HOCHSCHULE RHEIN-WAAL

Rhine-Waal University of Applied Sciences

Module Handbook / Modulhandbuch

Engineering for Sustainability, Bachelor of Science

Faculty of Technology and Bionics

Kleve

[Stand: 13.05.2024]

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Orientation Phase

Module name/Module Code	Fundamentals of Personal and Social Competences / 2201
Module coordinator	Anja Viermann
Lecturer	Anja Viermann, … (+ external lecturer for Creativity & Innovation)
Timetabled hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
Workload	120 h project work 60 h self-study
Credit Points	6
Prerequisites	Required prerequisite: none Recommended prerequisite: none
Module Objectives	The aim of this module is to support students in developing and expanding a framework of personal and social competences and to sensitise them to the need for continuous, lifelong personal development in this area. Core competencies that form an important basis for employability and success in any future professional context as an individual or as a member of a team or organisation. The focus of this module will lay on improving: • cooperation competence, with special attention and emphasis on team work competence • diversity and intercultural collaboration competence • self-competence & self-reflection • communication skills as well as presentation abilities
Content	For this purpose, students are given access to the necessary knowledge, methods and skills in various learning units and "experience spaces" in direct interaction with other students. An appropriate framework for individual and collective learning, application, experience and reflection is provided both within and outside the courses (e.g. supplementary online lectures and assignments, independent work in various teams on specified semester tasks). The learning, experience and competence-building processes are supported by the lecturer, including moderated feedback loops in various phases blocked course. Content contributing to the core competencies addressed: **<u>Social Competence:</u>** **Communication Competence:** • "The First impression" • Filters forming perception, thinking, reactions and behaviour

	• Active listening and levels of communication • Basic insights into negotiation, dealing with conflicts, presentation techniques **Cooperation Competence:** • Teamwork: team roles & team process • First insights into methods of "Facilitation" **Diversity and Intercultural competence:** • Human nature dealing with differences • Impact and potential of diversity; incl. bias effects • Diversity in organizational and business context • Term and nature of 'CULTURE'; culture building processes • Impact of culture on any form of human group forming process as common base of collective values & beliefs, thinking, perception and (re)action patterns and rules (Group, Organizational and National Culture) **<u>Personal Competence:</u>** **Self-Competence** • Mindfulness • Self-awareness - Self- reflection; incl. dealing with feedback • Dealing with stress **Flexibility & Adaptability Competence** • Change: human mechanisms & coping strategies • Adaptation to different roles, responsibilities, and context and change priorities and direction, if needed • Ambiguity tolerance **(Creativity & Innovation Competence)** • Term and importance of creativity & innovation • Repertoire of methods and strategies that support creative processes and know-how and to build a supportive work environment and innovative climate to make best use of creative potentials. **Analytical & Critical Thinking** • Exploring, application and critical reflection on scientific models, concepts and approaches (e.g. Hofstede: Cultural Dimensions, Oberg: Cultural Shock Model). • Adopt systemic thinking by exploring and integrating different perspectives and interdependencies **Integrity and Work Ethics** • Appreciate transparency, honesty and work ethic and apply them in relationships and in their own work • Admit faults and seek guidance if needed • open-minded and accountable for own actions • Be reliable and trustworthy • motivation and commitment to task
Assessment	**Attestation:** • Active participation in learning & "experiential spaces" in classroom in presence (attendance) 50% • Working in diverse team on semester assignments (partly outside of class): preparation, submission written assignment (term paper); presentation in class (50%)
Literature	De Bono, Edward: Serious Creativity, (2015, Vermilion // TradePaperback)

	Gardenswartz, Lee et al.: Diverse Teams at Work: Capitalizing on the Power of Diversity (2002, Society for Human Resource Management) Hofstede, Geert et al.: Cultures and Organizations; Software of the Mind (2010, Mcgraw-Hill) Keeley, Larry Ten Types Of Innovation, (2013, Wiley) Lewis, Richard: When cultures collide – Leading across cultures (2006, Brealey Publishing) Michalko, Michael: Thinkertoys, (2006,Ten Speed Press) Trompenaars, Fons: Riding the Waves of Culture, (2012, BrealeyPublishing) Van Aerssen, B. et al: The Innovator's Dictionary, (2018, Vahlen) V9. on Oech, Roger: A Kick In The Seat Of The Pants, (1986, Warner Books) Wolff, Jurgen: CREATIVITY NOW, (2012, Pearson International) Supplemental readings, e.g. additional literature, exercises, cases and other learning materials will be provided during class.

Module name/Module Code	Working in Laboratories and Technical Centre / 2202
Module coordinator	William Megill
Lecturer	William Megill, KC Leaders, Scientific and Technical Staff
Timetabled hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
Workload	120 h project work 60 h self-study
Credit Points	6
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	Students tour the faculty workshops and laboratories, and learn about their research and manufacturing capabilities. They are introduced to the workshop and laboratory staff, and to the different working cultures. Students learn the importance of risk assessment and safe working practice. They learn to work in groups and develop proficiency in some core digital manufacturing skills for prototyping.
Content	Part 1: R&D in the Faculty of Technology and Bionics • Workshop tour • Introduction to machines, processes, and people • What is R&D – definitions and differences • Introduction to safety and risk assessment

	• Engineering documentation
	Part 2: Digital manufacture for prototyping
	• Safe use of hand tools and hand held power tools
	• Sketching an idea on paper and in drawing software
	• 2D CAD, CNC cutting, laser cutting, routing
	• Prototyping in card, wood, plastic, and metals
	  ○ Making: bridge, race car, paddle-wheeler
	  ○ Documentation, incl lessons learned
	Part 3: Project work in the Knowledge Centres
	• A day in each of the KCs – prepared projects
	• Practical themes, simulation, and serious games
	• Working practice, project work, documentation

Assessment	Attestation
Literature	Online documentation

Module name/Module Code	Ethics and Technical Impact Assessment / 2203
Module coordinator	Andreas von Bubnoff
Lecturer	Andreas von Bubnoff tbd
Timetabled hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
Workload	120 h project work 60 h self-study
Credit Points	6
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	The appearance of Rachel Carson's book "Silent Spring" in 1962 made clear that science and technology isn't always a good thing. Today, in contrast, it is normal to discuss "dual-use" concerns with new technologies such as genome editing/GMOs, artificial intelligence, self-driving cars, or gain-of-function studies with viruses. Students will learn general ethical concepts and how to apply them to critical appraisals of new technoloogies in case studies. By the end of the course, they will be able to apply what they've learned to new cases they might encounter in their professional lives.
Content	• Introduction to ethical theories like utilitarianism, Kantian ethics, virtue ethics, and social contract theory.” • Case studies including discussion of the Value Alignment Problem in artificial intelligence • Students give presentations applying what they've learned to concrete examples of new technologies

Assessment	Continuous Assessment
Literature (selection)	**Main textbook:** Nyholm, S. (2023). This is Technology Ethics: An Introduction. Wiley. **Additional readings (selection):** **Carson, R.** (1962). Silent Spring. Houghton Mifflin. **von Bubnoff, A.** (2005). Spanish flu papers put spotlight on 'dual use' decisions. *Nat Med.* **11**: 1130. **Lynas, M.** (2018). Seeds of Science: Why We Got It So Wrong On GMOs. Bloomsbury. **Grunwald, A.** (2019). Technology Assessment in Practice and Theory. Routledge. **Othman, K.** (2021). Public acceptance and perception of autonomous vehicles: a comprehensive review. *AI Ethics* **1**, 355–387. **Stahl, B.C.** (2022). From computer ethics and the ethics of AI towards an ethics of digital ecosystems. *AI Ethics* **2**, 65–77. **Bloom, P.** (2023). How Moral Can A.I. Really Be? *New Yorker.* **Hennen, L.** *et al.* (2023). Technology Assessment in a Globalized World. Springer. **Prem, E.** (2023). From ethical AI frameworks to tools: a review of approaches. *AI Ethics* 3, 699–716.

Module name/Module Code	Abstraction and logical reasoning / 2204
Module coordinator	Alexander Struck
Lecturer	Alexander Struck tbd
Timetabled hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
Workload	120 h project work 60 h self-study
Credit Points	6
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	Students are introduced to critical thinking and logical reasoning. They will sharpen there senses and minds and exercise scientific approaches to small problems based on the skills and competencies they bring already bring with them. They will learn to define scopes and boundaries to their solutions and grasp the difficult concept of truth in science.

	Students will be exposed to the fundaments of logic and how to apply logical skills to improve their awareness of misinterpretation or spurious solutions of apparently easy tasks
Content	• Revision of school knowledge in mathematics and physics • Crash course in descriptive statistics which will serve as a useful method to discuss specific problems showcasing possibilities and limits of scientific assessments • Introduction to logic in various contexts
Assessment	Continuous Assessment
Literature	Kahneman: Thinking Fast and Slow DeVeaux et al: Stats: Models and Data Spiegelhalter: The Art of Statistics Steward: Calculus

Module name/Module Code	Group project / 2205
Module coordinator	Alexander Struck
Lecturer	tbd
Timetabled hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
Workload	120 h project work 60 h self-study
Credit Points	6
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	Students will deploy their acquired competencies in a small project that will prepare them to enter professional project teams and to perform their thesis in aprofessional environment
Content	A student team of 3 to 5 students will work on a project that they need to design, plan and conduct entirely on their own. Each team member is required to take responsibilty for a specific role in the team. Project supervisors and mentors will ensure that the responsibilities and workloads are balanced within the teams. Overall requirements for fulfilling the assessment are: • All teams are required to keep a detailed project log book and an attendance recorder of some form.

	• Regular project meetings with the supervisors are required in which individual team members must present the status of their tasks. • A detailed report must be delivered including the project plan, the achieved results according to scientific standards (proper analysis, literature, correct report form, ...), an analysis of the unachieved tasks, time and cost analysis and a final presentation of the results
Assessment	Continuous assessment. Students will be evaluated individually based on their performance and reliability in the project team.
Literature	Project specific literature will be collected and documented by the team.

Centre of Knowledge
Automation Engineering

General Information	Centre of Knowledge Desciption	Automated or partially automated systems are highly relevant due to current developments and represent significant added value in product innovations. The Center of Knowledge in the field of Automation Engineering deals with the monitoring, control and regulation of technical systems. Devices and systems should be monitored, controlled and regulated by automation devices in such a way that they fulfil their functions largely independently or provide the user with maximum support in their performance. The safety requirements must always be taken into account and met.
	Module Coordinator	Prof. Dr.-Ing. Dirk Nissing
	Literature	Nise, Norman S.: Control Systems Engineering. 2011, John Wiley & Sons. ISBN 978-0-470-64612-0 Dorf, R. C., R.H. Bishop: Modern Control Systems. 2011, Pearson Education. ISBN 978-0-13-138310-4 Franklin, G. F., J.D. Powell, A. Emami-Naeini: Feedback Control of Dynamic Systems. 2010, Pearson Education. ISBN 978-0-13-500150-9 Ogata, K.: Modern Control Engineering. 2010, Pearson Education. ISBN 978-0-13-713337-6
	Primary interfaces to other Centres	Engineering Design Fundamental Science and Mathematics Process Cycles of Energy and Matter

Project Semester 2	Module name / Module Code	AE2: Automation Engineering, project semester 2 / 2210
	Lecturers	Prof. Dr.-Ing. Dirk Nissing Dipl.-Ing. (FH) Michael Titze, M.Sc.
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6

	Prerequisites	Required prerequisite: Recommended prerequisite:
	Module Objectives:	After finishing the module students can experimentally parameterize and use a simple controller or regulator for a mechatronic system and are able to recognize changes. The students can plan and implement the necessary hardware.
	Content	• System description via block diagrams • Functionality and basic structure of control circuits
	Competencies and Qualification	Professional competence The students … • analyse a process and present the analysis in the form of a block diagram. • know principles for measuring physical quantities. • know principles for actuating systems. • plan and take into account the necessary hardware for control and data acquisition. • implement simple sensors for measurement data acquisition. • implement a simple control or regulator and parameterize it experimentally based on measurements. • explain and quantify the effects of system behaviour for different controller settings. Methodological competence The students … • abstract technical systems and describe the causal relationships using block diagrams. • develop technical content using pre-selected literature and tutorials. • classify their sub-project in the overall context of the project and recognize interfaces to other specialist disciplines. • detect effects caused by different controller settings and classify them. • identify knowledge gaps for the systematic execution and description of regulated systems. • document the results and findings in an appropriate scientific form. Sustainability competence The students … • detect the energy input to fulfil the automation task and are able to discuss the effects. • understand the effect of efficiency at different operation points and its effects to energy consumption. • choose sensor technologies with sustainability in mind.
	Assessment	Continuous Assessment

		• learning diary • group presentation • project report • oral examination
Project Semester 3	Module name / Module Code	AE3: Automation Engineering, project semester 3 / 2220
	Lecturers	Prof. Dr.-Ing. Dirk Nissing Dipl.-Ing. (FH) Michael Titze, M.Sc.
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	160 h project work 65 h self-study
	Credit Points	7.5
	Prerequisites	Required prerequisite: AE2 Recommended prerequisite:
	Module Objectives:	After finishing the module students can simulate the behaviour of a process as a basis for the controller design and use existing software tools. Furthermore the system behaviour can be identified and classified.
	Content	• Mathematical modelling of technical systems by means of differential equations • Characteristics of control systems – Linear and non-linear systems – Linearization – Systems with concentrated / distributed parameters – Time-variant and time-invariant systems – Causal and non-causal systems • Description of linear continuous systems in the time domain: step response, impulse response
	Competencies and Qualification	Professional competence The students … • understand numerical methods for solving linear and non-linear state equations (initial value problems) and can use these for different tasks and problems. • are able to implement and simulate dynamic equations and analyse and plausible the results. • can categorize LTI systems based on the equation structure. Methodological competence The students … • are able to select suitable simulation methods for technical systems and to apply them practically e.g. in MATLAB/Simulink. • are able to setup a simulation model on a methodological approach.

		Sustainability competence The students … • understand strategic concepts for the implementation of sustainable models. • understand the complexity of change processes. • can discuss sustainability effects in modelling and simulation and are able to incorporate this into the simulation model. • can identify social, ecological and economic implications and can identify the limitations of the models.
	Assessment	Continuous Assessment • learning diary • group presentation • project report • oral examination
Project Semester 4	Module name / Module Code	AE4: Automation Engineering, project semester 4 / 2230
	Lecturers	Prof. Dr.-Ing. Dirk Nissing Dipl.-Ing. (FH) Michael Titze, M.Sc.
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10
	Prerequisites	Required prerequisite: AE3 Recommended prerequisite:
	Module Objectives:	After finishing the module students can select appropriate controllers and design the controller based on state of the art model-based design and analysis approaches.
	Content	• Frequency domain: Laplace transformation, transfer functions • Characteristics of systems • Proportional, integral, derivative and its combinations • Controller introduction • Block diagram transformation • Closed-loop transfer function: Reference and disturbance transfer function • Stability analysis • Controller parameterization
	Competencies and Qualification	Professional competence The students …

		• understand the need for the Laplace transformation and can derive transfer functions and incorporate the transfer functions in a simulation model. • understand the system theory of different system types and can explain the effects on step responses, impulse responses, pole/zero locations, Bode-diagram and Nyquist plots. • incorporate controllers in a model, decide parameters and justify the overall behaviour. Methodological competence The students … • are able to create a complex simulation model by use of the decomposition approach. • can test the controller by use of the Model-in-the-Loop (MiL) approach. Sustainability competence The students … • can evaluate the system behaviour with respect to energy consumption and are able to optimize the controller parameters in order to improve the efficiency. • create ideas how to incorporate social, ecological and economic implications to their models.
	Assessment	Continuous Assessment • learning diary • group presentation • project report • oral examination
Project Semester 5	Module name / Module Code	AE5: Automation Engineering, project semester 5 / 2240
	Lecturers	Prof. Dr.-Ing. Dirk Nissing Dipl.-Ing. (FH) Michael Titze, M.Sc.
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project 130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: AE4 Recommended prerequisite:
	Module Objectives:	After finishing the module students can realize and implement different controllers and optimize these for the required task. External effects will be considered and a systematic implementation is essential for complex systems.
	Content	• Controller and parameter optimization • State-space-control • Observer techniques • Disturbance rejection and robustness

		• Rapid Control Prototyping (RCP), Software-in-the-Loop (SiL), Processor-in-the-Loop (PiL) and Hardware-in-the-Loop (HiL)
	Competencies and Qualification	Professional competence The students … • understand the state-space-control technique and can design a state-space-controller. • can design an observer for unknown states. Methodological competence The students … • can discuss different controller techniques and decide based on the system requirements. • understand different design and implementation steps (MiL, RCP, SiL, PiL, HiL) and are able to apply these practically e.g. by the tool chain MATLAB/Simulink/dSpace. Sustainability competence The students … • decide for the usage of different design and implementation steps in order to consider the sustainable goals.
	Assessment	Continuous Assessment • learning diary • group presentation • project report • oral examination

Centre of Knowledge
Fundamentals of Science and Mathematics

General Information	Centre of Knowledge Desciption	Every exact science needs quantitative and sometimes qualitative methods to gain insight into empirically studied systems from observations and measurements. Therefore, a sound knowledge in mathematics and physics is necessary for all engineering sciences. A particular importance lies on modelling, since an accurate and exact mathematical description of reality is in general not possible. On the other hand, well designed models that capture the relevant parts of reality allow to study effects in a suitably abstract way enhance the understanding of the real system. The Centre of Mathematics and Fundamental Sciences (CMFS) provides projects and teaching units that gather skills in modelling and the necessary skills to use and evaluate them. Data competencies and critical evaluation of results as well as the basics of simulation are central topics in the offers of CMFS.
	Module Coordinator	Prof. Dr. Alexander Struck
	Literature	
	Primary interfaces to other Centres	All other centres

Project Semester 2	Module name / Module Code	CMFS2: The nature of motion , project semester 2 /
	Lecturers	Prof. Dr. Alexander Struck
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6
	Prerequisites	Required prerequisite: Introductory module 1st semester Recommended prerequisite:

	Module Objectives:	Students review and enhance their skills in fundamental physics and mathematics. While trying to understand experiments and observations, they develop methodological questions to futther their understanding and learn new methods and techniques in mathematics and physics
	Content	1. Uniform motion, uniformly accelerated motion: Throwing balls down the staircase, record data, find patterns, describe: Basic statistics, units, reporting data correctly, derivatives, integral 2. Generalization of forces: Springs and pendula, rotatory motion, vectors and vector operations 3. Describing motions in time and space: equations of motion, coordinate systems 4. Constants of motion and the structure of time and space: Energy, momenta and conservation laws 5. Model objects versu real objects: How to treat motions of extended bodies: Advanced integration 6. Forces, fields and potentials, multivariate calculus and differential operators, theoretical and experimenta 7. ODEs and the phantasmagoric journey to resonance
	Competencies and Qualification	**Professional competence** Students will understand: • fundamental physical and mathematical concepts • the limits of measurement and the assessment of errors • Scientific reporting and discussion **Methodological competence** Students will understand: • how to record data • Process data on paper and with a computer • How to model data • How to document results Personal competence Students will understand how observations relate to models and theories. They enhance their ability to think

		and reflect their own thinking critically. They learn how to maintain scope and validity of scientific research and develop the ability to acknowledge the range of cases in which their results can be applied and how to improve their methods and models when their limits are reached.
	Assessment	Continuous Assessment
Project Semester 3	Module name / Module Code	CMFS3:Measuring reality, project semester 3 /
	Lecturers	Prof. Dr. Alexander Struck
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	160 h project work 65 h self-study
	Credit Points	7.5
	Prerequisites	Required prerequisite: CMFS22 Recommended prerequisite:
	Module Objectives:	Students continue to review and enhance their skills in fundamental physics and mathematics. While trying to understand experiments and observations, they develop methodological questions to futther their understanding and learn new methods and techniques in mathematics and physics
	Content	1. Ray and Wave optics: Playing with lenses and diffraction gratings, eventually build a spectroscope, investigate artificial and natural light sources 2. Improve the spectroscope by adding a data processing system: Program software in python, record spectra on a raspi or something similar, get the basics of electronics and circuit design, learn how an oscilloscope works by examining and error-tracing the measurement circuit 3. Go further on the wave nature of light, Maxwells equation and corresponding mathematic (introductory level) 4. Formulate mathematical models of circuits and waves, solve numerically with python/numpy 5. Apply results to understand how structure of matter is investigated, model atom spectroscopy with Hg lamps

	Competencies and Qualification	**Professional competence** Students will understand: • How to conceptualize a project • Principles of software development in an applied context • Fundamentals of electronics **Methodological competence** Students will understand: • Advanced modelling on a computer • Use user-friendly electronics to construct a device for specific data collection Personal competence • Students need to create effective teams and take responsibility for tasks within the team-work
	Assessment	Continuous Assessment
Project Semester 4	Module name / Module Code	CMFS4: Abstraction and Simulation – the world according to models, project semester 4 /
	Lecturers	Prof. Dr. Alexander Struck
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10
	Prerequisites	Required prerequisite: Recommended prerequisite: CMFS3
	Module Objectives:	Students learn and apply advanced modelling and simulation concepts.
	Content	1. Understanding simulation: from life to math to computation to life 2. Exploring certain techniques: Optimization, physical simulation on different scales 3. Examine and evaluate simulation results 4. Examined system: preferably one that has been dealt with in an earlier project 5. Probabilistic techniques: How to plot the future, analyze data from open sources to break down insight to own project

	Competencies and Qualification	**Professional competence** Students will understand: • Advanced techniques in programming and data analysis • Simulation techniques • Optimization and basics of machine learning **Methodological competence** Students will understand: • How to collect and evaluate data from public sources • How to use standard computational libraries Personal competence • Students need to create effective teams and take responsibility for tasks within the team-work
	Assessment	Continuous Assessment
Project Semester 5	Module name / Module Code	CMFS5: Exploration enhanced – solve a real problem, project semester 5 /
	Lecturers	Prof. Dr. Alexander STruck
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project 130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: Recommended prerequisite: CMFS4
	Module Objectives:	Deploy aquired competencies, skills and methods to an interesting project mimicking requests encountered in professional environments. Learn how to make unsolvable problems solvable
	Content	1. Work on a project that has been treated or even is about to be treated in a research project, company assignment etc. 2. Example (10/2023): Construct a drone for water sampling, amphibic/groundlevel or flying device with dedicated sample grip/hook system Follow “customer” specifications, create research report
	Competencies and Qualification	**Personal competence:** **Students will demonstrate**

		• **That they are able to deliver reliable results using professional standards** • **That they are able to explain and defend their results** • **That they are resistant to stress and can make the best out of “unfinished business”**
	Assessment	Continuous Assessment

Centre of Knowledge
Biological Transformation

General Information	Centre of Knowledge Desciption	Engineering for sustainability is at its core a process of change, a transformation, from established exploitative design philosophies and production methods to modern integrated concept development and equilibrated productivity. Traditional industrial processes rely on high impact extraction of raw materials from the earth and seas, energy-intensive conversion of state, ever-increasing public consumption, and a one-way flow of resources back into the earth and seas via landfills and runoff. Modern integrated design looks for more balanced resource extraction, conversion, production, and disposal by implementing more efficient, low-temperature, low-pressure, pH neutral, and distributed manufacturing technologies. In the Knowledge Centre for Biological Transformation, students will be introduced to the models that biology can provide as inspiration for the required change and to the tools being used to reverse engineer natural processes so that the resulting understanding can be implemented in new biomimetic and ecologically compatible processes. The KCBT curriculum starts with a fundamental understanding of biology and ecology, then works through the abstraction tools of biomimetics, and finally leads to the development of novel sustainable solutions to engineering challenges. Students will acquire a mix of theoretical knowledge and practical skills as they progress through the programme, experiencing increasing levels of both independence and team-work. In the end they will be able to integrate biological and biomimetic principles, materials, functions, structures and resources in order to design and develop intelligent, sustainable engineering and manufacturing processes.
	Module Coordinator	Prof. Dr. phil. William Megill Prof. Dr. Lily Chambers
	Literature	Campbell NA, Reece JB (2011). *Campbell biology*. 9th ed. Boston: Pearson. ISBN 978-0-321-55823-7 Vincent JFV (2012). Structural biomaterials 3rd ed. Oxford: Princeton UP. ISBN 978-0-691-15400-8 Ahlborn BK (2004) Zoological physics. Berlin: Springer. ISBN: 978-3-642-05877-6

		Knudson: Fundamentals of Biomechanics. Berlin: Springer. 978-0-387-49312-1 Neugebauer R (2020) Biological Transformation. Springer. ISBN 978-3-662-59659-3
	Primary interfaces to other Centres	

Project Semester 2	Module name / Module Code	BT2: Biological Transformation, project semester 2 / 2211
	Lecturers	Prof. Dr. phil. William Megill Prof. Dr. Lily Chambers
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6
	Prerequisites	Required prerequisite: Introductory module 1st semester Recommended prerequisite:
	Module Objectives:	On completion of this module, students are introduced to the across multiple levels of organisation from molecules to ecosystems. They will have an understanding of the relationship between form and function in adaptation and evolution. They are able to set this knowledge in the context of biomimetic design and development. They will be able to document and review their own work, present and reflect.
	Content	Biological Form and Function • Foundations of biology: ○ Water, carbon, cells, DNA, genetics ○ Biodiversity, ecosystems ○ Natural selection, evolution, and extinction • Form and function: Adaptations for: ○ Thermodynamics & materials ○ Locomotion in air & water and on land ○ Plant biomechanics • Biomimetics as a transformation science • Bionics and ethics • Biological transformation, sustainability and UN SDGs
	Competencies and Qualification	**Professional competence** Students will understand: • fundamental biological concepts: cells, tissues, organs, organisms, populations, ecosystems. • classify core concepts of evolution, natural selection and biodiversity. • clarify biomimetic abstraction. **Methodological competence** Students will understand:

		• sample preparation and light microscopy. • field observation procedures. Students will apply their understanding of: • documentation with notes, logbooks & Mahara. **Sustainability competence** Students will have knowledge of: • ecosystem function. • ecosystem resources . • biological transformation and UN SDGs. Students will understand: • energy flow and the balanced energy equation. • ecosystem services.
	Assessment	Continuous Assessment
Project Semester 3	Module name / Module Code	BT3: Biological Transformation, project semester 3 / 2221
	Lecturers	Prof. Dr. Lily Chambers Prof. Dr. phil. William Megill
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	160 h project work 65 h self-study
	Credit Points	7.5
	Prerequisites	Required prerequisite: BT2 Recommended prerequisite:
	Module Objectives:	On completion of this module students have an understanding of biological materials and structures and the experimental techniques required to measure their properties. They understand the role that the environment has on nature’s structures and the functions thereof. Through project work with lightweight and composites structures they have a core understanding of natural materials in engineering for sustainability.
	Content	Biomimetic Materials and Structures Introduction to biological materials and structures, including biopolymers, bone, skin, scales, feathers, shells, and wood. Sample preparation (traditional and digital) and basic mechanical analysis. Biological lightweight structures and composites. Energy requirements for materials processing and production in biology and technology. Papermaking as a demonstration technology.

		Incorporation of natural materials and structures in engineering design, including CAD and SKO, additive and subtractive digital manufacturing.
	Competencies and Qualification	**Professional competence** Students will have knowledge of: • key biological, mechanical and chemical terms for biological materials and structures (F1) Students will understand: • experimental exploration of biological materials and structures in nature. • molecular building blocks of natural materials. • natural and technical case studies in BT and sustainability. Students will apply their understanding to: • lightweight structures (Leichtbau). • composites and woven materials. • the conduct of scientific experiments. Students will analyse: • natural form and function in engineering context. **Methodological competence** Students will understand: • material properties requirements in CAD, including SKO. • additive vs subtractive digital manufacture (3D printing vs CNC machining). Students can apply their understanding of: • materials testing experiments. • sample preparation using tools such as laser cutter and/or conventional machines. • manufacture and use of natural fibres to make paper. Students can analyse: • data and perform write ups in specified forms. **Sustainability competence** Students will understand: • biological synthesis from elements. • materials selection for sustainability, performance. • materials and structures in the environment. • reprocessing routes for wood-based materials. Students can apply their understanding of: • energy requirements for materials processing and industrial production. Students will analyse: • design for use of natural materials.
	Assessment	Continuous Assessment

Project Semester 4	Module name / Module Code	BT4: Biological Transformation, project semester 4 / 2231
	Lecturers	Prof. Dr. Lily Chambers Prof. Dr. phil. William Megill
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10
	Prerequisites	Required prerequisite: BT3 Recommended prerequisite:
	Module Objectives:	In this module students learn to analyse form and function in zoology with the tools of fundamental physics, and to abstract the underlying principles to enable biomimetic design. They can design biomechanical experiments and build the relevant apparatus. They can communicate at an advanced level, setting their biomimetics knowledge into the context of environmental sustainability.
	Content	Sensing and Actuation Zoological physics: energy, thermodynamics, fluids, statics, dynamics, locomotion, acoustics, optics, as they relate to organisms and natural systems. Basic techniques and engineering science of sensors and actuation in biology and technology Abstraction of biological principles and implementation of biomimetic technologies. Sustainability/energy efficiency of biomechanical structures and systems for various environments (water, land, air).
	Competencies and Qualification	**Professional competence** Students will understand: • biomechanics: muscles, nerves, feedback control. Students will apply their understanding to: • sensors and actuation in biology and technology. Students will analyse: • zoological physics. • abstraction of biological principles. • implementation of biomimetic technologies. **Methodological competence** Students will apply their understanding to: • design and build experimental apparatus incorporating motors and sensor feedback control. Students will analyse: • experiments in biology, biothermodynamics, biomechanics, bioacoustics, vision. Students will abstract: • analysis and write-up in free form

		Sustainability competence Students will apply their understanding of: • environmental and health sensing. Students will analyse… • 3Rs in assistive technology and robotic systems. • energy efficiency of biomechanical structures.
	Assessment	Continuous Assessment
Project Semester 5	Module name / Module Code	BT5: Biological Transformation, project semester 5 / 2241
	Lecturers	Prof. Dr. phil. William Megill Prof. Dr. Lily Chambers
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project 130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: BT4 Recommended prerequisite:
	Module Objectives:	Application of biotransformation knowledge, tools and techniques for the production of assistive and/or wearable technologies to extend human performance in sport, in rehabilitation, and in the workplace.
	Content	Analysis of the biomechanical requirements of sports, workplace assistance and rehabilitation. Advanced biomimetic abstraction and engineering design. Project planning and management. Iterative prototyping with conventional and digital manufacturing approaches. Product documentation, evaluation and customer communication Ethics in sports, rehabilitation, assistance & the workplace.
	Competencies and Qualification	**Professional competence** Students will analyse: • biomimetic and “smart” materials. Students will abstract: • biological principles integrated into human-centred design. • human performance, sports, workers and assistive technology. Students will create: • application of biological transformation knowledge for the production of assistive technology (sports, work, accessibility). **Methodological competence** Students will apply their understanding of:

		• project planning and management. Students will abstract: • production skills – design, CAD, digital manufacture of functional prototypes. Students will create: • documentation: physical and virtual logbooks, engineering reports. **Sustainability competence** Students will analyse: • design for use, repair, modification, upgrade, end-of-life, and SDGs. Students will abstract: • efficiency in concept, design, and manufacture, especially materials. • efficiency in energy: biofuels and algal energy harvesting, energy of production.
	Assessment	Continuous Assessment

Centre of Knowledge
Digital Product Creation

General Information	Centre of Knowledge Description	The mission of the Centre of Knowledge *Digital Product Creation* (DPC) is to foster interdisciplinary collaboration, research, and education to drive the creation of sustainable products and systems that meet the evolving needs of society and industry. By harnessing the power of digital technologies, the centre aims for efficient product development and places a strong emphasis on modern engineering design approaches, leveraging state-of-the-art software tools and methodologies to optimize product performance and functionality. Through collaborative projects, students address pressing challenges in product development and explore sustainable design solutions by combining expertise from diverse fields such as agile design methodology, 3D CAD, 3D scanning and additive manufacturing (3D printing). By embracing the principles of sustainability, creativity, and collaboration, the center seeks to equip students with skills and knowledge through hands-on training and experiential learning opportunities.
	Module Coordinator	Prof. Dr.-Ing. Stéphane Danjou
	Literature	Krause, D., & Heyden, E. (Eds.). (2022). Design methodology for future products: Data driven, agile and flexible. Springer. Danjou, S. & Morling, K. (2022). Geometric and engineering drawing (4th edition). Routledge. Schilling, P. J. (2023). Parametric modeling with SolidWorks 2023. SDC Publications. Darbyshire, A., & Gibson, C. (2022). Mechanical engineering (4th edition). Routledge. Juvinall, R. C., & Marshek, K. M. (2017). Fundamentals of machine component design (6th edition). John Wiley & Sons. Dixon, J., & Gullo, L. J. (Eds.). (2018). Quality and reliability engineering series. Design for safety. John Wiley & Sons Ltd.

		Has, M. (2022). Sustainable Products: Life Cycle Assessment, Risk Management, Supply Chains, Eco-Design. De Gruyter textbook. de Gruyter. Confalone, G., Kinnare, T., & Smits, J. (2023). 3D scanning for advanced manufacturing, design, and construction. Additive manufacturing skills in practice series. John Wiley & Sons Inc. Gebhardt, A., Kessler, J., & Thurn, L. (2019). 3D printing: Understanding additive manufacturing (2nd edition). Hanser Publishers.
	Primary interfaces to other Centres	

Project Semester 2	Module name / Module Code	DPC2: Digital Product Creation, project semester 2 / 2213
	Lecturers	Prof. Dr.-Ing. Stéphane Danjou Dipl.-Ing. Angelika Michel Dipl.-Ing. (FH) Martin Schlösser
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6
	Prerequisites	Required prerequisite: Recommended prerequisite:
	Module Objectives:	The overall objective of this module is to design a real life product within a team, from the requirements analysis to the development of design concepts and the modeling design phases up to the physical prototype of the design result. The students learn methods for systematic problem structuring and solution finding, and they can successfully transfer these to an applied development project. The project is completed with an evaluation of the product design regarding aspects such as quality of the 3D CAD models, manufacturing and function oriented design, and collaboration within a team.
	Content	Exemplary project outline: Development of a component from a bottle conveyor line Hollow glass containers such as glass bottles are produced by going through the so called ‘hot end’, i.e. a furnace, a forming machine and an annealing lehr. The subsequent ‘cold end’ handles the transportation for bottle inspection and to packaging equipment. In this project, students are supposed to develop a solution for

		a bottle alignment station which re-orients bottles in case of non-rotationally symmetric shapes of the bottle. Students will work in teams of 4-6 people to develop a bottle alignment station. Concept and design − Define project requirements and objectives for the bottle alignment station − Creation of a functional structure and development of basic solutions. − Concept development for the bottle alignment station in the context of its use of application. − Comparison and evaluation of different concepts. Design and layout − Implementation of the favored concept into a simple 3D model using the CAD software SolidWorks. − Selection of appropriate third-party components. − Calculation of the necessary speeds for realigning bottles. Simulation and presentation − Create a simulation of a simple bottle conveyor system with integrated product design of the bottle alignment station. − Evaluate the performance and efficiency of the station in the context of its application. − Preparation of a final presentation in which the developed product or system is presented.
	Competencies and Qualification	After completing the project, students are able to carry out project planning for specific development tasks and design sustainable product components that meet requirements and fulfil expected functions. Professional competence The students … • know and systematically apply the fundamentals of design methodology to develop sustainable technical products or systems • know design guidelines and are able to apply them for target-oriented solutions • identify product requirements • generate and evaluate concepts for assigned components • create appropriate 3D CAD models and drawings for digital product specification • check and evaluate the product design based on the created requirements catalog Methodological competence The students … • abstract the task to identify key problems • determine the functional structure of the product

		• choose suitable interfaces between the design spaces of the individual teams • combine suitable operating principles to create active structures • evaluate concepts with regard to technical and economic criteria • document the project progress and partial results in an appropriate form • use suitable methods and software tools for collaboration
	Assessment	Continuous Assessment
Project Semester 3	Module name / Module Code	DPC3: Digital Product Creation, project semester 3 / 2223
	Lecturers	Prof. Dr.-Ing. Stéphane Danjou Dipl.-Ing. Angelika Michel Dipl.-Ing. (FH) Martin Schlösser
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	160 h project work 65 h self-study
	Credit Points	7.5
	Prerequisites	Required prerequisite: DPC2 Recommended prerequisite:
	Module Objectives:	The aim of the module is to provide students with in-depth knowledge and practical skills in the area of 3D printing and structural design for additive manufacturing technologies. The module is project-based and aims to give students practical experience in 3D printing-friendly design. The focus is on the development of a functional product using 3D printing techniques. The students learn how to adapt design, functionality and ergonomics to the special requirements of 3D printing.
	Content	<u>Exemplary project outline:</u> Development of a 3D printed robot arm Basics and concept development − Introduction to the various 3D printing technologies − Selection of materials and properties for 3D printing − Understanding of printing parameters and settings − Safety aspects and environmental impacts − Team composition and role distribution − Development of the project goals and requirements − Concept development and initial sketches Modeling and prototype development − 3D CAD modeling of the product while applying design guidelines for 3D printing

		– Prototype design using 3D printers and materials – Validation of the prototype and optimization Completion and presentation – Print, post -processing and testing of the manufactured components – Completion of the robot arm – Final tests and quality control – Preparation of presentations and reports for documentation of the project – Final presentation in front of lecturers and fellow students for the presentation of the developed product and the underlying methods Students will be assessed based on their active participation in the project, their presentations and reports, and their skills in 3D modeling and printing assessment. The evaluation takes place according to the previously defined criteria.
	Competencies and Qualification	After completing the project, the students are able to carry out project planning for specific development tasks and design product components that meet requirements and functions. Professional competence The students … • know the different 3D printing technologies and their materials and can select and use them on a case-by-case basis • design and develop components that are optimized for 3D printing • select suitable materials taking into account requirements and 3D printing parameters Methodological competence The students … • create complex components and assemblies in a professional 3D CAD environment • create a prototype using 3D printing technologies and can evaluate it using suitable methods • acquire the ability to clearly document and present project results
	Assessment	Continuous Assessment
Project Semester 4	Module name / Module Code	DPC4: Digital Product Creation, project semester 4 / 2233
	Lecturers	Prof. Dr.-Ing. Stéphane Danjou Dipl.-Ing. Angelika Michel Dipl.-Ing. (FH) Martin Schlösser
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks

Workload	200 h project work 100 h self-study
Credit Points	10
Prerequisites	Required prerequisite: DPC2 Recommended prerequisite:
Module Objectives:	The module focuses on the application of advanced design and analysis techniques in the development of products in mechanical engineering. In this project-based module, students are introduced to advanced principles of product development and acquire advanced knowledge and skills in the areas of design, calculation, material selection and scanning processes to solve real technical challenges. The project concludes with an assessment of the product design, particularly taking sustainability aspects into account.
Content	<u>Exemplary project outline:</u> Development of a vertical conveyor in a bottle conveyor belt system The module lasts three weeks and is accompanied by a practice-oriented project. The project process is divided into different phases. Project initiation and requirements analysis − Introduction to the project topic: Vertical conveyor for bottle conveyor systems − Team composition and role distribution − Development of project goals and requirements − Analysis of the given bottle conveyor system and identification of the requirements for the vertical conveyor − Development of a safety concept for the use of the vertical conveyor Conception and modeling − Concept development for the vertical conveyor − Creation of 3D CAD models and integration of scan data to capture bottle geometries − Selection of suitable materials taking into account the requirements and strength criteria − Application of calculation methods to validate the concept Prototype development and presentation − Implementation of the selected concept into a digital prototype of the vertical conveyor − Simulation and validation of the prototype − Preparation of presentations and reports to document the project − Final presentation to lecturers and fellow students to introduce the developed vertical supporter and the underlying methods

	Competencies and Qualification	At the end of the module, students should be able to apply advanced product development methods to solve a technical problem. You should understand and be able to apply the link between design and calculation, select materials taking into account requirements and strength criteria and be able to use scanning technologies. In addition, they should develop teamwork and presentation skills and be able to communicate their solutions clearly. Professional competence The students … • acquire in-depth knowledge of 3D CAD modeling in order to create technical drawings and models • learn the principles and processes of product development in mechanical engineering • acquire the ability to apply calculation methods to check and optimize the strength and functionality of products • develop skills in selecting materials, taking requirements and strength criteria into account • can select suitable scanning methods and use them to capture geometries Methodological competence The students … • acquire the ability to develop creative concepts and implement them in 3D CAD models • learn how to validate and optimize concepts and models through calculations and tests • can document project results clearly and understandably and present them to a specialist audience • organize and coordinate a project team to achieve the project goal within the time frame
	Assessment	Continuous Assessment

Centre of Knowledge
Engineering Design

General Information	Centre of Knowledge Desciption	Engineering Design and hence product development is to be seen as a central process within the engineering sciences and has interfaces with economic, manufacturing and materials science disciplines. In contrast to classic product design, which even today prioritizes the most economical realization of functions, future products must be designed sustainably in terms of a social, ecological and economic balance. These and other sustainability aspects must be taken into account when selecting materials, designing components and systems and evaluating solutions against the background of the associated energy and resource properties. The center is dedicated to this task. new approaches, for example to requirements for the reuse of products (second life) and the implementation of the circular economy, are applied in selected projects and thus advance the sustainability transformation in the Lower Rhine region. The center's work is complemented by the teaching of classic design fundamentals and basic knowledge of materials, their possible applications and limitations, as well as systemic, interdisciplinary thinking and the use of creativity techniques. Through the chosen project-oriented approach with theo-retic knowledge transfer in a blended learning format, students acquire not only technical competencies but also methodological competencies in the field of project management.
	Module Coordinator	Prof. Dr.-Ing. Peter Kisters
	Literature	Engineering Design: Kisters, Peter: Lectures Notes on Engineering Design (script, videos, tasks, sample solutions) Richard G. Budynas: Shigley's Mechanical Engineering Design, international students edition ISE, 12th edition, ISBN-13 978-1266929894, McGraw-Hill College, 2024 Karl-Heinz Grote, Hamid Hefazi: Handbook of Mechanical Engineering, 2nd ed. 2021 edition, ISBN-13 978-3030470340, e-ISBN 978-3030470357, Springer 2021 Further Reading:

		Beate Bender, Dietmar Göhlich: Dubbel Taschenbuch für den Maschinenbau, Band 1 bis 3, 26. Auflage, ISBN-13 978-3662620182, Springer 2021 Roloff/Matek: Maschinenelemente: Normung, Berechnung, Gestaltung, 26. Edition, ISBN-13 978-3658409135, Vieweg Teubner, 2023 Decker: Maschinenelemente: Funktion, Gestaltung und Berechnung, 21. Auflage, ISBN 978-34461472303, Carl Hanser Verlag, 2023 Sustainability: Yates, J. K., Castro-Lacouture: Sustainability in engineering design and construction, ISBN 978-1-4987-3391-5 (alk. paper), CRC Press Taylor & Francis Group, Boca Raton, 2016 Jane Penty: Product Design and Sustainability - Strategies, Tools and Practice, ISBN 978-0203732076 (ebook), Routledge Taylor & Francis Group, New York, 2020 Toolseeram Ramjeawon: Introduction to Sustainability for Engineers, ISBN-13 978-0367254452 (Hardback), CRC Press Taylor & Francis Group, Boca Raton, 2020 Michael von Hauff: Nachhaltige Entwicklung – Grundlagen und Umsetzung, eISBN 978-3486856002, de Gruyter Oldenbourg Wissenschaftsverlag GmbH, Munich, 2014
	Primary interfaces to other Centres	• Centre for Digital Product Creation (DPC, Prof. Dr.-Ing. S. Danjou) • Centre of Fundamental Science and Mathematics (FSM, Prof. Dr. A. Struck) • Centre for Material Strength and Simulation (MSS, Prof. Dr. N. Ostergaard)

Project Semester 2	Module name / Module Code	ED2: Engineering Design, project semester 2 / 2214
	Lecturers	Prof. Dr.-Ing. Peter Kisters
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	Project work: 120 h Self-study: 60 h

Credit Points	6
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives:	• Sketching components and structures • Sharpening spatial vision • Performing assemblies / disassemblies • Recognizing different design strategies • Development of new perspective: Design for Sustainability • System identification, system limits, practical experience with load limits • Construction of a stress optics device
Content:	Analysis and understanding of technical relationships Students gain an overview of fundamental mechanical engineering competencies and develop an eye for technical interrelationships, elements and the design of interfaces between them. They gain a spatial understanding of load and stress situations and are able to communicate their ideas and thoughts using sketches. They identify necessary process steps and learn how to use fundamental tools for product development. They develop a basic understanding of sustainability in engineering.
Competencies and Qualification	**Professional competencies** Students acquire knowledge about... … standardized elements and structural, specifically manufactured components and their treatment in the design process … different machine elements and naming these components … the physical quantities, strengths and surface properties commonly used to describe components … the differentiated determination of static and dynamic loads … the creation of simple drawings and the reading of drawings … design guidelines and principles … comparative stress concepts for deriving comparable uniaxial stress conditions … various manufacturing processes including additive manufacturing processes … intuitive and rational problem-solving approaches … dealing with norms and standards … the creation and definition of specifications … dealing with design documents and guidelines … the necessities, advantages and limitations of standardization and norms … the classification of materials and their properties (acc. Ashby)

		They understand… … basic physical-technical functional principles and the naming of these … system limits and material, energy and signal flows … static and dynamic load scenarios … influences of shape and notch effects on the loading of components … principles of system identification … types of and differences between loads and stresses … procedures for isolating components from a system … differences between various connection concepts (material-locking, force-locking, form-locking) … influences of surface properties on component and system properties They apply their knowledge to... … load scenarios on the calculation of individual parts … calculation approaches for different connections of components … influences of stress cycles on the service life of components … functional principles on the design of connection elements **Methodological competencies** The students acquire knowledge about... … the description and optimization of material properties … manufacturing and joining methods and their influence on component properties sketching components … Selection criteria and limitations of methods against the background of the state of the art … optimized and compact designs with multiple use of imposed loads … suitable verification concepts for various development tasks (e.g. welded joints) … dealing with norms and standards … the importance of the House of Quality for the systematic development of products … phases and steps of product development … the evaluation of results for component calculations … the phases of a product development process They understand... … concepts for the calculation of components … the expected results and limitations of the methods used … design concepts against the background of functional and economic aspects (Design to X approaches) … necessary safety factors and their significance They apply their knowledge to...

		… the sketching of components … spatial representations for the development of spatial imagination … basic calculation procedures for determining the service life of components **Sustainability competencies** The students acquire knowledge about... … the basic interrelationships of sustainable acting … the sustainability goals of the United Nations … the necessity and maintenance of life-sustaining systems … design in nature (organic design) compared to design in technology (inorganic design) … the three pillars of sustainability and their effects on construction processes … socio-ecological systems or coupled human-environment systems and their complexity … key components and dynamics of systems … cause-effect relationships … system integrity and civility … the implementation of intervention points (disruptive change points) … intentions of actors, systemic inertia, path dependencies, barriers, alliances … for the assessment of feasibility and feasibility They understand... … the necessity of systemic considerations … the importance of balances and the consequences of disturbing them … inter- and intragenerational equity … structured vision work … principles of technical and natural lightweight construction … interaction of structure, components and dynamics/change of systems … rebound and cascade effects as well as (change) inertia They apply their knowledge to... … of sustainability values, principles and objectives … conditions for a successful circular economy … multi-criteria evaluation schemes … design, negotiation and definition of future scenarios … structuring and mapping of influencing variables on scenarios
	Assessment	Continuous Assessment including • Mahara Learning diary (incl. Publishing of results within the group of students) • Graded project reports and homeworks • oral examinations

		• written, digital assessments (tests, quizzes)
Project Semester 3	Module name / Module Code	ED3: Engineering Design, project semester 3 / 2224 Recognition, action competencies and technology as a language
	Lecturers	Prof. Dr.-Ing. Peter Kisters
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	Project work: 160 h Self-study: 65 h
	Credit Points	7.5
	Prerequisites	Required prerequisite: ED2 Recommended prerequisite:
	Module Objectives:	Students go on learning the "language" of engineering and, in addition to drawing tasks take on their first calculation tasks. They interpret their drawings and calculation results and are able - if necessary - correct them. They begin to consider the sustainability of technical solutions in their designs and recognize the various influences. The students begin to take into account customer requirements and understand the need for anticipation and strategic competence necessary to find sustainable solutions. In addition, they are able to isolate components from systems, describe those using suitable and permitted methods and designs with regard to suitable manufacturing processes.
	Content	• Calculation of components • Functional design and its effects on shape and stress concentration • Failures modes and utilization of components • Planing of design processes and manufacturing steps • Engineering drawing of components and systems • Selection of suitable materials and possible treatments to improve material properties • Understanding the need for methods and methodologies in Engineering Design • Understanding the influences on sustainable design • Basics and complexity of sustainability theory • Development of solutions for customer projects
	Competencies and Qualification	**Professional competencies** Students acquire knowledge about... … conceptual, temporary, economic, mental and social influences on the development process … integrated product and process development

		… the significance of errors for the further development of components and systems They understand… … design phases and associated tasks … the steps required to calculate a component … calculation steps for determining stresses and strains as well as the stress limits of machine elements … differences between corrective and generative product design They apply their knowledge to... … principles of assembly-oriented design … free body principles for isolating individual parts from systems … principles of self-locking for functional fulfillment … the selection of suitable drive concepts … heat treatment processes to optimize components … application-specific calculation procedures for welded joints … design guidelines according to VDI 2221 … abstraction concepts for dividing systems into subsystems … test-operate-test-exit routines for the optimization of components and systems They analyze... … assemblies and machine elements with regard to function and load … stresses on rolling bearings … correlations between deformation, strain, load and function … form and position tolerances and their effects on the dimensioning and function of components … degrees of freedom (DOF) … functional system limits … given systems with regard to boundary and support conditions for deriving bearing loads **Methodological competencies** The students acquire knowledge about... … methods for evaluating the CO2 footprint of systems … transportation and logistics requirements for technical products … the environmental impact caused by design and materials They understand... … the principles of recycling-friendly design … the differences, advantages and disadvantages between forward engineering and reverse engineering

		They apply their knowledge to... … methods for the creation of design variants … FMEAs to minimize the risks of product failure … standardized calculation methods for the design of machine elements … control and release routines for product development part results (drawings, calculations) … and calculation routines for changed calculation conditions They analyze... … properties of functional surface optimizations … plausibility of calculation processes … systems and components under consideration of the utilization phase … material properties on the basis of tests and material characteristics **Sustainability competencies** The students acquire knowledge about... … creativity techniques and approaches from out-of-the-box thinking to innovative and disruptive product development … planetary boundaries (Brundland Report, IPCC's) They understand... … strategic concepts for the implementation of sustainable solutions … the potential of unforeseen consequences … the complexity of change processes They apply their knowledge to... … fields of action and requirements of the United Nations Sustainable Development Goals … Identification of social, ecological and economic implications of decisions made and change processes … peer-reviewed "classics" of sustainability transformation to your own issues … sustainability-relevant methods and methodologies for design, testing, implementation and evaluation … the adaptation of implementation programs and policies They analyze... … sustainability aspects and situations with regard to their prioritization and setting of these … purposes, options, impact, reducing effect and extensions of sustainable solution approaches … complex systems over different scales … empirical evidence … direct and indirect effects on people and ecosystems

	Assessment	Continuous Assessment
Project Semester 4	Module name / Module Code	ED4: Engineering Design, project semester 4 / 2234
	Lecturers	Prof. Dr.-Ing. Peter Kisters
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10
	Prerequisites	Required prerequisite: ED3 Recommended prerequisite:
	Module Objectives:	Students develop their skills in engineering design by taking an increasingly holistic view of the requirements for sustainable solutions and temporarily adopting the perspectives of other stakeholders. In addition, they will develop from technical draughtsmen or calculators to those responsible for the entire design process, which increasingly requires strategic thinking, negotiating skills and foresight in addition to technical skills. At the same time, students strengthen their creative skills, learn creativity techniques and provide impetus with regard to innovative technical approaches and sustainable implementation.
	Content	Conceptualizing and design, procedural competencies • Calculation of various machine elements and connections of those • In-depth understanding of material properties and surface modifications • Boundary conditions and their influence on function and reliability • System analysis in order to reduce loads and stresses • Impact of stiffness / resilience on load and stressing • Selection of drives, drive systems under consideration of the related properties of these • Improvement of technical communication skills • Development of project management skills • Forward engineering under consideration of SDGs • Analysis of the impact of different perspectives and actors on the design process • Dealing with deviations in terms of time and content
	Competencies and Qualification	**Professional skills** The students understand... … the importance of communication with the partners involved during the design process … the need for teamwork in the design process

		… differences between tasks and problems … influences defined by the design on product success (responsibility of the engineer) They apply their knowledge to... … different modeling levels to gain insights … suitable and target-oriented methods for the respective design step … basic design rules on the design process (Keep it...) They analyze... … economically sensible changes against the background of design costs and product costs … manufacturing costs, product costs / life cycle costs … damage to components … influences of drive systems on components and subsystems The students evaluate... … the design and calculation of welded joints as an example of adhesive joints … the design and calculation of bolt connections as an example of form-fit connections (alternative) … Design and calculation of bolted connections as an example of combined connections (alternative) … influencing factors and material limits such as yield strength, yield point and breaking strength on simple components … influences of stiffness and resilience on the loading and stressing of components … effects of changing environmental properties (temperature, pressure, humidity, ...) on the function and properties of components … possible manufacturing errors and their effects on developed designs … drive concepts against the background of energy use and efficiency They create… … connecting elements, taking into account specified requirements … systems such as brakes, clutches and gearboxes using standardized components … sealed tribological systems such as hydrostatic and hydrodynamic bearings **Methodological skills** The students understand... … legal regulations for the commissioning of machines and systems … requirements for ergonomics and user-friendliness They apply their knowledge to... … Calculation approaches for the $C0_2$ footprint

		… different perspectives on costs They analyze... … deficits (informational, technical) in product development … statistical and structural errors of a method The students evaluate... … mechanical and physical dependencies … competing methods with regard to their applicability and manageability … manufacturing processes and their suitability for guaranteeing the required component properties … the reliability and safety of components and systems, taking into account individual survival probabilities of single parts and assemblies … differences between various manufacturing processes in terms of design and component properties They create… … functional surface modifications with regard to product optimization … adapted calculation and evaluation methods **Sustainability competencies** The students understand… … rebound effects of optimized technologies and effects on social and ecological sustainability … influences of time and uncertainty … unintended consequences and intergenerational equality They apply their knowledge on… … different dimensions of sustainability … the transfer of SDGs to technical development processes … the derivation of additional, required process steps as a result of taking the SDGs into account They analyze… … different social actors … different perspectives and interests … different languages of the actors involved … logistical challenges The students evaluate... … sustainability and (un-)sustainability of current and future states of socio-ecological systems … potential for change and feasibility … sustainability goals They create… … products and systems that allow subsequent use

		… "from cradle to cradle" products … ethically and morally just and sustainable conditions
	Assessment	Continuous Assessment
Project Semester 5	Module name / Module Code	ED5: Engineering Design, project semester 5 / 2244
	Lecturers	Prof. Dr.Ing. Peter Kisters
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project 130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: ED4 Recommended prerequisite:
	Module Objectives:	Students focus on key technical parameters such as energy, friction, wear against the backdrop of the search for sustainable solutions, and take on an increasingly analytical, evaluative and generative role in the design process. They combine knowledge of economic and social implications and look for ideal solutions against this background. At the same time, students develop the skills to deal with setbacks and disruptions in the processes and to use the resulting energy sensibly for the further development process. They understand the importance of communication and a unifying language and use these to form a team of all those involved in the sustainable design process.
	Content	Decision making competencies, building and testing • Generalist perspective on the technical development process supplemented by an understanding of social and ecological goals • Calculation of cost and life cycle costs combined with sourcing decisions • Analysis and evaluation of manufacturing processes and their deviations • Calculation of drive systems and evaluation of the dynamic load scenarios on the fatigue strength of components • Strengthening of an analytic approach to manage complexity (contextual and personal) • Evaluation of rebound effects on specific designs • Active anticipation and strategic responsiveness
	Competencies and Qualification	**Professional skills** They analyze... … life cycle costs and factors influencing them

		… skills and expertise required for the development of a product … functional system boundaries to users, users themselves and the environment The students evaluate... … measures to reduce friction and wear … measures to increase the energy efficiency of systems … manufacturing costs, product costs and life cycle costs … influences of production-related deviations (tolerances) on the function and stress of components … quality against the background of the fulfillment of customer interests … the description of socio-technical systems … the influence of complexity, public attention, type and scope of the market on the product development process … different solution concepts with identical functional fulfillment They create… … complete descriptions of the boundary conditions characterizing the function of the component … decisions on suitable manufacturing methods, heat treatments and production processes … variants taking into account suitable gradations … calculations using finite elements … documentation of the development process and product properties … modeling and prototypes … functional structures of complex products … organizational structures and framework conditions for a successful design process … assumption of responsibility for executed design processes … technical products, taking into account primary and secondary effects on costs and system reliability **Methodological skills** They analyze... … technological consequences and rebound effects … re-use possibilities and recycling properties The students evaluate... … different organizational approaches in product development … requirements and wishes in a differentiated manner … effects of growing product diversity on companies and customers

		… make-or-buy decisions and the associated opportunities and risks They create… … modular designs … optimal cost structures through target costing … specifications and functional specifications … time-optimized, rapid sequences of design steps … make-or-buy decisions … products optimized with regard to environmental compatibility **Sustainability competencies** They analyze… … visions of the future by and for various actors against the background of economic, social and ecological effects The students evaluate... … political and strategic dependencies … short and long-term implementation options … inconclusive evidence / research results due to uncertainties … different scenarios and developments of transformation processes against the background of the current state of knowledge … future scenarios and associated simulations They create… … participative systemic awareness building and understanding / wisdom … systemic solution approaches based on broad interdisciplinary knowledge-adapted implementation speeds … challenging issues and positioning at the right time … framework conditions that enable sustainable implementation images and stories of sustainable change … qualitative and quantitative descriptions of sustainable solutions
	Assessment	Continuous Assessment

Centre of Knowledge
Material Strength and Simulation

General Information	Centre of Knowledge Desciption	Material strength and simulation covers the engineering core disciplines related to analysis of the relationship between forces applied to bodies and states of deformation or motion. This discipline does not only provide highly relevant skills in order for engineers to perform mechanical design, but is additionally required in order to ensure the reliability of machines and structures. The sub-discipline related to simulation and validation is often referred to as qualification engineering, and will most likely gain importance not only in the context of design of sustainable mechanical systems for the future energy supply, but also in the age of AGI, as machines are likely to a higher extend to design machines. Engineering mechanics has traditionally been closely linked to analytical mathematics, and originally served as motivation for the development of infinitesimal calculus. In the past decades, high-speed computing has enabled application of a wide range of numerical simulation techniques (MBD, FEA, etc.) in the field of engineering mechanics. It is in the current centre of knowledge the general objective to cover both relevant analytical maths and numerical simulation techniques (using Python) as an integral part of the project based teaching.
	Module Coordinator	Prof. Dr. Niels Højen Østergaard
	Literature	Østergaard, NH: Lectures Notes on Strength of Materials chapter 1, 2, 3, 4, 5, 6, 7, 8, 9, 10 (Matrix Methods in Structural Mechanics) and 11 (Fatigue in Metallic Materials), 2018, HSRW Østergaard, NH: Lecture Notes on Particle Dynamics, HSRW, 2021, HSRW Østergaard, NH: Lecture Notes on Machine Dynamics, HSRW, 2019, HSRW Humar, JL: Dynamics of Structures, 2012, 3rd Ed. Taylor&Francis Group, ISBN 978-0-415-62086-4 Budynas, RG & Sadegh, AM: Roark's Formulas for Stress and Strain, 2020, 9th Ed, McGraw Hill Book Co, ISBN 978-1260453751

		Kreyszig, E: Advanced Engineering Mathematics, 1999, 8th Ed, John Wiley & Sons, ISBN 0-471-33328-X Sørensen, AM: Elementary Mechanics Using Python, 2015, Springer, ISBN 978-3-319-19595-7
	Primary interfaces to other Centres	

Project Semester 2	Module name / Module Code	MSS2: Strength and Simulation, project semester 2 / 2218
	Lecturers	Prof. Dr. Niels Højen Østergaard
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6
	Prerequisites	Required prerequisite: Recommended prerequisite:
	Module Objectives:	Students will after completing this project be able to conduct static structural analysis with accurate qualitative results in terms of stress and strain of a real life structural system constituted by axially loaded members. Furthermore, students will qualitatively obtain understanding of underlying design choices with particular focus on notched details and assemblies. Furthermore, the students will learn the basics of qualification/validation by comparing quantitative results obtained by two different methods to the dimensions of a real-life structural design. The considered structure can either be selected by the module coordinator, by the individual project groups under active supervision by teaching personal or supplied by external cooperation partners. Additionally, the students will learn to organize themselves into groups and together formulate common objectives (problem formulation) based on a break-down of the overall scope, before dividing the work tasks with particular focus on time management and the importance of acting on commitment (delivering on time). Emerging conflicts will be resolved under supervision for the module coordinator. The students will learn to document obtained results in written engineering reports and perform quality assurance by correcting each other’s written draft documentation This project can be carried out as stand-alone module only involving students with no prior knowledge of

		mechanics or as a joint-project with third semester students having already completed the two first mechanics project modules
	Content	Reverse engineering analysis of real life static structures • Calculation of resultant forces and moments with assessment of basic load cases • The concept of static equilibrium • The method of joints • Linear algebra in engineering mechanics using Python (vector and matrix operations, in particular rotation matrices) • Structural analysis of bar and truss systems using matrix methods for statically determinate structures • Definition of 1-d stresses and strains and material failure criteria for linear elastic materials
	Competencies and Qualification	Professional competence • … Methodological competence • … Sustainability competence • …
	Assessment	Continuous Assessment
Project Semester 3	Module name / Module Code	MSS3: Strength and Simulation, project semester 3 / 2228
	Lecturers	Prof. Dr. Niels Højen Østergaard
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	160 h project work 65 h self-study
	Credit Points	7.5
	Prerequisites	Required prerequisite: MSS2 Recommended prerequisite:
	Module Objectives:	The students will after completing this project be able to conduct structural analysis and calculate stresses and strains for 1-d mechanical components subjected to combined loads. Students will quantitatively handle basic failure mechanisms and will, in addition, be able to successfully qualitatively identify complex failure modes. Students will obtain a profound understanding of the mechanics and failure of linear elastic materials, while having a basic qualitative understanding of non-linear materials and failure modes. Furthermore, students will compare results obtained by classical linear strength of

		materials models to results from numerical analysis using basic CAE/FEA tools The considered structure can either be selected by the module coordinator, by the individual project groups under active supervision by teaching personal or supplied by external cooperation partners. Students will independently on basis of experiences gained in SaS Prj. 1 form groups and on basis of a breakdown of the overall task (problem formulation) conduct analysis work where results obtained by two different methods will be compared to the nominal dimensions of a real life structure. The teaching form applied is fully equivalent to Prj. 1, however, with increased complexity level, in order to develop the students understanding for validation of obtained results and social competences to a further level. In particular, the very high influence of FEA meshing in component regions with high stress gradients will be considered in the projects. While students will not have gained a profound understanding of accurate meshing yet, they will have obtained a basic understanding of the influence on the obtained results. The current project can either be conducted as stand-alone module or as joint-project with students taking the 4th project module, who in the ladder case will focus the project work on assessment of loads due to system dynamics.
	Content	Analysis of advanced mechanical systems • Combined states of stress due to various loads (axial/torsion/bending/internal pressure etc.) for bars, trusses, shafts, selected shells and beams • Mechanics of metallic materials / introduction to non-metallic materials & failure criteria • SAFs for notched details and analytical solutions • Design against fracture due to cyclic loads (fatigue) • Introduction to advanced failure mechanisms (buckling, collapse, burst etc.) • Basic statically indeterminate structures • Infinitisimal calculus recap (differentiation and integration of functions of one-variable) with particular focus on seperation of the variables for solving simple differential equations of first order • Introduction to basic FEA with commercial software
	Competencies and Qualification	Professional competence • … Methodological competence • … Sustainability competence • …
	Assessment	Continuous Assessment

Project Semester 4		
	Module name / Module Code	MSS4: Strength and Simulation, project semester 4 / 2238
	Lecturers	Prof. Dr. Niels Højen Østergaard
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10
	Prerequisites	Required prerequisite: MSS3 Recommended prerequisite:
	Module Objectives:	Students will after completing this project be able to conduct structural analysis of mechanical systems constituted by various types of structural members in 2- and 3-d by calculation of stresses and deformations. Particular focus will be given to structures comprised by beam members forming frames. The considered structure can either be selected by the module coordinator, by the individual project groups under active supervision by teaching personal or supplied by external cooperation partners. Students will independently form project groups and in groups under active supervision from the module coordinator formulate, structure and solve the considered problem. Students will independently on basis of experiences gained in previous projects form groups and on basis of a breakdown of the overall task (problem formulation) conduct analysis work where results obtained by two different methods will be compared to the nominal dimensions of the considered structure. The students will learn two different methods required for advanced structural analysis (see above). The current project can either be conducted as stand-alone module or as joint-project with students taking the 1st project module, in which case senior students will act as supervisors for junior students simulating an industrial engineering environment.
	Content	Analysis of dynamic systems • Structural mechanics of frames and frame-like structures applying both classical mechanical methods from strength of materials and matrix methods applying Python • Eigenfrequency- and buckling analysis formulated as eigenvalue problems • Advanced statically indeterminate structures • Introduction to energy methods in structural mechanics • Introduction to non-linear effects regarding materials and geometry.

	Competencies and Qualification	Professional competence • … Methodological competence • … Sustainability competence • …
	Assessment	Continuous Assessment
Project Semester 5	Module name / Module Code	MSS5: Strength and Simulation, project semester 5 / 2248
	Lecturers	Prof. Dr. Niels Højen Østergaard
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project 130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: MSS4 Recommended prerequisite:
	Module Objectives:	Students will after completing this project be able to independently analyse the dynamical behaviour (forward- and inverse dynamics along with determination of eigenfrequencies) of single- and multi degree of freedom mechanisms consisting of particles as well as rigid bodies. The considered mechanism can either be selected by the module coordinator, by the individual project groups under active supervision by teaching personal or supplied by external cooperation partners. The current project can either be conducted as stand-alone module or as joint-project with students taking the 2nd project module, in which case senior students will focus the project work on determination of the dynamic system analysis and load spectrum generation for the considered structures that serves as basis for the structural analysis performed by junior students.
	Content	• The kinematics of particles and rigid bodies with particular focus on the principle of relative motion formulated both classically using vectors and using rotation matrices (MBD approach) • The Newton-Euler and their applications for kinetic analysis • Methods for numerical integration of second order ordinary systems of differential equations • Frequency analysis by FFT (using Python) and calculation of eigenfrequencies for multi-degree of freedom systems as eigenvalue problems • Introduction to machine dynamics, fault frequencies and vibro-acoustics

		• Introduction to computational multibody dynamics (using Python)
	Competencies and Qualification	Professional competence • … Methodological competence • … Sustainability competence • …
	Assessment	Continuous Assessment

Centre of Knowledge
Process Cycles of Energy and Matter

General Information	Centre of Knowledge Desciption	Achieving closed loop energy and material cycles is becoming increasingly relevant due to the goals of sustainable resource management and mitigating the climatic consequences of industrialization. This results in increased demands on the thermodynamic optimal design of process engineering processes. The general focus of the centre *Process Cycles of Energy and Matter* is the thermodynamic evaluation of existing and upcoming technologies with regard to their environmental and climatic sustainability in relation to their economic feasibility. The focus of the development activities and of the study courses lies on the utilization potential of effluents from energy and separation processes as well as on the redesigning optimization of the processes with regard to the usability of existing by-products. A special, but not exclusive, focus is on the resource-optimized design of biomass processes. The processes are quantified with process engineering modeling procedures, such as process diagrams and flow charts and balancing the systems using the MESH equations (M - Material balances, E - Equilibrium relations, S - Summation relations, H - Energy balance [heat]). In terms of quantifiable sustainability that goes beyond a pure CO_2 balance, these are extended by entropic-exergetic key figures for an accompanying process evaluation (MESHEx+). Students of the centre *Process Cycles of Energy and Matter* are able to analyse, design, evaluate and optimize processes of energy and material conversion. The study projects are modelled and analysed in terms of their overall process design parameters using sustainability indicators.
	Module Coordinator	Prof. Dr.-Ing. Kai Masuch
	Literature	Gregory Szekely Sustainable Process Engineering. De Gruyter. ISBN 978-3110717129 Michael J. Moran, Howard Shapiro: Fundamentals of Engineering Thermodynamics SI-Version, ISBN 978-0-470-54019-0 Peter Stephan, Karlheinz Schaber, Karl Stephan,

		Franz Mayinger Thermodynamik: Grundlagen und technische Anwendungen – Band 2: Mehrstoffsysteme und chemische Reaktionen, Springer Verlag ISBN 978-3-662-54438-9, e-ISBN 978-3-662-54439-6 Alfons Mersmann, Matthias Kind, Johann Stichlmair: Thermal Separation Technology: Principles, Methods, Process Design. ISBN 978-3-642-12524-6 Warren L. McCabe, Julian Smith, Peter Harriot: Unit Operations of Chemical Engineering, 7th edition, ISBN 978-0-07-284823-6 Hans Dieter Baehr, Karl Stephan Heat and Mass Transfer Springer, 3rd revised edition, ISBN 978-3-642-44401-2 Merle C. Potter, David C. Wiggert, Bassem H. Ramadan: Mechanics of fluids. 4th edition, ISBN 978-1-4390-6203-6 Klaus Lucas Molecular Models for Fluids, Cambridge University Press, ISBN 978-0521852401
	Primary interfaces to other Centres	**Automation Engineering** - Import from: Sensors and actuators / process control engineering (PCE), system-theory, block-diagrams - Export in: Top-down-system development, IPO-pattern, energetic quantification of systems **Biological Transformation** - Import from: Biological transformation processes, fluid flows in biological systems, carbon cycles - Export in: Technical treatment of biological systems, flow and heat quantification **Bussiness and Entrepreneurship** - Import from: Key figures for general sustainability, integration of economic consideration in process design, economic quantification of sustainability parameters - Export in: Key figures for exergy rated sustainability, fundamental process engineer cost optimization strategies **Digital Product Creation** - Import from: Requirements definition and target achievement validation, systematic development of products, visualization and documentation of technical processes - Export in: Planning of technical processes and systems, process representation methods,

		integration of technical subsystems into higher-level processes **<u>Fundamental Science and Mathematics</u>** - Import from: Transfer of real systems into mathematical models, understanding of conservation variables, finding and evaluating approximations, experimental analysis methods - Export in: Conservation variable balancing in communicating systems, structural abstraction of technical realities **<u>Science Communication</u>** - Import from: Communicating results and procedures, data analysis and finding underlying structures, Integration of AI tools for process optimisation - Export in: Finding and Rating fluid intrinsic properties from varying sources, visualisation strategies of process engineering **<u>Strength and Simulation</u>** - Import from: Operation unit design under consideration of stability, strength of technical components, force equilibrium conditions - Export in: Applications of large technical equipment under static load, forces due to flow **<u>Engineering Design</u>** - Import from: Pressure and tension in technical components, strategies of choosing technical equipment and operation units - Export in: heat and temperature flow in materials and effects on stability, energetical and exergetic considerations for choosing manufacturing technologies

Project Semester 2	Module name / Module Code	PCEM2: Process Cycles of Energy and Matter , project semester 2 / 2216
	Lecturers	Prof. Dr.-Ing. Kai Masuch Dipl.-Ing. Karsten Schacky
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6
	Prerequisites	Required prerequisite: - Recommended prerequisite: -

	Module Objectives:	Students explain basic process engineering sub-processes and recognize their implementation in systems engineering.
		
		Therein:
		• Analysis of a technical installation in the process engineering pilot plant, e.g.
		  ○ Stirred tank
		  ○ CO_2-absorption
		  ○ Wind-sifter
		  ○ Sedimenter
		  ○ Rankine-machine
		  ○ Further 'new' plant components in the current projects
		• Research (literature & WWW) on function and realization
		• Representation of the function in self-selected and standard-compliant diagrams
		• Creation of technical functional descriptions
		• Mathematical mass- and energy flow balancing (Sankey diagram)
		• Summary of the most important findings in a presentation

	Content	Analysis of Processes Using the example of an arbitrary process engineering installation in a technical centre, e.g. a temperature-controlled stirred tank with heat recovery, the students systematically analyse real systems of a technical problem solution. For this purpose, the students create technical process drawings, first according to their own specifications and then according to standards. The relevant regulations are to be learned and observed. Students inform themselves independently about the purposes, variations and basic technical and physical principles of the process under consideration. The focus is on an explorative, inclination-driven acquisition of the technical content in addition to the analysis and standard-compliant representation of processes. The ability to analyse provides the basis for the synthesis aimed for in the following learning fields. <u>Comprehensive social form:</u> • Free inclination-related assignment in groups of 3-4 people <u>Technical content:</u> • Representation of technical contexts in simple process flow diagrams • Mass balances and simple energy balances • Standardized representation of apparatuses and measuring instruments • Piping diagrams

		• Basic analysis and portrayal of the function of basic process engineering operations and system implementations • Valves, pipes, functional tanks • Basic measurement technology (Temperature, pressure, power, volume flow rate) Activity outputs: • Technical description of an implemented process, presentation, final reflection and sustainability assessment in written form
	Competencies and Qualification	Professional competence The students… • explain technical issues using model tests on pilot plants. • explain the tasks and purpose of subsystems of a plant • select methods of representation for mapping process engineering relationships • identify control volumes and apply these to material flows and simple types of energy • advise customers on possible applications of the process • identify interfaces to neighboring systems Methodological competence The students… • abstract technical systems using control volumes • acquire technical content using the training literature, textbooks and tutorials provided • choose a simple planning model to structure their analysis • explain technical systems in a system context and select simple model equations for mass and initial energy balances • independently select assumptions in the event of insufficient data • present work results in plenary sessions Sustainability competence The students… • identify energy requirements of the operation unit • choose suitable types of providing energy under ecological considerations • identify losses of energy • explain environmental impacts of the supplied ingoing matter and energy flows • explain downstream processes for a possible regeneration of the effluents
	Assessment	Continuous Assessment
Pr	Module name / Module Code	PCEM3: Process Cycles of Energy and Matter, project semester 3 / 2226

Lecturers	Prof. Dr.-Ing. Kai Masuch Dipl.-Ing. Karsten Schacky
Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
Workload	160 h project work 65 h self-study
Credit Points	7.5
Prerequisites	Required prerequisite: PCEM2 Recommended prerequisite: BT2, DPC2, FSM2, BAE2

Module Objectives:	Students are able to choose system components on the basis of an existing preliminary design using calculations and present their process engineering context in the form of flow diagrams.
	
	Therein:
	• Clarification of the objective and summary of the process engineering principles
	• Accompanying testing (over the entire course of the project) of the assumptions to be made on test setups.
	• Selection of systems and plant components using the M(E)SH equations (excluding modeling of thermodynamic equilibria)
	• Formulation of the component specification
	• Calculations, measurements, drawings and system descriptions in the form of
	  ○ Basic & process flow diagrams
	  ○ Pressure loss calculations
	  ○ Sketching of an installation plan in a given environment
	• Review of the preliminary design with regard to local impact on people and the environment
	• Advice on a possible revision of the design based on concerns and suggestions

Content	<u>Exemplary project outline:</u> Calculation-based component selection of a drying system using heat recovery from a biogas engine installation In the context of heat recovery from the gas engine cooling system of a biogas plant, the aim is to design a drying system for biological dry goods. The engine waste heat from an existing installation is used at the start of the project via a rudimentary district heating system for a distant outdoor pool and can therefore only be used in summer. The heating concept envisages using the waste heat in winter to dry the fermentation products using a simple belt dryer.

		As part of the project, a partial design planning based on Annex 15 HOAI, III will be carried out on the basis of existing preliminary planning of LP I&II and the corresponding planning documents will be concretized in the top-down procedure according to the above-mentioned detailing. The technical dimensioning of the air system is to be carried out in the form of the selection of fan, heat exchanger and exhaust air duct and integrated into a given building context. More complex modeling requirements such as the determination of pressure loss coefficients of the bed and according drying kinetics are initially replaced here by an experimental determination close to the operating point of the system to be designed. For this purpose, rudimentary test setups in the form of a pressure loss measurement and a test dryer are used. The technical-mathematical-modeling depth is limited by the use of simplified diagrams. (Characteristic diagrams of the pressure losses, Mollier diagram to describe the humid air, etc.). <u>Comprehensive social form:</u> The work packages mentioned are worked on in autonomous groups of 3...5 people each. The respective responsibilities are fixed in the form of an initial target agreement within the group. The roles of a drawing expert, calculation expert and experimenter are also defined at the beginning of the project in terms of their main responsibilities. The main person responsible ensures that the work packages grouped accordingly are processed and that all group members are familiar with the respective methodology and has authority to issue instructions in their area. The role of the group spokesperson is worked out during the course of the project. <u>Technical contents:</u> • Balancing of mass and energy in stationary systems • Heat transfer coefficients and simple heat exchangers • Pressure losses in stationary flow systems and determining the operating point • Basic planning of process engineering processes • Basic process diagrams (I/O, GFB, VFB) • Simple dimensionless numbers in process engineering and dimensional analysis <u>Activity outputs:</u> • Design folder of basic engineering for given process,
	Competencies and Qualification	Professional competence The students... • present process engineering contexts in the form of basic and process flow diagrams.

		• check system components by applying material and energy balances. • identify key figures for flow fluids and calculate pressure losses. • differentiate and quantify mechanisms of heat transfer. • list requirements for process engineering systems. • place technical components in drawings, taking structural boundary conditions into account. Methodological competence The students… • differentiate between technical systems using process pictograms • develop technical content using pre-selected training literature, textbooks and tutorials • plan your approach based on the complete action model • carry out your sub-project in the context of the superordinate planning structure for the technical equipment service profile (HOAI). • model technical systems using equations • independently check assumptions in the event of insufficient data Sustainability competence The students… • determine pressure losses and evaluate the according energy losses • develop a piping concept to lower energetic losses of viscous effects • calculate and quantify energetic losses of the process • Correlate and summarise the respective losses and quantise these in terms of energy demand • Choose alternative elements for creation of the driving forces decreasing the overall energy demand
	Assessment	Continuous Assessment
Project Semester 4	Module name / Module Code	PCEM4: Process Cycles of Energy and Matter , project semester 4, 2236
	Lecturers	Prof. Dr.-Ing. Kai Masuch Dipl.-Ing. Karsten Schacky
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10

	Prerequisites	Required prerequisite: PCEM3 Recommended prerequisite: BT3, DPC3, FSM3
	Module Objectives:	Students are able to select suitable basic operations for a process engineering material and energy conversion process in a differentiated manner, check their efficiency and carry out comprehensive process planning and translate it into specific installations of a plant. Therein: • Determining the functionality and identifying the processes systematics of an existing system • Identify the interfaces for connecting the process extension • Determine the process parameters to be observed at the interfaces • Determine the process parameters of the sub-process to be developed for compatibility with the first and second law of thermodynamics after reduction to IPO balances • Assess the suitability of various basic process engineering operations for a sub-process • Determine suitable equipment for carrying out the selected basic operation • Create a digitally implemented balance calculation of the systems and plant components using the MESH equations, including modeling of simple thermodynamic equilibria • Combining the individual systems into a complex process sequence • Calculations, measurements, drawings and system descriptions in the form of • Interface description • Detailed material and energy flow table • Integration into a P&I and process planning in the activity diagram • Energy assessment and CO_2-equivalent balancing of the process • Identification of sustainability-focused optimization potentials and cost/benefit prioritization of possible technical modifications
	Content	<u>Exemplary project outline:</u> Extension and system integration of a processing line for a biomass drying plant Based on the project defined in the previous course, an extension of the processing line for the drying plant mentioned is to be planned, designed and integrated into the existing project. In order to obtain a component condition suitable for a belt dryer from the effluents of the fermentation plant, various processing techniques must be implemented in advance to achieve the target moisture content and consistency for a downstream drying process at ambient pressure.

		The students independently select possible basic operations (filtration, pressing, comminution, etc.) and their technical implementations (e.g.) and necessary conveying units (pumps, blowers, conveyor belts, screw conveyors, etc.) from the process engineering kit and check their suitability by means of energetic and simple entropic model calculations. For this purpose, previous graphical, diagram-driven methods are replaced by simple mathematical functional models (calculation of pressure loss characteristics taking into account the non-linear dependencies of the Reynolds number, flow-dependent heat convection, influences of substance-dependent parameters of the solids and fluids involved, namely heat conduction coefficient, heat capacities, simple equations of state, etc.). Simple equilibrium models (e.g. ideal gas-vapor mixture) are used here to describe thermodynamical target states. The developed process is integrated into the overall concept of inventory planning by means of a higher-level P&I flow diagram and control concept and digitally modeled. The subsystems (individual plant components) are defined in the interfaces in such a way that they are integrated into a higher-level material flow table. The differentiated material flow table serves as an input variable for the final sustainability assessment based on energy and CO2 equivalent. <u>Comprehensive social form:</u> Based on the experiences in the small groups in the previous course, the applied concept is to be consolidated here. On the basis of a strengths/weaknesses (self-)analysis, small groups of 3-5 people are again formed in which an 'interface coordinator' is determined in the group dynamic process after the process concept has been determined inter pares (after approx. 1 week). The extended mathematical modeling focused on here requires a similarity in the individual subtasks, which is achieved by defining sub-processes (e.g. comminution, mechanical separation, solids conveying, fluid conveying) within the overall process engineering task, in the modeling of which each group member is individually involved. The 'interface coordinator' ensures that the balances of the subsystems are linked, but is also responsible for a separate (smaller) subsystem. For continuous coordination, the students organize regular coordination meetings with circular minutes of the most important agreements. <u>Technical contents:</u> • Balancing mass and energy in complex steady state systems

		• Kelvin and Planck statement, feasibility analysis by simple entropy balancing and sign analysis. • Modeling of thermal state variables in ideal approximation • Modeling of caloric state variables in simple proportionalities • Fluid modeling as a quasi-pure substance • Heat conduction and convection • Selection of heat exchanger and stage model- Determination of pressure loss in pipe systems and bulk solids • System operating points • Systems and fan characteristics, interconnection of fans and pumps • Simple phase equilibria (gas/vapor mixtures) • Detailed planning of process engineering processes (P&I) • Process control technology and activity diagrams for process control • Basic operations of process engineering and their representation • Layout plans and plant design with 3D CAD software Activity outputs: Written balancing documentation of the subsystems, comprehensive P&I flow diagram with process control definition and control activity diagram, digitally stored dynamic material flow table of quasi-stationary operating states,
	Competencies and Qualification	Professional competence The students… • assess topics relating to energy and material conversion with regard to their technical feasibility • transfer real process engineering issues into technical flow charts • adapt suitable basic process engineering operations to a combined overall process • determine suitable plant components for the realization of the basic operations • create balance systems and balance variables and determine resulting process variables • determine operating points of a stationary standard operation • identify the need for a differentiated heat and flow analysis and carry this out • check the validity of simple process engineering model equations by means of experiments and use them to predict expected inaccuracies • transfer the model equations into a digital image of the plant

		• create execution documents for process planning in the form of P&I flow diagrams and dynamic material flow tables • create a process control flow structure as an interface to the control engineer • create layout plans of the plant as a basis for factory planning Methodological competence The students... • determine the level of detail of the depth of consideration required for the respective purpose and place it in a superordinate context • identify and select specialist literature from an extended pool of material • plan their approach in a self-modified variation of common planning approaces (e.g. *Modell der Vollständigen Handlung*) • identify sub-processes in the context of the superordinate planning structure for the technical equipment performance profile and modify planning phases accordingly • model communicating technical systems using digitally implemented equations • design a process engineering subsystem in the requirements context of the adjacent systems • fit process engineering subsystems into an overall concept and make a prediction about possible operating states of the overall system • identify limits of the current modeling capability as a basis for later concretization Sustainability competence The students… • are able to quantify sustainability using entropic balances • identify exergetic losses of a system as a marker for work lost in heat conversion • rate processes under consideration of the aforementioned balances • find process parameters for lowering exergetic losses of processes and process steps
	Assessment	Continuous Assessment
Project Semester 5	Module name / Module Code	PCEM5: Process Cycles of Energy and Matter , project semester 5 / 2246
	Lecturers	Prof. Dr.-Ing. Kai Masuch Dipl.-Ing. Karsten Schacky
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project

		130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: PCEM4 Recommended prerequisite: BT4, FSM4
	Module Objectives:	Central objective: Students are able to use multi-component thermodynamic equilibrium models and exergetic modeling procedures to evaluate processes holistically and design optimized process sequences. Therein: • Selection of an optimization field of activity in the context of preceding learning projects. • Exergetic evaluation of the optimization potentials • Definition of the work packages for the groups involved • Comprehensive familiarization with relevant topics (see exemplary technical content) • Carrying out optimization calculations in conjunction with molecular thermodynamic models • Generation of parameters for a specific (previous) plant design • Integration of the results of the working groups into their own optimization task • Creation of a multi-criteria quantitative evaluation structure of the sustainability of the optimization measure, e.g. through entropic-exergetic evaluation. • Applicable assessment of the aforementioned evaluation structure and final reflection
	Content	<u>Exemplary project outline:</u> Exergetic optimization of an overall treatment line for biomass processing and its sub-processes In the exemplary context of the projects of a biomass processing line from prior courses, the aim here is to optimize the overall system and the sub-processes. The students are involved in the guidance of the students from the previous semesters with personnel responsibility, whose work results are integrated into their own objectives. In addition to the leadership role, the project leader students also have the role of a scientific expert, whereby the weighting of the role shares is left to the student mentor. In the opposite direction, the students provide process parameters from their own optimization calculations within this learning field, which are used as design parameters for the process engineering equipment in the preceding learning situations. In the overall context of the plant process under consideration, these can be optimized pressure and temperatures for the actual drying process, the selection of optimized solvents for the air washing

		systems or even a material selection for membrane modules. These are developed based on multicomponent models (extended thermal and caloric equations of state, GE models, group contribution methods, COSMO) and, if necessary, digitally simulated. Comprehensive social form: Split role in scientific experts in individual work and group leadership for project semester students of previous courses. Technical contents: • Balancing mass, energy and entropy in transient systems • Transient / differential heat conduction equations • Dissipation models for determining pressure loss / extended Navier Stokes equations • Exergetic evaluation, non-ideal models for energy and entropy • Molecular thermodynamics (physical chemistry, partition functions of different ensembles) • Equilibrium models, phi-phi, phi-gamma, gamma-gamma approach, GE models, group contribution methods • Spectroscopic measurement methods in process control Activity outputs: Written elaboration according to scientific standards
	Competencies and Qualification	Professional competence The students… • Assess thermodynamic equilibria of non-ideal systems • Design exergetic models for process engineering subsystems and overall processes • Reflect entropic modeling in their application to real systems • Design models for real transient heat and mass transfers • Simulate transient heat and mass transfer processes as well as thermodynamic equilibrium calculations in silico and evaluate the results on the basis of comprehensive knowledge of molecular thermodynamics Methodological competence • Break down complex process sequences into subsystems • Evaluate sustainability from both exergetic and multi-criteria perspectives • Design procedural patterns for understanding topics in scientific depth

		Sustainability competence • Optimise processes and sub-process due to their exergetic performance • Design evaluate alternative processes under consideration of entropy minimisation strategies • Create tailor made dimensionless numbers for rating a specific sustainable process
	Assessment	Continuous Assessment

Centre of Knowledge
Science Communication

General Information	Centre of Knowledge Desciption	This knowledge center aims to teach students the ability to critically assess the reliability and quality of scientific information or data and to preserve this reliability and quality while communicating scientific content to different audiences in an ethical way. Information quality is therefore at the heart of this knowledge center, followed by learning the appropriate tools and strategies to preserve and communicate this information in ways that are adapted to content and audience. The different parts of the knowledge center build on each other, moving from simple text-based communication to more complex forms of communication such as video and audio, data analysis, visualization or sonification, spatial video and sound, VR and AR, photogrammetry, all the way up to how to turn science into art pieces or exhibitions, if need be in a way that involves the public in creating the communication project (participatory projects or public engagement). The sustainability aspect will primarily be addressed through choosing appropriate communication project topics.
	Module Coordinator	Prof. Dr. rer. nat. Andreas von Bubnoff
	Literature	• Artis, AQ (2nd ed. 2020): The Shut Up and Shoot Documentary Guide: A Down & Dirty DV Production • Bucher (2017): Storytelling for virtual reality: methods and principles for crafting immersive narratives • Cairo, A. (2016): The Truthful Art • Cairo, A. (2023): The Art of Insight: How Great Visualization Designers Think. • Hermann, T. *et al.* (2011): The Sonification Handbook • Kern, J. (2008): Sound Reporting: The NPR Guide to • Audio Journalism and Production •Kirk, A (2019): Data Visualization A Handbook for Data Driven Design, Second Edition (Revised Edition) • Lankow, J. & Ritchie, J. (2012): Infographics: The Power of Visual Storytelling • Lupi, G. & Posavec, S. (2016): Dear Data. •Murray, S. (2017): Interactive Data Visualization for the Web: An Introduction to Designing with D3 • Murray-Schafer, R. (1977/1993): The Soundscape • Rich, C. (2015): Writing and Reporting News: A Coaching Method (paperback) 8th ed (+ student workbook) • Riche, NH & Hurter, C. (2018): Data-Driven Storytelling

		•Scanlan, C. (1999): Reporting & Writing: Basics for the 21st Century (a classic)
	Primary interfaces to other Centres	• Business & Entrepreneurship (Berndsen) • Fundamental Science and Mathematics (Struck)

Project Semester 2	Module name / Module Code	SC2: Science Communication, project semester 2 / 2217
	Lecturers	Prof. Dr. rer. nat. Andreas von Bubnoff TBD
	Timetabled Hours	Blockcourse: 3 weeks (9 days presence + 6 days in presence or home office) Self-study: 1.5 weeks
	Workload	120 h project work 60 h self-study
	Credit Points	6
	Prerequisites	Required prerequisite: Introductory module 1st semester Recommended prerequisite:
	Module Objectives:	After completing this module, students will be able to use what they learned in their introductory module on information quality assessment and types of science communication to choose and produce a text-based communication project all the way from research to final text on their project web site. They will also know how to collaborate as a team to do so.
	Content	Students research and produce a relatively simple text-based communication project, like a series of blog entries or Q&As on a topic of their choice. The content could be based on work in one of the other KCs or a project from anywhere on campus, combined or enriched with comments from outside experts to place the project in a larger context. In this and all other projects, the team will primarily learn the tools they need to produce the project; in this case, this might include anything from content management systems, project management skills and tools, transcription software, or web design.
	Competencies and Qualification	Professional competence • Find and produce text-based communication project all the way from research to final text. • Identify and collect high-quality information from primary sources and turn it into a text-based communication project on a project web site • Choosing the appropriate audience and communication channel • Contacting and interviewing information source(s) Methodological competence • Using content management systems and web design tools

		• Using transcription software • Interview skills Sustainability competence • Students learn to identify issues relevant for sustainability.
	Assessment	Continuous Assessment
Project Semester 3	Module name / Module Code	SC3: Science Communication, project semester 3 / 2227
	Lecturers	Prof. Dr. rer. nat. Andreas von Bubnoff TBD
	Timetabled Hours	Blockcourse: 4 weeks (12 days presence + 8 days in presence or home office) Self-study: 1.5 weeks
	Workload	160 h project work 65 h self-study
	Credit Points	7.5
	Prerequisites	Required prerequisite: SC2 Recommended prerequisite:
	Module Objectives:	Students will be able to research and produce a more complex communication project, adding audio or video elements, and/or complexity in content (i.e. moving from news-based to more complex storytelling structures). Along the way, they will continue to improve their collaboration and project management skills.
	Content	Students team will produce a more complex communication project, potentially building on material and insights from the previous semester, adding audio or video elements, and/or adding complexity in content (i.e. moving from news-based to more complex storytelling structures).
	Competencies and Qualification	Professional competence • Plan, record and edit professional-level audio and video pieces on scientific topics • Principles of non-linear audio and video editing • Assess which equipment is appropriate for which project and budget • Assess which storytelling device is best to present the material in public (i.e. web video versus gif etc.) • Independently learn new tools or techniques by locating information online (i.e. YouTube, reddit, etc.) Methodological competence • Learn how to use non linear editing tools like Hindenburg Pro (audio) and DaVinci Resolve

		(video) Sustainability competence • Students learn to identify issues relevant for sustainability.
	Assessment	Continuous Assessment
Project Semester 4	Module name / Module Code	SC4: Science Communication, project semester 4 / 2237
	Lecturers	Prof. Dr. rer. nat. Andreas von Bubnoff Prof. Dr. Alexander Struck
	Timetabled Hours	Blockcourse: 5 weeks (15 days presence + 10 days in presence or home office) Self-study: 2.5 weeks
	Workload	200 h project work 100 h self-study
	Credit Points	10
	Prerequisites	Required prerequisite: SC3 Recommended prerequisite:
	Module Objectives:	After completing this module, students will be able to add data analysis and visualization to their communication projects.
	Content	Tools and skills will depend on the project but will cover the four basic steps of data storytelling: Collecting the data; cleaning the data; data analysis; and data visualization. Basic coding in Python or R might also be a part of this module, if need be.
	Competencies and Qualification	Professional competence • Know how to find a story in a data set • Data discovery strategies and tools (from Google advanced search and database search to knowledge about public databases and scraping techniques and tools) • Data cleaning strategies and tools (including Open Refine) • Data analysis strategies and tools (in Excel and Google sheets but also if needed copding in R and Python) • Using AI tools like ChatGPT for help with coding • Data visualization strategies and tools (such as datawrapper or Tableau public) Methodological competence • Learn how to use data cleaning, analysis and visualization tools including Open Refine, Excel, Google Sheets, Chat GPT, R and Python Sustainability competence

		• Students learn to identify issues relevant for sustainability.
	Assessment	Continuous Assessment
Project Semester 5	Module name / Module Code	SC5: Science Communication, project semester 5 / 2247
	Lecturers	Prof. Dr. rer. nat. Andreas von Bubnoff TBD
	Timetabled Hours	Blockcourse: 8 weeks (24 days presence + 16 days in presence or home office) Self-study: 3.25 weeks
	Workload	320 h project 130 h self-study
	Credit Points	15
	Prerequisites	Required prerequisite: SC4 Recommended prerequisite:
	Module Objectives:	After completing this project, students will be able to add creative elements like 360 degree video, data sonification, spatial sound or live data from sensors to their projects. Tools and skills will depend on the project.
	Content	In this final module, students will build on what they've learned in the previous modules and add a creative dimension to really develop something that is more than just communication in and of itself but stands out. This could be an artistic element or 360-degree video or sonification of data. This could also involve collaboration with outside communication agencies or partners.
	Competencies and Qualification	Professional competence (depending on project needs) • 360 degree video and spatial sound • AR & VR • Photogrammetry • LiDAR • Turning data into sound • Using live sensor data with tools like Raspberry Pi • Turning science into art projects or exhibitions • Citizen science and participatory projects Methodological competence (deoending on projectg needs) • Learning how to use tools like Raspberry Pi Sustainability competence • Students learn to identify issues relevant for sustainability.
	Assessment	Continuous Assessment

Finishing Phase

Module name/Module Code	Internship / Semester abroad / 2250
Module coordinator	Head of degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	900 h
Credit Points	30
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	Internship Semester: Students work in one or more functional units of an external organization. They will apply their gained knowledge and methods in technical, analytical, and social matters. The students will have to use their theoretical gained knowledge in their respective practical discipline and reflect it afterwards. Students have to use the following key skills: • Interdisciplinary project work • Intercultural skills • Transfer theoretical knowledge into the practical knowledge • Organization and self-management skills • Set priorities and organize work according to priorities • Team oriented work and communication skills • English as international language • Ability to handle changes during task • Work under pressure of time The internship can be completed abroad. Semester abroad: Students can decide to substitute the internship semester with a study abroad semester. Selecting a study abroad semester offers the student to being immersed into a different educational system and helps therefore understanding other tertiary systems. Study abroad is defined as a semester at a university in a country other than their nationality or country of origin. The study abroad semester tailors a strengthening of the following key skills: • Deepen and broaden their knowledge of certain subjects (e.g. additional courses) • Gain knowledge of other political, economic, and cultural systems • Widen the cultural background • Increase language capabilities • Widen their social competencies • Interdisciplinary project work

	• Intercultural skills • Organization and self-management skills • Interdisciplinary team oriented work and communication skills • English as international language • Planning and set-up skills Students will increase their intercultural competencies and get an insight into a different culture as well as organization including many administrative tasks
Content	Internship Semester: The contents of the internship are based on the business activities and the business environment of the external organization. They are closely coordinated between the organization and the university, so that a consistent professional tie is guaranteed to the study. Semester Abroad: The contents of the Semester abroad are based on the university programs selected by the student. They are closely coordinated between the sending university and the receiving university, so that a consistent professional tie is guaranteed to the study.
Assessment	Attestation
Literature	

Module name/Module Code	Bachelor Thesis / 2251
Module coordinator	Head of degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	360 h
Credit Points	12
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	The students • demonstrate their capability to work independently on a subject in alignment with their course of studies, meeting all topical and scientific requirements in a limited period of time • are able to organize their workflow in order to meet the demands of the problems formulated in their theses, as well as to monitor progress and make necessary amendments • are able to document their approach and their results to meet the requirements of a scientific publication
Content	Thesis content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an

	adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment	Written and graded thesis usually in the range of 15000 to 20000 words (50–70 DIN A4 pages)
Literature	

Module name/Module Code	Colloquium / 2252
Module coordinator	Head of degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	90 h
Credit Points	3
Prerequisites	Required prerequisite: 207 CP in the respective courses Recommended prerequisite:
Module Objectives	The students • are able to defend the results of the Bachelor Thesis • place their work in a suitable context and present their results in a proper form for the audience. They are able to explain their approach and to critically analyse their own results. • are able to analyze questions concerning their thesis and results and answer them suitably.
Content	Content is aligned with the content of the Bachelor Thesis, with an operative focus on discussion of their results, methods and alternatives.
Assessment	Oral examination, graded
Literature	M. Powell: Presenting in English – how to give successful presentations, Heinle Cengage Learning, 2011 S. Krantman: The Resume Writer’s Workbook, fourth edition, South-Western Cengage Learning, 2013

Electives

Module name/Module Code	Foreign Language 1 / 2260
Module coordinator	Head of the degree programme
Lecturer	Acc. selected module of the language centre
Timetabled hours	Acc. timetable of the language centre
Workload	Acc. Module description of the language centre
Credit Points	5
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	At the beginning of the course the students define a language level to be achieved based on the existing language skills in the chosen language. This happens together with the responsible teacher. The expected improvement of the language skills has to be defined in a learning agreement. The objective for the level improvement within this module is either from A1 to A2 or A2 to B1. For international students this language should be German, for German students any other language offered by the language centre of the university can be selected. After completion of the module the students should be able to communicate better in an additional foreign language. They are able to prepare documents required for applications in Germany or abroad.
Content	acc. module description of the selected module of the language centre
Assessment	Attestation
Literature	acc. module description of the selected module of the language centre

Module name/Module Code	Foreign Language 2 / 2261
Module coordinator	Head of the degree programme
Lecturer	Acc. selected module of the language centre
Timetabled hours	Acc. timetable of the language centre
Workload	Acc. Module description of the language centre
Credit Points	10
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	At the beginning of the course the students define a language level to be achieved based on the existing language skills in the chosen language. This happens

	together with the responsible teacher. The expected improvement of the language skills has to be defined in a learning agreement. The objective for the level improvement within this module is either from B1 to B2 or B2 to C1. For international students this language should be German, for German students any other language offered by the language centre of the university can be selected. After completion of the module the students should be able to communicate better in an additional foreign language. They are able to prepare documents required for applications in Germany or abroad.
Content	acc. module description of the selected module of the language centre
Assessment	Attestation
Literature	acc. module description of the selected module of the language centre

Module name/Module Code	Applied Research Project 1 / 2262
Module coordinator	Head of the degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	150 h
Credit Points	5
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	The students demonstrate their capability to work independently on an applied research subject in alignment with their course of study, meeting all topical and scientific requirements in a limited period of time. They have the ability to self-analyze and assess the results and make recommendations for improvements. They are able to organize their workflow in order to meet the demands of the problems formulated in their project, as well as to monitor progress and make necessary amendments. Additionally students are able to improve their documentation skills, thus documenting their approach and their results to meet the requirements of a scientific publication.
Content	The project content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment	Attestation: • Written documentation • Research results

	• Proceeded data and charts • Prototypes • Software code • Blueprints where applicable.
Literature	

Module name/Module Code	Applied Research Project 2 / 2263
Module coordinator	Head of the degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	300 h
Credit Points	10
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	The students demonstrate their capability to work independently on an applied research subject in alignment with their course of study, meeting all topical and scientific requirements in a limited period of time. They have the ability to self-analyze and assess the results and make recommendations for improvements. They are able to organize their workflow in order to meet the demands of the problems formulated in their project, as well as to monitor progress and make necessary amendments. Additionally students are able to improve their documentation skills, thus documenting their approach and their results to meet the requirements of a scientific publication.
Content	The project content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment	Attestation: • Written documentation • Research results • Proceeded data and charts • Prototypes • Software code • Blueprints where applicable.
Literature	

Module name/Module Code	Applied Research Project 3 / 2264
Module coordinator	Head of the degree programme

Lecturer	Supervising Professor
Timetabled hours	None
Workload	450 h
Credit Points	15
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	The students demonstrate their capability to work independently on an applied research subject in alignment with their course of study, meeting all topical and scientific requirements in a limited period of time. They have the ability to self-analyze and assess the results and make recommendations for improvements. They are able to organize their workflow in order to meet the demands of the problems formulated in their project, as well as to monitor progress and make necessary amendments. Additionally students are able to improve their documentation skills, thus documenting their approach and their results to meet the requirements of a scientific publication.
Content	The project content depends on the chosen topic and is agreed upon with the supervisor. Documentation is granted by an adequately sized description of the topic/problem, the chosen approach, used methods and results.
Assessment	Attestation: • Written documentation • Research results • Proceeded data and charts • Prototypes • Software code • Blueprints where applicable.
Literature	

Module name/Module Code	Supervision and Tutorship 1 / 2265
Module coordinator	Head of degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	150 h
Credit Points	5
Prerequisites	Required prerequisite: one 5th Semester project finished Recommended prerequisite: BE3
Module Objectives	The students demonstrate their capability to transfer their already learnt knowledge, expertise and experience to lower semester students. They are able to guide students in a lower semester in order to improve the study behaviour, thus

	supporting the onboarding process for a better integration. Students will understand the methods of supervision and tutorship and will directly apply these methods in practice. Students will gain their technical knowledge and understand the tasks and objectives of a supervisor and tutor. Additionally students can identify role conflicts and are able to decide solutions to overcome these conflicts.

Content	• Legal framework conditions
	  o tasks of a supervisor and tutor
	  o qualifications
	  o duties and policies
	• role model
	  o relationship triangle
	  o relationship supervisor/tutor and students
	  o relationship supervisor/tutor and lecturer
	• role conflicts
	  o conflicts with students
	  o conflicts with lecturer
	• methods for supervision and tutorship

Assessment	Continuous Assessment • learning diary • group presentation • project report
Literature	Hillebrecht, S.: Tutorien und Seminare vorbereiten und moderieren. Eine kleine Trickkiste für Tutoren und wissenschaftliche Mitarbeiter. 2016. Wiesbaden: Springer . ISBN 978-3658120849 Nkambou, R., Bourdeau, J., Mizoguchi, R.: Advances in Intelligent Tutoring Systems. 2010. Berlin: Springer. ISBN 978-3-642-14363-2

Module name/Module Code	Supervision and Tutorship 2 / 2266
Module coordinator	Head of degree programme
Lecturer	Supervising Professor
Timetabled hours	None
Workload	300 h
Credit Points	10
Prerequisites	Required prerequisite: one 5th Semester project finished Recommended prerequisite: BE4
Module Objectives	The students demonstrate their capability to transfer their already learnt knowledge, expertise and experience to lower semester students. They are able to guide students in a lower semester in order to improve the study behaviour, thus supporting the onboarding process for a better integration. Students will understand the methods of supervision and tutorship and will directly apply these methods in practice.

	Students will gain their technical knowledge and understand the tasks and objectives of a supervisor and tutor. Additionally students can identify role conflicts and are able to decide solutions to overcome these conflicts. They are able to plan and carry out the event independently. During the supervision and tutorship they are able to evaluate the learning success and can prioritize and decide for alternative approaches and can create an adapted approach. Ultimately the self communication is improved and students are able to reflect and adapt the communication if necessary.

Content	• Legal framework conditions
	  o tasks of a supervisor and tutor
	  o qualifications
	  o duties and policies
	• role model
	  o relationship triangle
	  o relationship supervisor/tutor and students
	  o relationship supervisor/tutor and lecturer
	• role conflicts
	  o conflicts with students
	  o conflicts with lecturer
	• methods for supervision and tutorship
	• tutorial planning
	  o organisation
	  o semester and event planning
	  o time management
	• communication
	  o appreciative communication
	  o reflection
	  o communication according to Schulz von Thun
	• evaluation

Assessment	Continuous Assessment • learning diary • group presentation • project report
Literature	Hillebrecht, S.: Tutorien und Seminare vorbereiten und moderieren. Eine kleine Trickkiste für Tutoren und wissenschaftliche Mitarbeiter. 2016. Wiesbaden: Springer . ISBN 978-3658120849 Nkambou, R., Bourdeau, J., Mizoguchi, R.: Advances in Intelligent Tutoring Systems. 2010. Berlin: Springer. ISBN 978-3-642-14363-2

Module name/Module Code	Free Elective / 2267
Module coordinator	Head of the degree programme [William Megill]
Lecturer	Various HSRW staff or visiting lecturers
Timetabled hours	Varies

Workload	150h
Credit Points	5
Prerequisites	Required prerequisite: Recommended prerequisite:
Module Objectives	The objective of this module is to provide students with the opportunity to study topics at the BSc level that are not necessarily directly related to their chosen course of study or knowledge centre mix.
Content	The content of the module can vary from semester to semester, depending on the expertise of the lecturing staff. Topics can include natural science, engineering, or social science components, and can vary from fundamentals to modern advances. Subject content can be offer (interested lecturer) or demand (student interests) driven. The module is also intended to accommodate visiting lecturers (for example on sabbaticals at HSRW). With the approval of the Examination Board, students can also have any BSc module of 5 CP or more recognised as equivalent to this one.
Assessment	Attestation
Literature	Varies