, they have acquired the ability to confidently use materials under mechanical load and to solve complex problems related to the mechanical behavior of materials.

Title	Mobile Machines and Commercial Vehicles
Number	2517180
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	1

After successful completion of this module, students are able to:

- describe different technical designs and typical areas of application of mobile machines, commercial vehicles, buses and industrial trucks.
- categorize the variety of mobile machines at a glance and assign the application areas of the machines.
- calculate, compare and evaluate machine concepts and components through comprehensive knowledge in the areas of structure, process technology, powertrain technology, chassis and wheel-to-ground interaction.
  - decide which mobile machine including equipment is suitable based on the requirements and the work task.
- name the basic requirements of the Machinery Directive, its national implementation and the use of harmonized standards in the development of mobile machinery.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Modelling of Mechatronic Systems
Number	2540310
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	Written exa (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
Students are able to app body) systems, electrica	ly a uniform approach to mathematically description of the dynamics of mechanical (multi- l networks and mechatronic (electromechanical) systems. The use of different types of cons-

body) systems, electrical networks and mechatronic (electromechanical) systems. The use of different types of constraints can also be analysed and evaluated with regard to their solution behaviour. They can formulate and analyze equations of motion of selected mechatronic systems. They are thus able to independently develop and evaluate problem-adapted models for mechatronic problems.

# ↑

Title	Sustainable Space Engineering
Number	2514690
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 Examination: Written exam (120 min) or oral examination (45 min)
Course achievement	
Module grade composition	
Objective qualification	

Students can name the different types of earth orbits and describe them using orbit parameters. They are able to explain the selection of sustainable fuel combinations and stage technologies for launchers. They can describe the risks of space debris for satellite missions and calculate the fuel requirements for evasive maneuvers. They learn to consider the most important measures in end-of-life procedures to mitigate space debris. They are able to analyze the uncertainties in orbit propagation as part of re-entry predictions. They can assess the impact of mitigation measures on the future evolution of the space debris environment. They are able to define criteria for the sustainability of the mission of a satellite or space probe.

Title	Railway Vehicles
Number	2539120
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
<b>Objective</b> qualification	1

After completion of this module, students will be able to compare the design, construction and structure of various means of rail transport using selected examples. They will be able to investigate and assess the basic relationships between rail vehicle technology, operating modes and transport use as well as interactions with the environment and surroundings. The specific strengths and weaknesses of subsystem solutions for chassis, drive, brakes and body can be evaluated and discussed in the context of user requirements. Through the theoretical as well as practical oriented lecture the students acquire a transport related understanding regarding the common aspects of vehicle technology for the solution of cross-mode tasks, e.g. regarding logistic and environmental aspects, among others by means of design examples. They are able to recognise analogies and transfer and network transport-specific knowledge. In addition, the students can describe the basics of computer-aided design of rail vehicles, explain methodological knowledge for the optimization of complex products using case studies.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Engineering Mechanics 3	
Number	2543040	
ECTS	5,0	
Compulsory requirements		
Compulsory attendance		
Expected performance/ Type of examination	written exam, 90 minutes	
Course achievement		
Module grade composition		
Objective qualification	1	
<ul> <li>Students are capable of</li> <li>1 naming important types of partial differential equations.</li> <li>2 associating important partial differential equations with exemplary engineering problems based on their mathematical behaviour.</li> </ul>		

3. ... choosing appropriate solution methods for various math problems within the scope of partial differential equations.

4. ... applying these solution methods on short exemplary math problems.

5. ... assessing analytic solutions of exemplary problems according to the definition of models presented in this module.

# ↑

Title	Thermodynamics 2
Number	2519190
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam, 90 minutes
Course achievement	
Module grade composition	
Objective qualification	
Students are able to name the different forms and basic laws of thermodynamics and heat transfer. The students can discuss problems of thermodynamics and heat transfer using dimensionless characteristic numbers. The students are able to apply methods of thermodynamics and heat transfer to specific and practical problems. Students can analyze	

able to apply methods of thermodynamics and heat transfer to specific and practical problems. Students are technically relevant problems of thermodynamics and heat transfer with help of the learned methods. The students are able to evaluate which of two processes is better suited to solve a problem of thermodynamics and heat transfer.  $\uparrow$ 

Title	Internal Combustion Engines and Fuel Cells
Number	2536200
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam, 120 minutes
Course achievement	
Module grade composition	
Objective qualification	
The Students can name	the structure and technical details of internal combustion engines. They are able to understand

the function and the calculation of internal combustion engines and are able to explain the relationships of the energy conversion in internal combustion engines. The Students can apply scientific statements and procedures on internal combustion engines to specific, practical problems. The students gain an insight into the development focus of internal combustion engines and are able to understand and assess new developments regarding the technical, economic and environmental aspects. They are capable of professional communication with specialists in engine technology.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Traffic Control Engineering	
Number	2539400	
ECTS	5,0	
Compulsory requirements		
Compulsory attendance		
Expected performance/ Type of examination	1 examination element: written exam (120 min)	
Course achievement	written report on practical exercices	
Module grade composition		
Objective qualification	1	
Students are able to analyse the functions, structures and technologies of traffic control systems as well as the physi- cal, technological and operational fundamentals of land vehicles and infrastructure and to evaluate these using techni- cal examples from the operations of road and railway transport. In doing so, they apply the technical terminology and the basics of transport technology as well as specific definitions and model concepts of road and rail transport and use them when working on technical examples. Students have the capacity of transferring what they have learned to the practical and operational conditions as they are presented in practical exercises at vehicle manufacturers and infrastruc- ture facilities as well as operators of road and rail transport. They are able to explain traffic control concepts related to those practical examples. Students analyse the technical possibilities of influencing individual vehicle movement, traf-		

fic flows and traffic streams in mono- and multimodal networks and derive suitable solutions on the basis of case studies. Building on that, they discuss dynamic model concepts based on microscopic physical models up to aggregated flow models using practical examples and are able to apply those methods, means of description and tools to reproduce and analyse behaviour patterns with the aid of simulation models.

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Specialisation: Sustainable Energy and Process Engineering

Specialisation Sustainable Energy and Process Engineering - Compulsory Modules	
ECTS	43

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Plant Engineering and Construction (ME)
Number	2521340
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
After completion of the module, students are able to plan plants, to illustrate them in flowcharts and layout plans and to design machines and apparatuses mathematically. They are able to explain the processes involved in the construction	

of a plant and are able to avoid common problems.

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Title	Chemistry for Process Engineering and Materials Science
Number	2521570
ECTS	5,0
Compulsory requirements	expected basic knowledge: atomic structure, PTE, structure of matter, atomic mass, amount of substance, basic acid base theory (Arrhenius, Brönstedt), fundamentals of gases, liquids and solids.
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam #(120 min)
Course achievement	
Module grade composition	
Objective qualification	

The students will be able to describe basic properties of the elements based on a fundamental understanding of atomic structure and chemical bonding. They are able to reproduce and explain bonding relationships in molecules. In addition, they can describe the most important elements of the main groups and their most important compounds, and can derive their basic chemical behavior. Through the detailed discussion in the exercise section, students are able to quantify chemical reactions, including equilibrium reactions. They will also be able to formulate acid-base reactions and describe redox processes and electrochemical processes. Furthermore, the students are able to analyze basic organic reactions based on their knowledge of the most important organic types of substances and the fundamental organic reaction mechanisms.

Title	Collaborative Work Sustainable Energy and Process Engineering
Number	2598160
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	2 examination elements (project work): a) Preparation of the results in written form (to be weighted 5/6 in the calculation of the overall mark) b) Presentation of the project work (to be weighted 1/6 in the calculation of the overall mark)
Course achievement	1 course achievement (laboratory): colloquium and/or protocoll according to examiner's speci- fications
Module grade composition	
<b>Objective qualification</b>	1

The students are able to work self-employed on a scientific topic and to handle the resulting tasks in teams based on the division of labor. They are qualified to research the relevant state of knowledge and technology for the question they have developed, to adopt the results of others, to compare them with each other and to present them. After successful completion of this course, students are able to carry out experiments either independently or under supervision, depending on the experimental set-up, to record measurement data and to evaluate these within the framework of scientific work with a concluding discussion of the experiments. They apply knowledge acquired in the lecture and the exercise in the practical lab.

# ↑

Title	Introduction into Numerical Methods
Number	2520330
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	Written exam (120 min)
Course achievement	
Module grade composition	
Objective qualification	
Students are able to select numerical methods for solving engineering problems in a goal-oriented manner based on the imparted methodological knowledge and to solve them on the computer using a proprietary programming language. They can evaluate simulation results in terms of numerical artifacts using error calculation rules. In the accompanying exercises, the students apply the practical handling of current numerical methods. The students discover the possibilities with and limitations of numerical methods on the basis of calculation examples and thereby acquire the ability to evaluate the results of numerical simulations on their practical significance.	

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Title	Basics of Solids Process Engineering (ME)
Number	2521360
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
After completion of this module, students are able to name and describe disperse properties of particles, forces and motion of particles in fluids, interactions between particles and flows of fluids through particulate packings, to derive	

motion of particles in fluids, interactions between particles and flows of fluids through particulate packings, to derive important mathematical relationships and to graphically illustrate these relationships. Furthermore, the students are able to describe particle size analysis as well as the basic operations of mechanical process engineering separation, mixing, comminution and agglomeration by applying the above described fundamentals and to calculate example processes. Furthermore, students are able to sketch and describe selected facilities of the basic operations.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fundamentals of Sustainable Processes in Energy and Process Engineering
Number	2541470
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	<ul> <li>2 examination elements:</li> <li>a) group work with presentation and written report (to be weighted 2/5 in the calculation of module mark)</li> <li>b) written exam (60 min) or oral exam (20 min) (to be weighted 3/5 in the calculation of module mark)</li> </ul>
Course achievement	
Module grade composition	
Objective qualification	

- Students can define the term sustainability, apply it to production processes and entire value chains and discuss it.
- As a basis for the assessment of energy and process industry related production processes, students are able to model these processes in different degrees of detail, formulate and solve the corresponding mass and energy balances.
- By means of focal analyses, students can discuss the results of an assessment, highlight influencing variables and derive recommendations for actions.
- They can describe different system boundaries for the assessment of products and processes and analyze their effects on the results of a sustainability assessment.
- Students are able to reproduce the approaches of life cycle costing and social-LCA.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Unit Operations in Fluid Separations
Number	2541350
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	

For a given separation task, students can identify which pure component and phase equilibrium data is needed for the selection and design of a suitable separation process. For the practical realization students are able to select a feasible process concept and execute the necessary calculations. They can describe alternative designs and their advantages and disadvantages. They can select and plan the dimensions of corresponding equipment according to operational and economical aspects. The students are able to execute experiments at laboratory scale (vapor-liquid-equilibrium, adsorption, rectification and crystallization) individually or in small groups. Further they can discuss and interpret the corresponding results.

# $\uparrow$

Title	Thermodynamics 2
Number	2519190
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam, 90 minutes
Course achievement	
Module grade composition	
Objective qualification	
Students are able to name the different forms and basic laws of thermodynamics and heat transfer. The students can discuss problems of thermodynamics and heat transfer using dimensionless characteristic numbers. The students are	

discuss problems of thermodynamics and heat transfer using dimensionless characteristic numbers. The students can able to apply methods of thermodynamics and heat transfer to specific and practical problems. Students can analyze technically relevant problems of thermodynamics and heat transfer with help of the learned methods. The students are able to evaluate which of two processes is better suited to solve a problem of thermodynamics and heat transfer.

Specialisation Sustainable Energy and Process Engineering - Elective Modules	
ECTS	20

Title	Batteries and Fuel Cells – Basics, Production and Circular Economy
Number	2521000000
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam, 90 minutes or oral exam, 30 minutes
Course achievement	
Module grade composition	
Objective qualification	
Students gain knowledg	e of the structure function production and use of batteries in particular lithium-ion batteries

Students gain knowledge of the structure, function, production and use of batteries, in particular lithium-ion batteries, and fuel cells as well as the recycling of the used materials. After completion of the lecture as well as theoretical and practical exercises, the students know the materials for batteries and fuel cells, the function of the batteries and fuel cells in detail and can describe their processing and the processes for manufacturing batteries and fuel cells, discuss and reflect on the entire material cycle from the material, through component and system manufacturing, the usage scenarios and subsequent recycling, and name and explain the relevant technologies

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Bioreactors and Bioprocesses
Number	2526340
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min)
Course achievement	
Module grade composition	
Objective qualification	
The students can name and describe the different processes of bioprocess engineering. They are able to carry out calcu-	

are able to select and calculate the required process parameters on this basis. The students are also able to transfer the theoretical knowledge they have acquired to real reactors. The students can evaluate the suitability of different process parameters for a defined problem. The students can derive the analogy between mass, momentum and heat transport.

# $\uparrow$

Title	Chemical Process Engineering
Number	2541320
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
Students can list how to	characterize the acceptial elements of reaction systems. They are enclosed to evelop the help

Students can list how to characterize the essential elements of reaction systems. They are enabled to explain the behaviour of fluid dynamics, mixing and residence time for the reactor types STR, CSTR, PFR and CSTR-cascade. Furthermore, they can calculate this applying different models and name their field of application. Students are capable to explain the individual mechanisms of reactions for integral kinetics, heat and mass transfer, and can describe these quantitatively - also in the superposition.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fundamentals of Sustainable Product Development and Engineering Design
Number	2516500
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
The students are capable of:	

- describing the development process of technical systems using product examples
- planning, carrying out and review a development project using the general approaches and selected methods
- naming principle methods used for task explanation and development fundamental solutions and by applying them for the development of new products
- explaining the basics of systems thinking and apply them to any system
- describing the importance of a holistic approach in the context of product development, especially for aspects of sustainability
- describing the Systems Engineering (SE) approach and apply it using selected SE methods
- naming and applying methods for the consideration of costs and the planning of projects
- planning a development task independently and apply individual methods in a targeted manner

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Introduction to Micro- and Nanotechnology
Number	2521590
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: Presentation on a selected topic of micro- and nanotechnology, consi- sting of a written elaboration of slides and an oral presentation
Course achievement	
Module grade composition	
Objective qualification	

After completion of the module, the students are able to present basic aspects of micro- and nanotechnology. They will understand the special features and modes of operation of miniaturized structures and systems They will know typical methods for the two different approaches of top-down and bottom-up generation of micro- and nanostructures. They can describe the special features of nanomaterials, differentiate between nanomaterials and nanostructures and can deduce which types of nanomaterials and micro- and nanosystems (such as sensors) exist and what the most important applications are.

# ↑

Title	Introduction to Sustainable Bioproduction
Number	2526530
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min)
Course achievement	1 course achievement: colloquium (oral or written) and protocol of the completed laboratory experiments
Module grade composition	
Objective qualification	
The students can describe the fundamentals of biological processes and explain single examples quantitatively. They	

The students can describe the fundamentals of biological processes and explain single examples quantitatively. They can discuss characteristics and application possibilities of biocatalysts and derive strategies for their improvement. By using assessment tools the students can compare biological processes and declare the fields of application for the energetic and material usage of biomass.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Process Simulation
Number	2521600
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	1 course achievement: report on the completed simulations of the practical simulations course
Module grade composition	
Objective qualification	

After completing this module, students will be able to describe different simulation methods, AI-based process control and modeling approaches for individual and interconnected engineering processes. Students can select and evaluate suitable methods by means of the theoretical and practical knowledge acquired on solid processes in process engineering and the modelling and simulation methods, such as the classical population balance and flow sheet simulation methods or the modern methods of machine learning. In particular, they have the ability to use software tools based on these methods and to apply them to practical problems. On this basis, students are able to combine and further develop these methods properly.

# $\uparrow$

Title	Electrochemical Energy Engineering
Number	2520400
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	Written exam (120 min) or oral examination (30 min)
Course achievement	
Module grade composition	
Objective qualification	
The students can explain the functionality of electrochemical energy converters such as fuel cells, batteries and electro- lysers and are able to describe the underlying electrochemical and physical processes. Participation in the course puts them in a position to name quality, purpose and operating range of the cells. Furthermore, they can select the appro- priate electrochemical cell for a given application, analyze them with respect to reaction and transport kinetic on the	

basis of dynamic electrochemical measurement methods, design them based on fundamental physical equations and define adequate operation modes.

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Specialisation: Sustainable Production

 Specialisation Sustainable Production - Compulsory Modules

 ECTS
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Title	Enterprise Organisation
Number	2545000010
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam+ (120 min) or oral exam+ (30 min)
Course achievement	1 course achievement: presentation and/or written report in the context of a teamproject (on application, the result of the course achievement is taken into account in the assessment of the written examination+ or of the oral examination+, respectively, and can account maximum 20% of the respective grade).
Module grade composition	On application, the result of the course achievement is taken into account in the assessment of the written examination+ or of the oral examination+, respectively, and can account maximum 20% of the respective grade.
<b>Objective qualification</b>	

#### Objective quan

Students

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- are able to analyse the reference model of the company organisation with regard to internal processes and functions and the associated environmental influences
- reproduce the product, order and factory process within the company organisation (e.g. using the VDI guideline 5200)
- present the challenges in the field of production and logistics as well as their consequences for company organisation by means of practical case studies and empirical studies and apply the knowledge gained in the context of Industry 4.0 and digitization
- understand the need for integrated management systems to support operational processes in terms of quality, environment & energy, data, risk and technology
- · describe further cross-sectional functions in the area of accounting/controlling as well as financing and investment
- learn about the role of employees in companies (e.g. personnel management, organisation, leadership)
- are able to identify the interests of relevant shareholders and stakeholders and apply them in the context of practical issues
- are able to present the challenges of the business environment and their consequences in the context of economics, ecology and social issues

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Collaborative Work Sustainable Production
Number	2598140
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	2 Examination elements (project work): a) project thesis (written) (weighting for grade 5/6) b) presentation (30 min) (weighting for grade 1/6)
Course achievement	1 course achievement (laboratory): colloquium and/or protocoll according to examiner's speci- fications
Module grade composition	
Objective qualification	

Project work: Graduates are able to solve scientific and technical problems discrete by a theoretical and practical handling of tasks of production and system engineering. Thereby, they also use acquired skills in project management, team organization, literature review and the presentation of scientific results. They are able to plan and prepare a scientific lecture, apply methods for literature research and select suitable forms of presentation.

Laboratory: After successful completion of this module, students are able to carry out experiments either independently or under supervision, depending on the experimental set-up, to record measurement data and to evaluate these within the framework of scientific work with a concluding discussion of the experiments.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Energy Efficiency in Production Engineering
Number	2522930
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam+ (120 min) or oral exam+ (30 min)
Course achievement	presentation and/or written report in the context of a teamproject (On application, the result of the course achievement is taken into account in the assessment of the written examination+ or of the oral examination+, respectively, and can account maximum 20% of the respective grade.)
Module grade composition	
Objective qualification	

The students...

- ... explain the planning, design and development of sustainability-oriented production systems in different contexts
  ... assess different strategies (e.g. efficiency strategy) and principles (e.g. avoidance principle) of sustainable deve-
- lopment in defined use cases on a laboratory scale
- ... evaluate existing production systems in economic, ecological and social dimensions
- ... are able to illustrate the results of various efficiency strategies to non-experts and to apply relevant assumptions, restrictions and framework conditions correctly
- ... design their own research questions within the team project, evaluate experiments and derive a presentation of the results of the research
- ... organize themselves in a team project and gain experience in relevant soft skills such as teamwork, communication and presentation skills
- ... analyze sustainability-oriented production systems within a given topic
- ... are able to select relevant fields of action and measures for sustainable production

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Production Technology
Number	2522420
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	1

• Students are able to differentiate production engineering from other fields of mechanical engineering

- Students are able to classify manufacturing processes according to DIN 8580
- Students are able to explain the process of industrially relevant production methods and their advantages and disadvantages
- Students are able to select suitable manufacturing processes for applications
- Students are able to enumerate and explain novel and research-oriented manufacturing processes in the field of lightweight construction
- Students are able to explain the potentials and challenges of hybrid lightweight construction
- Students are able to explain the interactions and connections between the disciplines of production, construction and materials engineering
- Students are able to calculate and interpret parameters and key figures of machining

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Title	Finite Element Methods
Number	2529310
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min) or oral exam (60 min) in groups
Course achievement	
Module grade composition	
Objective qualification	
After completing the course attendees will be able to describe the basics of the finite element method and calculate deformations using the taught elements. Shape functions can be selected with regard to the mathematical problem. Stu-	

dents can solve engineering motivated problems of elastostatics and heat conduction.

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Title	Fundamentals of Sustainable Product Development and Engineering Design
Number	2516500
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	

The students are capable of:

- · describing the development process of technical systems using product examples
- planning, carrying out and review a development project using the general approaches and selected methods
- naming principle methods used for task explanation and development fundamental solutions and by applying them for the development of new products
- explaining the basics of systems thinking and apply them to any system
- describing the importance of a holistic approach in the context of product development, especially for aspects of sustainability
- describing the Systems Engineering (SE) approach and apply it using selected SE methods
- naming and applying methods for the consideration of costs and the planning of projects
- · planning a development task independently and apply individual methods in a targeted manner

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Total Life-Cycle-Management
Number	2522990
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam+ (120 min) or oral exam+ (30 min)
Course achievement	1 course achievement: presentation and/or written report in the context of a teamproject (On application, the result of the course achievement is taken into account in the assessment of the written examination+ or of the oral examination+, respectively, and can account maximum 20% of the respective grade.)
Module grade composition	(On application, the result of the course achievement is taken into account in the assessment of the written examination+ or of the oral examination+, respectively, and can account maximum 20% of the respective grade.
Objective qualification	

Students...

• can spot and identify relevant challenges and interrelationships between global economic and ecological developments and place them within the framework of reference of Total Life Cycle Management.

- can name the central elements of sustainable development and analyse them with the help of the framework.
- are able to analyse life cycle oriented concepts in order to develop sustainable life cycles of technical products.
- are able to think in complex dynamic systems and to outline the model of viable systems.
- are able to distinguish between life-phase and life-cycle related disciplines and to discuss them with the help of the St. Gallen management concept and the framework of Total Life Cycle Management.
- are able to reproduce the procedure of a life cycle assessment, naming the framework conditions (e.g. environmental impact, functional unit) and discuss the results of a life cycle assessment.
- are able to independently carry out an economic impact analysis using the Life Cycle Costing method.
- are able to organise themselves effectively within group work, to divide the work, to ensure that goals are achieved on time and to use solution-oriented communication.

Specialisation Sustainable Production - Elective Modules	
ECTS	25

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Actuators
Number	2538220
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	

The students are able to distinguish a total of 12 different physical actuator principles with regard to their functionality and their application-specific properties and can draw conclusions about their possible applications. The students can define an actuator, describe the actuator principles and derive the factors influencing the actuator forces and actuator travel from the given mathematical equations. They are able to construct actuator concepts with a basic function (positioning movement). In addition, they can use the scaling laws to calculate how the power density and other characteristics of actuator principles behave when scaling and determine the consequences of this.

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Title	Plant Engineering and Construction (ME)
Number	2521340
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
After completion of the module students are able to plan clearts to illustrate them in flower barts and becaut plans and to	

After completion of the module, students are able to plan plants, to illustrate them in flowcharts and layout plans and to design machines and apparatuses mathematically. They are able to explain the processes involved in the construction of a plant and are able to avoid common problems.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Automation of Industrial Manufacturing Processes
Number	2522610
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
Students	

• are able to name automation technology devices (robot structures, control devices, transport systems, sensors, actuators...) and assign them to the respective scenarios (automotive, electronics and aviation industry).

• are able to classify the presented scenarios with regard to quantity, production costs and automation costs.

• gain the ability to analyse challenges arising in the scenarios and independently develop solutions based on the scenarios presented and transfer them to new problems.

• can use #Petri-Nets# to model complex process sequences in control systems.

• can use CFC programming (Continous Function Chart) to perform simple control tasks.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Introduction to Metrology
Number	2511360
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam, 150 minutes
Course achievement	
Module grade composition	
Objective qualification	
The students are familiar with the basics of measurement technology. That contains issues concerning preparations of	

the measurement and its realization as well as the evaluation and interpretation of the measured data. The students are able to recognize and avoid or at least minimize possible error sources by understanding the interactions between measuring device, measuring object, environment and user. Beyond that, they can handle the measured data, in particular statistic methods enabling them to test the validity of data and to estimate a measurement uncertainty. Furthermore, the students get an overview of state-of-the-art metrology techniques determining variables in process monitoring and quality control.

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Title	Applied Electronics
Number	2538000000
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
Students are able to name and describe all basic passive electrical components and to design their application. With the help of the given mathematical equations they are able to design, calculate and evaluate basic electronic circuits, star- ting with linear networks, passive filters and resonant circuits, rectifier and transistor circuits up to operational ampli-	

fiers.

Title	Joining Technology
Number	2537210
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	written exam (120 min)
Course achievement	
Module grade composition	
Objective qualification	

After completion of the module "Joining Technology", students understand the theoretical basics and methods for designing and executing joining connections. They are fully able to outline properties of different joining processes and can categorize processes based on selected criteria. Furthermore, the students gain the theoretical knowledge using selected examples of industrial applications of the individual joining processes. Furthermore, they are able to design concepts within the scope of joining suitability, joining processes and constructions according to critical requirements. At the end of the module, the students can derive potentials from joint connections.

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Title	Basics of Solids Process Engineering (ME)
Number	2521360
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
After completion of this module, students are able to name and describe disperse properties of particles, forces and motion of particles in fluids, interactions between particles and flows of fluids through particulate packings, to derive important mathematical relationships and to graphically illustrate these relationships. Furthermore, the students are able to describe particle size analysis as well as the basic operations of mechanical process engineering separation, mixing, comminution and agglomeration by applying the above described fundamentals and to calculate example pro-	

cesses. Furthermore, students are able to sketch and describe selected facilities of the basic operations.

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Title	Fundamentals of Microsystem Technology
Number	2538200
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (90 min) or oral exam (30 min)
Course achievement	
Module grade composition	
Objective qualification	
The students are able to describe and evaluate the established manufacturing technologies of microsystems technology that are in line with the current state of the art and to determine their application. Furthermore, they are able to assess the factors that have an influence on the quality of the individual technologies (factors influenced by e.g. environmen-	

the factors that have an influence on the quality of the individual technologies (factors influenced by e.g. environmental conditions and mutual interference) and, on this basis, plan a realistic sequence for the fabrication of simple microtechnical components. They are able to represent and evaluate the materials frequently used for microsystems and their characteristic properties. Finally, students can transfer the possibilities of microtechnical manufacturing to simple application examples.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Fundamentals of Sustainable Processes in Energy and Process Engineering	
Number	2541470	
ECTS	5,0	
Compulsory requirements		
Compulsory attendance		
Expected performance/ Type of examination	<ul> <li>2 examination elements:</li> <li>a) group work with presentation and written report (to be weighted 2/5 in the calculation of module mark)</li> <li>b) written exam (60 min) or oral exam (20 min) (to be weighted 3/5 in the calculation of module mark)</li> </ul>	
Course achievement		
Module grade composition		
Objective qualification	Objective qualification	

- Students can define the term sustainability, apply it to production processes and entire value chains and discuss it.
- As a basis for the assessment of energy and process industry related production processes, students are able to model these processes in different degrees of detail, formulate and solve the corresponding mass and energy balances.
- By means of focal analyses, students can discuss the results of an assessment, highlight influencing variables and derive recommendations for actions.
- They can describe different system boundaries for the assessment of products and processes and analyze their effects on the results of a sustainability assessment.
- Students are able to reproduce the approaches of life cycle costing and social-LCA.

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Industrial Quality Management
Number	2511210
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	1 examination element: written exam (120 min)
Course achievement	
Module grade composition	
Objective qualification	1
Students can explain the term quality and its relevance for a company on the basis of theoretical principles and prac- tical examples. They can name several management systems. Furthermore, the students use suitable QM tools to illu- strate the causes of problems and derive correlations from it. They can also describe various quality programs in Total Quality Management. Finally, students can analyze the economic efficiency of quality management systems using several calculation models. In addition, they can determine the quality of products using various measurement and testing methods and make a suitable selection of test parameters for this purpose. The students compare different QM methods in development and construction and distinguish between QM systems in procurement. They can explain QM tools used in production and draw a quality control chart. They are also able to define the importance of quality for the customer and evaluate it using methods for data acquisition and analysis like lifetime tests. Finally, the students can illustrate quality management systems along the supply chain.	

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Introduction to Mechatronics
Number	2538000040
ECTS	5,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	<ul> <li>2 examination elements:</li> <li>a) written exam, 45 minutes or oral exam 20 minutes (to be weighted 2,5/5 in the calculation of module mark)</li> <li>b) Seminar lecture, 20 minutes (to be weighted 2,5/5 in the calculation of module mark)</li> </ul>
Course achievement	
Module grade composition	
Objective qualification	

Students are able to define and describe mechatronic systems and to name essential functions or components. They are able to discuss and apply approaches for the development of mechatronic systems (system engineering methods, development methods) and to describe analogies from the different technical domains mechanics, electrical engineering and computer science and to transfer them to application examples. Furthermore, students are able to explain sensors and actuators as essential components of mechatronic systems and their basic functional principles. In the course of the seminar, the students apply the lecture contents to an example of their choice. They are able to present the acquired knowledge (lecture) and discuss it in a team.

Integrated Modules	
ECTS	8

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	
Number	2598180
ECTS	8,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	
Course achievement	Course achievement: exact examination modalities depend on the chosen courses
Module grade composition	
Objective qualification	
Students are able to classify their subject of study in societal, historical, legal or career-oriented references (depending	

Students are able to classify their subject of study in societal, historical, legal or career-oriented references (depending on the focus of the course). They are able to recognise, analyse and evaluate higher-level subject-related connections and their significance. Students are also able to identify and implement possible interconnections of their own field of study with other subject areas as well as application references of their field of study in professional life.

Internship	
ECTS	10

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Internship
Number	2599650
ECTS	10,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	
Course achievement	1 Course achievement: Internship report (to be prepared according to the internship guidelines of the Faculty of Mechanical Engineering)
Module grade composition	
Objective qualification	
The internship complem practical relevance and fic basic knowledge of t detailed internship repo ble, taking balanced acc accompanying their stud sional activity in the con The students gain insigh the company as a social organisational problems discuss them in a solution preferably serve as an o study knowledge, in that nal strengths and inclina	hents the degree programme by enabling acquired theoretical knowledge to be deepened in its already applied to a certain extent. The students acquire further engineering and/or scienti- technical products and processes in a company and are able to describe and explain these in a rt. They know how to design a process and manufacture a product as independently as possi- bount of technical, economic, ecological and social constraints. Through the practical training dies, they acquire and demonstrate the absolutely necessary socialisation skills for later profes- mpany environment in daily dealings with employees of the most varied hierarchical levels. Ats into company organisational structures and the social aspects of the working world, grasp structure and in particular the relationship between managers and employees. Confronted with in the company, the students are able to transfer these to other company situations later on and on-oriented manner. Depending on the type and timing of its implementation, the internship can rientation aid for decisions in study planning and specialisation or as a deepening of acquired t the students critically consider their experiences and evaluate them in relation to their perso- nations.

Bachelor's Thesis	
ECTS	14

Technische Universität Braunschweig | Appendix to the examination regulations: Sustainable Engineering of Products and Processes (Bachelor)

Title	Bachelor's Thesis Sustainable Engineering of Products and Processes
Number	2598150
ECTS	14,0
Compulsory requirements	Only those who have completed the project work and can prove at least 142 LP in the course of study can be admitted to the Bachelor's thesis.
Compulsory attendance	
Expected performance/ Type of examination	<ul><li>2 examination elements</li><li>a) Written work of the assignment (to be weighted 6/7 in the calculation of module mark)</li><li>b) Presentation (to be weighted 1/7 in the calculation of module mark)</li></ul>
Course achievement	
Module grade composition	
Objective qualification	

The students are able to

work independently on a topic of Sustainable Engineering or on a corresponding research question,

- select and apply relevant literature for the successful processing of the topic,
- carry out their own measurements and data collection using appropriate procedures,
- scientifically process and evaluate self-collected data and measured values,

• present the scientific results both in the form of a written paper and orally in the form of a presentation and to defend them in critical discussion.

Title	Additional Courses
Number	2599340
ECTS	,0
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	
Course achievement	
Module grade composition	
Objective qualification	

Title	
Number	259900000
ECTS	
Compulsory requirements	
Compulsory attendance	
Expected performance/ Type of examination	
Course achievement	
Module grade composition	
Objective qualification	