CONSTRUCTOR
UNIVERSITY

Study Program Handbook

Electrical and Computer Engineering

Bachelor of Science

Subject-specific Examination Regulations for Electrical and Computer Engineering (Fachspezifische Prüfungsordnung)

The subject-specific examination regulations for Electrical and Computer Engineering are defined by this program handbook and are valid only in combination with the General Examination Regulations for Undergraduate degree programs (General Examination Regulations = Rahmenprüfungsordnung). This handbook also contains the program-specific Study and Examination Plan (Chapter 6).

Upon graduation, students in this program will receive a Bachelor of Science (BSc) degree with a scope of 180 ECTS credits (for specifics see Chapter 4 of this handbook).

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Fall 2023 – V1.1	Sep 01, 2023	May 26, 2023	Editorial changes in all handbooks by Program Support and Development
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		Jun 26, 2019	Originally approved by Academic Senate

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1 Program Overview

1.1 Concept

1.1.1 The Constructor University Educational Concept

Constructor University aims to educate students for both an academic and a professional career by emphasizing three core objectives: academic excellence, personal development, and employability to succeed in the working world. Constructor University offers an excellent research driven education experience across disciplines to prepare students for graduate education as well as career success by combining disciplinary depth and interdisciplinary breadth with supplemental skills education and extra-curricular elements. Through a multi-disciplinary, wholistic approach and exposure to cutting-edge technologies and challenges, Constructor University develops and enables the academic excellence, intellectual competences, societal engagement, professional and scientific skills of tomorrows leaders for a sustainable and peaceful future.

In this context, it is Constructor University's aim to educate talented young people from all over the world, regardless of nationality, religion, and material circumstances, to become citizens of the world who are able to take responsible roles for the democratic, peaceful, and sustainable development of the societies in which they live. This is achieved through a high-quality teaching as well as manageable study loads and supportive study conditions. Study programs and related study abroad programs convey academic knowledge as well as the ability to interact positively with other individuals and groups in culturally diverse environments. The ability to succeed in the working world is a core objective for all study programs at Constructor University, both in terms of actual disciplinary subject matter and also to the social skills and intercultural competence. Study-program-specific modules and additional specializations provide the necessary depth, interdisciplinary offerings and minor option provide breadth while the university-wide general foundation and methods modules, optional German language and Humanities modules, and an extended internship period strengthen the employability of students. The concept of living and learning together on an international campus with many cultural and social activities supplements students' education. In addition, Constructor University offers professional advising and counseling.

Constructor University's educational concept is highly regarded both nationally and internationally. While the university has consistently achieved top marks over the last decade in Germany's most comprehensive and detailed university ranking by the Center for Higher Education (CHE), it has also been listed by the renowned Times Higher Education (THE) magazine as one of the top 300 universities worldwide (ranking group 251-300) in 2019 as well as in 2021. Since 2022 Constructor University is considered to be among the top 30 percent out of more than 1600 universities worldwide and is ranked the most international university in Germany. The THE ranking is considered as one of the most widely observed university rankings. It is based on five major indicators: research, teaching, research impact, international orientation, and the volume of research income from industry.

1.1.2 Program Concept

The extensive developments in microelectronics over recent decades have triggered a digital revolution where computers take center stage. While we still think of a computer as a desktop or a laptop, digital computing and digital signal processing have become vital for many of the products in our everyday life such as cars, mobile phones, tablets, cameras, household appliances, and more. The Electrical and Computer Engineering program focuses on the areas of communications and digital signal processing, including the enabling digital processing elements and their programming. Those enabling technologies are mostly subsumed under the headline of embedded systems.

The first two years of the ECE program offer a rigorous theoretic foundation together with lab experiments that illustrate the principles practically and already show the programming of digital signal processors, printed circuit board design, and advanced measurement tools and procedures. The theoretical education with corresponding labs covers analog and digital circuitry, deterministic and random signal processing, probability and information theory, and communication. Signals covered start from DC and single sinusoids and move over to general deterministic or random functions and also specific ones like audio, speech, and video, enabling students to treat them with the corresponding mathematical and algorithmic tools. Different transmission media are characterized, be it wireline or wireless, and the suitable transmission methods and algorithms are covered together with them. The education in the first two years provides a solid foundation enabling students to do internships in research environments and professionally contribute to industrial projects. Specialization modules in the 3rd year finally guide to the frontiers of current knowledge and technology.

The third year, exposes students to advanced topics giving also the chance to already pick graduate level modules, such as protocol aspects and coding theory, also rounds up the knowledge with radio frequency engineering aspects and the programming of FPGAs (Field Programmable Gate Arrays).

During the three-year program, we make students discover over-arching relations between the central concepts, pointing them to links between subjects and modules. This should allow the students to develop a holistic view, e.g., recognizing that all linear transforms are directly linked to each other, hence, show tightly related properties; algorithms in error-correction coding are similar to those in signal processing; a complex baseband signal description for modulation shows links to the basic complex descriptions of sinusoidal signals introduced in the first study year. Students shall be capable to recognize the `string' linking topics vertically between their study years as well as horizontally between lectures and labs in the same semester. A rigid sequence of contents has been created, ensuring topics following each other smoothly in the right order.

Apart from the major-specific education, the program offers room for orientation and specialization, e.g., by choosing specific minors, offering views into other fields and majors. Additionally, due to the teaching in relatively small groups, many lab modules, the direct relation between students and faculty, and the very individual support in theses and also optional projects, mandatory modules from very different fields, and finally, internship and social activities, provide ample opportunities for interacting with fellow students and faculty, supporting organizational and presentation skills and fostering personal development.

1.2 Specific Advantages of the Electrical and Computer Engineering Program at Constructor University

- Focus on signal processing, communications, and corresponding implementation: The ECE program at Constructor University is designed to reflect the dynamic changes of electrical and computer engineering in industry and society. With a sharp focus on signal processing, communications, and implementation, students will be ready to face the challenges of emerging areas such as Cyber-physical Systems, Internet of Things, Connected Vehicles, Secure Communication, and more.
- Early involvement in research: ECE at Constructor University is strongly research-oriented. Each professor in the department has an independent research group including not only senior, but also junior students, even at the Bachelor studies level, some of whom have their first scientific publication together with ECE faculty at well-recognized journals or conferences.

- Advanced topics in Signal Processing and Communications are treated very early on, making ECE students prepared for advanced internship or research tasks after the 2nd year. The third year then offers some graduate-level modules, making students fit for any graduate school world-wide or professional jobs early on.
- Wide cooperation and open access to instructors: Constructor University as a whole is a flat institution, where professors, research staff, and students engage in open dialog and co-operation without barriers.

1.3 Program-Specific Educational Aims

1.3.1 Qualification Aims

The main subject-specific qualification aim is to enable students to take up a qualified employment in electrical and computer engineering environments, be it manufacturers, providers, sales organizations, consultants, agencies, research centers, or academia itself. Although the program focus is on signal processing and telecommunications, graduates will be prepared for a manifold of ECE environments and others, like, e.g., automotive and energy.

- Electrical and Computer Engineering competence

  Graduates are able to understand, measure, and analyze properties and theoretically describe tasks and possible solutions in signal processing and communications, plan, design, and implement realizations in hard- and software on modern signal processing and FPGA platforms.

- Communication competence

  Graduates are able to communicate subject-specific topics convincingly in both spoken and written form to other ECE graduates, to engineers in general, to industrial or academic colleagues with different backgrounds, as well as to a more general audience, such as non-technical administrators and decision makers or customers.

- Teamwork and project management competences

  Graduates are able to efficiently individually and also in a team, especially when carrying out lab experiments and doing corresponding lab reports jointly they are able to organize their work and work flows. They are familiar with supporting tools for analysis, development, design, measurement, and testing. Graduate should be able to plan and take decisions in a constructive and well justified way and also convey the corresponding reasoning convincingly.

- Learning competence

  Graduates have acquired a solid foundation enabling them to assess their own knowledge and skills, learn effectively and to stay up to date with the latest developments in the fast-changing field of Electrical and Computer Engineering.

- Personal and professional competence

  Graduates are able to develop a professional profile, justify professional decisions on the basis of theoretical and methodical knowledge, and critically reflect their behavior, also with respect to its consequences for society.

During the design of the program, corresponding national guidelines (Leitlinien für Bachelor und Master) by VDE (Verein Deutscher Elektrotechniker), ZVEI, Bitcom, and VDEW have been incorporated, as well as experiences of faculty from teaching at other universities in Europe, the US, and Japan.

1.3.2 Intended Learning Outcomes

By the end of the program, students will be able to

1. describe the underlying natural physical foundation, especially Maxwell' equations; describe and apply mathematical basics and tools;
2. describe the underlying theoretical concepts of deterministic and random signals in time and frequency domain;
3. compare results to theoretical limits, e.g., provided by Information Theory;
4. explain and implement signal processing components, methods, and algorithms, having studied the theoretical foundation and having learned programming languages Matlab, C, C++, assembler, VHDL for general-purpose, signal processor platforms, or FPGAs;
5. treat signals with dedicated algorithms, be it audio, video, or from other origin, e.g., by filtering, prediction, compression;
6. design suitable transmission methods for diverse channels, wireline and wireless on the basis of channel properties and models, knowing an almost complete set of transmission methods;
7. know typical electronic components and their standard base circuits and to implement dedicated circuitry, be it analog or digital, including the printed circuit board layout;
8. use advanced measurement equipment, like high-end scopes, spectrum and network analyzers including their remote control;
9. design MAC and higher protocols, error correcting codes, and compression schemes, also know major security schemes and their implementation;
10. use academic or scientific methods as appropriate in the field of Electrical and Computer Engineering such as defining research questions, justifying methods, collecting, assessing and interpreting relevant information, and drawing scientifically-founded conclusions that consider social, scientific, and ethical insights;
11. develop and advance solutions to problems and arguments in Electrical and Computer Engineering and defend these in discussions with specialists and non-specialists;
12. engage ethically with academic, professional and wider communities and to actively contribute to a sustainable future, reflecting and respecting different views;
13. take responsibility for their own learning, personal and professional development, and role in society, evaluating critical feedback and self-analysis;

14. apply their knowledge and understanding to a professional context;

15. take on responsibility in a diverse team;

16. adhere to and defend ethical, scientific, and professional standards.

1.4 Career Options and Support

A recent survey by a German engineering association showed high demand for EE and ECE engineers. Currently, inside Germany alone, there are twice as many positions than graduates, hence, ample job opportunities.

Higher demands for ECE engineers are to be expected. This is partly due to general economic trends, but especially related to unusually low student numbers in recent years. Especially, due to rapid developments, fundamental principles and cross-boundary knowledge become increasingly important. In addition, the required qualification profiles and personal attitudes differ for academic versus industrial careers. The ECE program at Constructor University responds to all of these conditions for a successful career through the flexibility of the program and the trans-disciplinary education. Constructor University ECE graduates start their careers in very diverse companies, successfully continue at renowned universities, or stay with Constructor University for graduate education or a PhD.

Career paths after graduation are very diverse. Constructor University's ECE alumni work in the aerospace industry, telecommunications, the automotive and energy sector, and in the field of information technology, in academia, at research centers, in management and in consultancy, even in finance. Having checked exemplary career paths of 75 former Constructor University ECE students, we found an enormous manifold of companies, research centers, and universities, where our alumni went or are currently working. It starts from well-known big companies, like Bosch, Continental, Deutsche Telekom, E.on, Ericsson, Google, Infineon, Intel, Nokia Bell Labs, Texas Instruments, Volkswagen, midsize ones, like Kapsch, Hirschmann, OHB, Rohde & Schwartz, to numerous small ones and start-ups like DSI, Snips, to consulting companies like McKinsey, Business Technology Consulting, Deloutte, financial institutions like PricewaterhouseCoopers, OpenLink Financial, even to companies like Fresenius and Proctor and Gamble, that would not come to mind immediately as typical work places for ECE graduates. Interestingly, also after intermediate further education steps or employments in other countries, a high percentage of alumni have found their long-term home in Germany and also Bremen.

Further graduate education that our students chose, is also covering a wide spectrum. Graduates have been accepted by universities like TUM, EPFL, ETH, Univ. of Edinburgh, KTH, Eindhoven, KU Leuven, Lauvain, Politecnico di Torino, Berkeley, Rice, UCSD, Constructor University itself.

After PhD, some of our students followed research paths at universities and research centers, like Fraunhofer, DLR, OFFIS, some are already teaching as professors or lecturers. A few earlier students already received prestigious industrial and research awards, like Forbes 30 under 30 and the Donald P. Eckman Award.

In line with the high demand for engineers, all ECE graduates successfully found employment. Likewise, they were able to easily adapt at many graduate schools as the preparation during Bachelor's had already covered contents of graduate modules to the advantage of our students.

In addition to the career support provided by a student's Academic Advisor, the central Career Services Center (CSC) at Constructor University together with the Constructor University Alumni

Office support students with high quality training and coaching in C.V. preparation, cover letter formulation, preparation for job interviews, business etiquette, and employer research. Furthermore, the Alumni Office helps students establish a long-lasting and worldwide network which provides support when exploring job options in academia, industry, and elsewhere.

1.5 Admission Requirements

Admission to Constructor University is selective and based on a candidate's school and/or university achievements, recommendations, self-presentation, and performance on standardized tests. Students admitted to Constructor University demonstrate exceptional academic achievements, intellectual creativity, and the desire and motivation to make a difference in the world.

The following documents need to be submitted with the application:

- Recommendation Letter (optional)
- Official or certified copies of high school/university transcripts
- Educational History Form
- Standardized test results (SAT/ACT) if applicable
- Motivation statement
- ZeeMee electronic resume (optional)
- Language proficiency test results (TOEFL Score: 90, IELTS: Level 6.5 or equivalent)

Formal admission requirements are subject to higher education law and are outlined in the Admission and Enrollment Policy of Constructor University.

For more detailed information about the admission visit:
https://constructor.university/admission-aid/application-information-undergraduate

1.6 More Information and Contacts

For more information on the study program please contact the Study Program Coordinator:

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or visit our website: https://constructor.university/programs/undergraduate-education/electrical-computer-engineering

For more information on Student Services please visit:

https://constructor.university/student-life/student-services

2 The Curricular Structure

2.1 General

The curricular structure provides multiple elements for enhancing employability, interdisciplinarity, and internationality. The unique CONSTRUCTOR Track, offered across all undergraduate study programs, provides comprehensive tailor-made modules designed to achieve and foster career competency. Additionally, a mandatory internship of at least two months after the second year of study and the possibility to study abroad for one semester give students the opportunity to gain insight into the professional world, apply their intercultural competences and reflect on their roles and ambitions for employment and in a globalized society.

All undergraduate programs at constructor University are based on a coherently modularized structure, which provides students with an extensive and flexible choice of study plans to meet the educational aims of their major and complete their studies within the regular period.

The framework policies and procedures regulating undergraduate study programs at Constructor University can be found on the website (https://constructor.university/student-life/student-services/university-policies)

2.2 The Constructor University 4C Model

Constructor University offers study programs that comply with the regulations of the European Higher Education Area. All study programs are structured according to the European Credit Transfer System (ECTS), which facilitates credit transfer between academic institutions. The three-year under-graduate program involves six semesters of study with a total of 180 ECTS credit points (CP). The undergraduate curricular structure follows an innovative and student-centered modularization scheme, the 4C Model. It groups the disciplinary content of the study program in three overarching themes, CHOICE-CORE-CAREER according to the year of study, while the university-wide CONSTRUCTOR Track is dedicated to multidisciplinary content dedicated to methods as well as intellectual skills and is integrated across all three years of study. The default module size is 5 CP, with smaller 2.5 CP modules being possible as justified exceptions, e.g., if the learning goals are more suitable for 2.5 CP and the overall student workload is balanced.

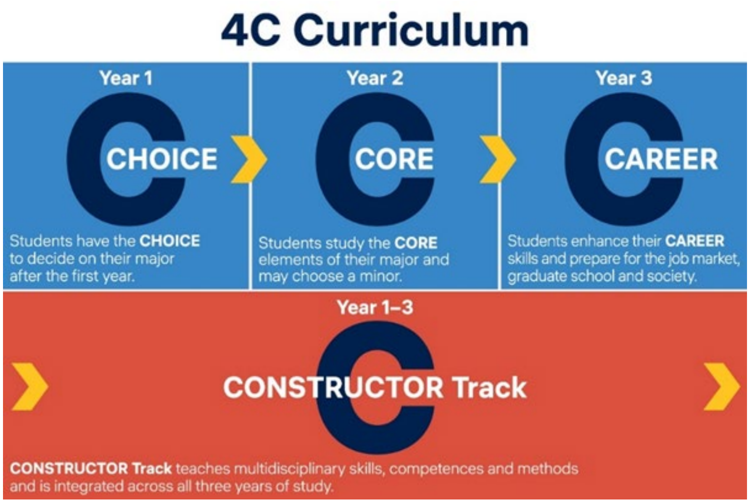

Figure 1: The Constructor University 4C-Model

2.2.1 Year 1 – CHOICE

The first study year is characterized by a university-specific offering of disciplinary education that builds on and expands upon the students' entrance qualifications. Students select introductory modules for a total of 45 CP from the CHOICE area of a variety of study programs, of which 15-45 CP will belong to their intended major. A unique feature of our curricular structure allows students to select their major freely upon entering Constructor University. The team of Academic Advising Services offers curricular counseling to all Bachelor students independently of their major, while Academic Advisors support students in their decision-making regarding their major study program as contact persons from the faculty.

To pursue ECE as a major, the following CHOICE modules (37.5 CP) need to be taken as mandatory modules:

- CHOICE Module: General Electrical Engineering I (m, 7.5 CP)
- CHOICE Module: General Electrical Engineering II (m, 7.5 CP)
- CHOICE Module: Classical Physics (m, 7.5 CP)
- CHOICE Module: Introduction to Computer Science (m, 7.5 CP)

Furthermore, ECE students must choose between the two mandatory elective modules:

- CHOICE Module: Programming in C and C++ (me, 7.5 CP)
- CHOICE Module: Programming in Python and C++ (me, 7.5 CP)

ECE students must further choose an elective module in the second semester. It is recommended that students select one of the following:

- CHOICE Module: Introduction to Robotics and Intelligent Systems (me, 7.5 CP)
- CHOICE Module: Algorithms and Data Structures (me, 7.5 CP)
- CHOICE Module: Core Algorithms and Data Structures (me, 7.5 CP)
- CHOICE Module: Modern Physics (me, 7.5 CP)
- CHOICE Module: Mathematical Modeling (me, 7.5 CP)

Students can still change to another major at the beginning of their second year of studies, provided they have taken the corresponding mandatory CHOICE modules in their first year of studies. All students must participate in an entry advising session with their Academic Advisors to learn about their major change options and consult their Academic Advisor prior to changing their major.

To allow further major changes after the first semester the students are strongly recommended to register for the CHOICE modules of one of the following study programs:

- Robotics and Intelligent Systems (RIS)
  CHOICE Module: Introduction to Robotics and Intelligent Systems (m, 7.5 CP)
  CHOICE Module: Programming in C and C++ (m, 7.5 CP)
  CHOICE Module: Algorithms and Data Structures (m, 7.5 CP)
  CHOICE Module: Introduction to Computer Science (m, 7.5 CP)
  CHOICE Module: Classical Physics (m, 7.5 CP)
  CHOICE Module: General Electrical Engineering (m, 7.5 CP)

- Computer Science (CS)
  CHOICE Module: Programming in C and C++ (m, 7.5 CP)
  CHOICE Module: Algorithms and Data Structures (m, 7.5 CP)
  CHOICE Module: Introduction to Computer Science (m, 7.5 CP
  CHOICE Module: Introduction to Robotics and Intelligent Systems (m, 7.5 CP)

2.2.2 Year 2 – CORE

In their second year, students take a total of 45 CP from a selection of in-depth, discipline-specific CORE modules. Building on the introductory CHOICE modules and applying the methods and skills acquired so far (see 2.3.1), these modules aim to expand the students' critical understanding of the key theories, principles, and methods in their major for the current state of knowledge and best practice.

ECE students take the following CORE modules:

- CORE Module: Signals and Systems (m, 7.5 CP)
- CORE Module: Digital Signal Processing (m, 7.5 CP)
- CORE Module: Communications Basics (m, 5 CP)
- CORE Module: Electromagnetics (m, 5 CP)
- CORE Module: Electronics (m, 5 CP)
- CORE Module: Wireless Communication (m, 5 CP)
- CORE Module: Information Theory (m, 5 CP)
- CORE Module: PCB design and measurement automation (m, 5 CP)

Since Electrical and Computer Engineering has a strongly sequential structure where course contents build onto each other, ECE students will not have the option of a minor in another study program within the 180 CP required for the Bachelor's degree.

2.2.3 Year 3 – CAREER

During their third year, students prepare and make decisions for their career after graduation. To explore available choices fitting individual interests, and to gain professional experience, students take a mandatory summer internship (see 2.2.3.1). The third year of studies allows ECE students to take Specialization modules within their discipline, but also focuses on the responsibility of students beyond their discipline (see CONSTRUCTOR Track).

The 5th semester also opens a mobility window for a diverse range of study abroad options. Finally, the 6th semester is dedicated to fostering the students' research experience by involving them in an extended Bachelor thesis project.

2.2.3.1 Internship / Start-up and Career Skills Module

As a core element of Constructor University's employability approach students are required to engage in a mandatory two-month internship of 15 CP that will usually be completed during the summer between the second and third years of study. This gives students the opportunity to gain first-hand practical experience in a professional environment, apply their knowledge and understanding in a professional context, reflect on the relevance of their major to employment and society, reflect on their own role in employment and society, and find a professional orientation. The internship can also establish valuable contacts for the students' Bachelor's thesis project, for the selection of a Master program graduate school or further employment after graduation. This module is complemented by career advising and several career skills workshops throughout all six semesters that prepare students for the transition from student life to professional life. As an alternative to the full-time internship, students interested in setting up their own company can apply for a start-up option to focus on developing of their business plans.

For further information, please contact the Student Career Support (https://constructor.university/student-life/career-services).

2.2.3.2 Specialization Modules

In the third year of their studies, students take 15 CP from major-specific or major-related, advanced Specialization Modules to consolidate their knowledge and to be exposed to state-of-the-art research in the areas of their interest. This curricular component is offered as a portfolio of modules, from which students can make free selections during their fifth and sixth semester. The default Specialization Module size is 5 CP, with smaller 2.5 CP modules being possible as justified exceptions.

To pursue ECE as a major, at least 15 CP from the following mandatory major-specific Specialization Modules need to be taken:

- ECE Specialization: Wireless Communication II (me, 5 CP)
- ECE Specialization: Coding Theory (me, 5 CP)
- ECE Specialization: Digital Design (me, 5 CP)
- ECE Specialization: Radio-Frequency (RF) Design (me, 5 CP)

2.2.3.3 Study Abroad

Students have the opportunity to study abroad for a semester to extend their knowledge and abilities, broaden their horizons and reflect on their values and behavior in a different context as well as on their role in a global society. For a semester abroad (usually the 5th semester), modules related to the major with a workload equivalent to 22.5 CP must be completed. Modules recognized as study abroad CP need to be pre-approved according to Constructor University study abroad procedures. Several exchange programs allow students to directly enroll at prestigious partner institutions worldwide. Constructor University's participation in Erasmus+, the European Union's exchange program, provides an exchange semester at a number of European universities that include Erasmus study abroad funding.

For further information, please contact the International Office (https://constructor.university/student-life/study-abroad/international-office).

ECE students that wish to pursue a study abroad in their 5th semester are required to select their modules at the study abroad partners such that they can be used to substitute between 10-15 CP of major-specific Specialization modules and between 5-15 CP of modules equivalent to the non-disciplinary New Skills modules (see CONSTRUCTOR Track). In their 6th semester, according to the study plan, returning study-abroad students complete the Bachelor Thesis/Seminar module (see next section), they take any missing Specialization modules to reach the required 15 CP in this area, and they take any missing New Skills modules to reach 15 CP in this area.

2.2.3.4 Bachelor Thesis/Seminar Module

This module is a mandatory graduation requirement for all undergraduate students. It consists of two module components in the major study program guided by a Constructor University faculty member: the Bachelor Thesis (12 CP) and a Seminar (3 CP). The title of the thesis will appear on the students' transcripts.

Within this module, students apply the knowledge skills, and methods they have acquired in their major discipline to become acquainted with actual research topics, ranging from the identification of suitable (short-term) research projects, preparatory literature searches, the realization of discipline-specific research, and the documentation, discussion, and interpretation of the results.

With their Bachelor Thesis students demonstrate mastery of the contents and methods of their major-specific research field. Furthermore, students show the ability to analyze and solve a well-defined problem with scientific approaches, a critical reflection of the status quo in scientific literature, and the original development of their own ideas. With the permission of a Constructor University Faculty Supervisor, the Bachelor Thesis can also have an interdisciplinary nature. In the seminar, students present and discuss their theses in a course environment and reflect on their theoretical or experimental approach and conduct. They learn to present their chosen research topics concisely and comprehensively in front of an audience and to explain their methods, solutions, and results to both specialists and non-specialists.

2.3 The CONSTRUCTOR Track

The CONSRUCTOR Track is another important feature of Constructor University's educational model. The CONSTRUCTOR Track runs parallel to the disciplinary CHOICE, CORE, and CAREER modules across all study years and is an integral part of almost all undergraduate study programs. It reflects a university-wide commitment to help transform late-stage adolescents into confident, competent and responsible young adults by providing an intellectual tool kit to become life-long learners and by giving them the capacity to employ a range of methodologies to approach potential solutions to problems across disciplines. The CONSTRUCTOR track contains Methods, New Skills and German Language / Humanities modules.

2.3.1 Methods Modules

Methods such as mathematics, statistics, programming, data handling, presentation skills, academic writing, and scientific and experimental skills are offered to all students as part of the Methods area in their curriculum. The modules that are specifically assigned to each study programs equip students with transferable academic skills. They convey and practice specific methods that are indispensable for each students' chosen study program. Students are required to take 20 CP in the Methods and Skills area. The size of all Methods and Skills modules is 5 CP.

To pursue ECE as a major, the following mandatory Methods modules (20 CP) need to be taken:

- Methods: Matrix Algebra & Advanced Calculus I (m, 5 CP)
- Methods: Matrix Algebra & Advanced Calculus II (m, 5 CP)
- Methods: Probability and Random Processes (m, 5 CP)
- Methods: Numerical Methods (m, 5 CP)

2.3.2 New Skills Modules

This part of the curriculum constitutes an intellectual and conceptual tool kit that cultivates the capacity for a particular set of intellectual dispositions including curiosity, imagination, critical thought, and transferability. It nurtures a range of individual and societal capacities, such as self-reflection, argumentation and communication. Finally, it introduces students to the normative aspects of inquiry and research, including the norms governing sourcing, sharing, withholding materials and research results as well as others governing the responsibilities of expertise as well as the professional point of view

All students are required to take the following modules in their second year:

- New Skills Module: Logic (m, 2.5 CP)
- New Skills Module: Causation and Correlation (m, 2.5 CP)

These modules will be offered with two different perspectives of which the students can choose. The module perspectives are independent modules which examine the topic from different point of views. Please see the module description for more details.

In the third year, students take three 5 CP modules that build upon previous modules in the track and are partially constituted by modules that are more closely linked to each student's disciplinary field of study. The following module is mandatory for all students:

- New Skills Module: Argumentation, Data Visualization and Communication (m, 5 CP)

This module will also be offered with two different perspectives of which the students can choose.

In their fifth semester, students may choose between:

- New Skills Module: Linear Model/Matrices (me, 5 CP) and
- New Skills Module: Complex Problem Solving (me, 5 CP).

The sixth semester also contains the choice between two modules, namely:

- New Skills Module: Agency, Leadership and Accountability (me, 5 CP) and
- New Skills Module: Community Impact Project (me, 5 CP).

Students who study abroad during the fifth semester and are not substituting the mandatory "Argumentation, Data Visualization and Communication" module, are required to take this module during their sixth semester. Students who remain on campus are free to take the Argumentation, Data Visualization and Communication module in person in either the fifth or sixth semester as they prefer.

2.3.3 German Language and Humanities Modules

German language abilities foster students' intercultural awareness and enhance their employability in their host country. They are also beneficial for securing mandatory internships (between the 2nd and 3rd year) in German companies and academic institutions. Constructor University supports its students in acquiring basic German skills in the first year of the CONSTRUCTOR Track. Non-native speaking students on campus are encouraged to take 2

German modules (2.5 CP each), but are not obliged to do so. Native Germans as well as online students (and on campus students who decide against German) do have alternative modules in Humanities in each of the first two semesters:

- Humanities Module: Introduction to Philosophical Ethics (me, 2.5 CP)
- Humanities Module: Introduction to the Philosophy of Science (me, 2.5 CP)
- Humanities Module: Introduction to Visual Culture (me, 2.5 CP)

3 ECE as a Minor

ECE as minor offers the central circuitry and major descriptions of signals and their processing together with the corresponding lab experiments. This would be a perfect combination to related majors like CS, Physics, and IEM. A CS student might be interested to see algorithms and programming from the boundary conditions of a signal-processing application and signal processing hardware. For other majors, different aspects could be of importance, e.g., a biologist that has to understand signals and their measurement.

3.1 Qualification Aims

ECE as a major will offer the central concepts of linear circuits, periodic and non-periodic, time-continuous and time-discrete deterministic signals, and all linear transforms of signals. In the labs, simple circuits will be built and measured and finally digital signal processors will be programmed for signal processing tasks.

3.1.1 Intended Learning Outcomes

With a minor in ECE, students will be able to

1. describe typical electronic components and their standard base circuits and implement analog circuitry;
2. describe the underlying theoretical concepts of deterministic signals in time and frequency domain;
3. explain and implement signal processing components, methods, and algorithms, having studied the theoretical foundation and having learned to program signal processor platforms;
4. treat signals with dedicated algorithms, be it audio, video, or from other origin, e.g., by filtering, prediction, compression.

3.2 Module Requirements

A minor in ECE requires 30 CP. The default option to obtain a minor in ECE is marked in the Study and Examination Plans in Chapter 6. It includes the following CHOICE and CORE modules:

- CHOICE Module: General Electrical Engineering I (m, 7.5 CP)
- CHOICE Module: General Electrical Engineering II (m, 7.5 CP)
- CORE Module: Signals and Systems (m, 7.5 CP)
- CORE Module: Digital Signal Processing (m, 7.5 CP)

3.3 Degree

After successful completion, the minor in ECE will be listed on the final transcript under PROGRAM OF STUDY and BA/BSc – [name of the major] as "(Minor: ECE)".

4 ECE Undergraduate Program Regulations

4.1 Scope of these Regulations

The regulations in this handbook are valid for all students who entered the ECE undergraduate program at Constructor University in Fall 2023. In case of conflict between the regulations in this handbook and the general Policies for Bachelor Studies, the latter applies (see https://constructor.university/student-life/student-services/university-policies/academic-policies).

In exceptional cases, certain necessary deviations from the regulations of this study handbook might occur during the course of study (e.g., change of the semester sequence, assessment type, or the teaching mode of courses).

In general, Constructor University reserves therefore the right to modify the regulations of the program handbook also after its publication at any time and in its sole discretion.

4.2 Degree

Upon successful completion of the study program, students are awarded a Bachelor of Science degree in Electrical and Computer Engineering.

4.3 Graduation Requirements

In order to graduate, students need to obtain 180 CP. In addition, the following graduation requirements apply:

Students need to complete all mandatory components of the program as indicated in the mandatory study and examination in Chapter 6 of this handbook.

5 Schematic Study Plan for ECE

Figure 2 shows schematically the sequence and types of modules required for the study program. A more detailed description, including the assessment types, is given in the Study and Examination Plans in the following section.

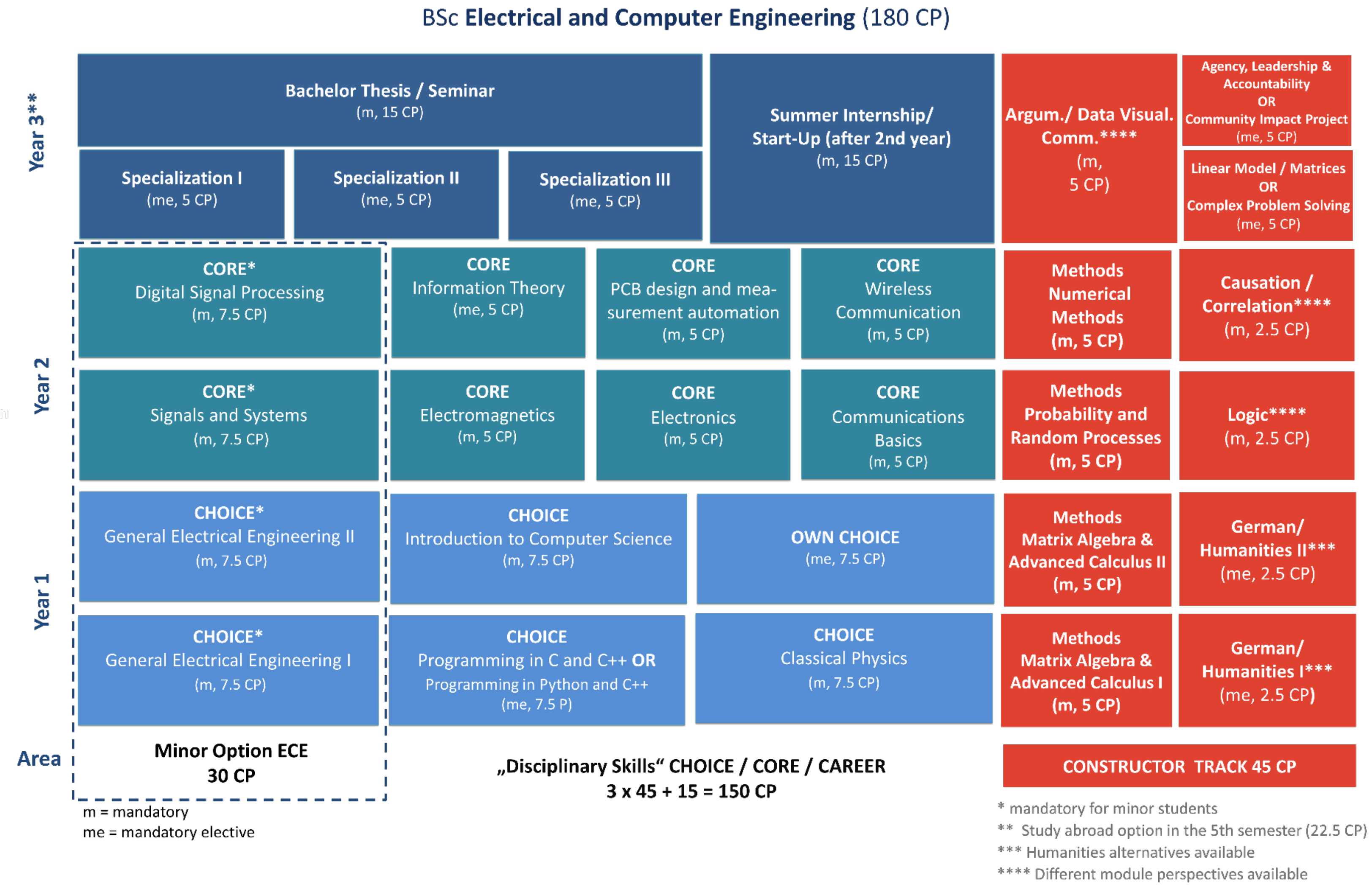

Figure 2: Schematic Study Plan

Electrical and Computer Engineering (ECE) BSc

Matriculation Fall 2023

	Program-Specific Modules	Type	Assessment	Period	Status[1]	Sem	CP
Year 1 - CHOICE							**45**
Take the mandatory CHOICE modules listed below, this is a requirement for the ECE program.							
	Unit: General Electrical Engineering (default minor)						**15**
CH-210	**Module: General Electrical Engineering I**				m	1	7.5
CH-210-A	General Electrical Engineering I Lecture	Lecture	Written exam	Examination period			5
CH-210-B	General Electrical Engineering Lab I	Lab	Lab report	During the semester			2.5
CH-211	**Module: General Electrical Engineering II** (pre-requisites GenEE I)				m	2	7.5
CH-211-A	General Electrical Engineering II Lecture	Lecture	Written exam	Examination period			5
CH-211-B	General Electrical Engineering Lab II	Lab	Lab report	During the semester			2.5
	Unit: Further CHOICE modules						**30**
CH-140	**Module: Classical Physics**				m	1	7.5
CH-140-A	Classical Physics	Lecture	Written exam	Examination period			5
CH-140-B	Classical Physics Lab	Lab	Lab report	During the semester			2.5
CH-232	**Module: Introduction to Computer Science**				m	2	7.5
CH-232-A	Introduction to Computer Sciences	Lecture	Written exam	Examination period			
Take one of the two listed mandatory elective CHOICE modules:							
CH-230	**Module: Programming in C and C++**				me	1	7.5
CH-230-A	Programming in C and C++	Lecture	Written examination	Examination period			2.5
CH-230-A	Programming in C and C++ Tutorial	Turorial	Practical Assessment	During the semester			5
CH-250	**Module: Programming in Python and C++**				me	1	7.5
CH-250-A	Programming in Python and C++	Lecture	Written exam	Examination period			5
CH-250-B	Programming in Python and C++ Lab	Lab	Practical Assessment	During the semester			2.5
Take one further CHOICE module from those offered for all other study programs. Below some recommendations:							
CH-220	**Module: Introduction to Robotics and Intelligent Systems**				me	2	7.5
CH-220-A	Introduction to Robotics and Intelligent Systems	Lecture	Written exam	Examination period			5
CH-220-B	Introduction to Robotics and Intelligent Systems Lab	Lab	Lab report				2.5
CH-231	**Module: Algorithms and Data Structures**				me	2	7.5
CH-231-A	Algorithms and Data Structures	Lecture		Examination period			
Module Code	**Module: Core Algoriths & Data Structures**				me	2	7.5
xxxx	Core Algorithms and Data Structures	Lecture	Written examination	Examination period			5
xxxx	Core Algorithms and Data Structures Lab	Lab	Practical Assessment	During the semester			2.5
CH-141	**Module: Modern Physics**				me	2	7.5
CH-141-A	Modern Physics	Lecture	Written exam	Examination period			5
CH-141-B	Modern Physics Lab	Lab	Lab report	During the semester			2.5
CH-152	**Module: Mathematical Modeling**				me	2	7.5
CH-152-A	Mathematical Modeling	Lecture	Written exam	Examination period			5
CH-152-B	Mathematical Modeling Lab	Lab	Lab report	During the semester			2.5
Year 2 - CORE							**45**
Take all CORE modules listed below							
	Unit: Signal Processing (default minor)						**15**
CO-520	**Module: Signals and Systems**				m	3	7.5
CO-520-A	Signals and Systems Lecture	Lecture	Written exam	Examination period			5
CO-520-B	Signals and Systems Lab	Lab	Lab report	During the semester			2.5
CO-521	**Module: Digital Signal Processing**				m	4	7.5
CO-521-A	Digital Signal Processing Lecture	Lecture	Written exam	Examination period			5
CO-521-B	Digital Signal Processing Lab	Lab	Lab report	During the semester			2.5
	Unit: Communications						**10**
CO-522	**Module: Communications Basics**				m	3	5
CO-522-A	Communications Basics Lecture	Lecture	Written exam	Examination period			2.5
CO-522-B	Communications Basics Lab	Lab	Lab report	During the semester			2.5
CO-523	**Module: Wireless Communication**				m	4	5
CO-523-A	Wireless Communication I	Lecture	Written exam	Examination period			5
	Unit: Electromagnetics and Information Theory						**10**
CO-524	**Module: Electromagnetics**				m	3	5
CO-524-A	Electromagnetics	Lecture	Written exam	Examination period			5
CO-525	**Module: Information Theory**				m	4	5
CO-525-A	Information Theory	Lecture	Written exam	Examination period			5
	Unit: Hardware						**10**
CO-526	**Module: Electronics**				m	3	5
CO-526-A	Electronics Lecture	Lecture	Written exam	Examination period			2.5
CO-526-B	Electronics Lab	Lab	Lab report	During the semester			2.5
CO-527	**Module: PCB design and measurement automation**				m	4	5
CO-527-A	PCB design and measurement automation	Lab	Written exam Lab report	Examination period During the semester			5

	Constructor Track Modules (General Education)	Type	Assessment	Period	Status[1]	Sem	CP
Year 1							**15**
	Unit: Methods						**10**
CTMS-MAT-09	**Module: Matrix Algebra & Advanced Calculus I**				m	1	5
CTMS-09	Matrix Algebra & Advanced Calculus I	Lecture	Written exam	Examination period			
CTMS-MAT-10	**Module: Matrix Algebra & Advanced Calculus II**				m	2	5
CTMS-10	Matrix Algebra & Advanced Calculus II	Lecture	Written exam	Examination period			
	Unit: German Language and Humanities (choose one module for each sememster)						**5**
	German is default language and open to Non-German speakers (on campus and online).[3]						
CTLA-	**Module: Language 1**				me	1	2,5
CTLA-	Language 1	Seminar	Various	Various	me		
CTLA-	**Module: Language 2**				me	2	2,5
CTLA-	Language 2	Seminar	Various	Various	me		
CTHU-HUM-001	**Humanities Module: Introduction to Philosophical Ethics**				me	1	2,5
CTHU-001	Introduction into Philosophical Ethics	Lecture (online)	Written Exam	Examination period	me		
CTHU-HUM-002	**Humanities Module: Introduction to the Philosophy of Science**				me	2	2,5
CTHU-002	Introduction to the Philosophy of Science	Lecture (online)	Written Exam	Examination period	me		
CTHU-HUM-003	**Humanities Module: Introduction to Visual Culture**				me	2	2,5
CTHU-003	Introduction to Visual Culture	Lecture (online)	Written Exam	Examination period	me		
Year 2							**15**
	Unit: Methods						**10**
CTMS-MAT-12	**Module: Probability and Random Processes**				m	3	5
CTMS-12	Probability and Random Processes	Lecture	Written exam	Examination period			
CTMS-MAT-13	**Module: Numerical Methods**				m	4	5
CTMS-13	Numerical Methods	Lecture	Written exam	Examination period			
	Unit: New Skills						**5**
Choose one of the two modules							
CTNS-NSK- 01	**Module: Logic (perspective I)**				me	3	2,5
CTNS-01	Logic (perspective I)	Online Lecture	Written Ex	Examination period	me		2,5
CTNS-NSK-02	**Module: Logic (perspective II)**						
CTNS-02	Logic (perspective II)	Online Lecture	Written Ex	Examination period	me		2,5
Choose one of the two modules							
CTNS-NSK-03	**Module: Correlation and Causation (perspective I)**				me	4	2,5
CTNS-03	Correlation and Causation (perspective I)	Online Lecture	Written Ex	Examination period	me		2,5
CTNS-NSK-04	**Module: Correlation and Causation (perspective II)**				me	4	2,5
CTNS-04	Correlation and Causation (perspective II)	Online Lecture	Written Ex	Examination period	me		2,5

Year 3 - CAREER							**45**
CA-INT-900	**Module: Internship / Startup and Career Skills**				**m**	**4/5**	**15**
CA-INT-900-0	Internship / Startup and Career Skills	Internship	Report or Businessplan	During the 5th semester			15
CA-ECE-800	**Module: Thesis / Seminar ECE**				**m**	**6**	**15**
CA-ECE-800-T	Thesis ECE	Thesis	Thesis	15th of May			12
CA-ECE-800-S	Seminar ECE	Seminar	Presentation	During the semester			3
	Unit: Specialization ECE				**m**	**5/6**	**15**
Take a total of 15 CP of specializatopn modules							
CA-ECE-801	Wireless Communication II	Lecture	Written exam	Examination period	me	5	5
CA-ECE-802	Coding Theory	Lecture	Written exam	Examination period	me	5	5
CA-ECE-803	Digital Design	Lecture/Lab	Written exam	Examination period	me	5	5
CA-ECE-804	Radio-Frequency (RF) Design	Lecture	Written exam	Examination period	me	6	5

							15
	Unit: New Skills						**10**
Choose one of the two modules							
CTNS-NSK-05	**Module: Linear Model / Matrices**				**me**	**5**	**5**
CTNS-05	Linear Model/ Matrices	Seminar (online)	Written Exam	Examination period			5
CTNS-NSK-06	**Module: Complex Problem Solving**				**me**	**5**	**5**
CTNS-06	Complex Problem Solving	Lecture (online)	Written Exam	Examination period			5
Choose one of the two modules							5
CTNS-NSK-07	**Module: Argumentation, Data Visualization and Communication**				**me**	**####**	**5**
CTNS-07	Argumentation, Data Visualization and Communication (perspective I)	Online Lecture	Written exam	Examination period	me	**5**	5
CTNS-NSK-08	**Module: Argumentation, Data Visualization and Communication**				**me**	**####**	**5**
CTNS-08	Argumentation, Data Visualization and Communication (perspective II	Online Lecture	Written exam	Examination period	me	**6**	5
Choose one of the two modules							
CTNS-NSK	**Module: Agency, Accountability & Leadership**				**me**	**6**	**5**
CTNS-09	Agency, Accountability & Leadership	Lecture (online)	Written Exam	Examination period			5
CTCI-CI-950	**Module: Community Impact Project**				**me**	**6**	**5**
CTCI-950	Community Impact Project	Project	Project	During the Sememster			5
Total CP							**180**

[1] Status (m = mandatory, me = mandatory elective)
[2] For a full listing of all CHOICE / CORE / CAREER / Jacobs Track modules please consult the CampusNet online catalogue and /or the study program handbooks.
[3] German native speakers will have alternatives to the language courses (in the field of Humanities).

Figure 3: Schematic Study and Examination Plan

7 Electrical and Computer Engineering Modules

7.1 General Electrical Engineering I

Module Name			Module Code	Level (type)	CP
General Electrical Engineering I			CH-210	Year 1 (CHOICE)	7.5
Module Components					
Number	Name			Type	CP
CH-210-A	General Electrical Engineering I			Lecture	5
CH-210-B	General Electrical Engineering Lab I			Lab	2.5
Module Coordinator Prof. Dr. Giuseppe Abreu	**Program Affiliation** • Electrical and Computer Engineering (ECE)			**Mandatory Status** Mandatory for ECE, RIS and minor ECE	
Entry Requirements Pre-requisites ☒ None	Co-requisites ☒ None	Knowledge, Abilities, or Skills Basic mathematics, including notions of vectors, matrices functions, and complex numbers	**Frequency** Annually (Fall) **Duration** 1 semester	**Forms of Learning and Teaching** • Lecture (35 hours) • Lab (25.5 hours) • Private Study (127) **Workload** 187.5 hours	

Recommendations for Preparation

It is highly recommended that students familiarize themselves with the contents of the appendices of a typical introductory textbook on Electrical Engineering (e.g. "Fundamentals of Electric Circuits", by Alexander and Sadiku and "Basic Engineering Circuit Analysis", by Irwin and Nelms), including Complex Numbers and basic Linear Algebra (in particular the solution of simultaneous linear equations). In addition, it is recommended that students acquire Calculus basics (differentiation and integration of simple functions).

Content and Educational Aims

The module, consisting of a lecture, supported by corresponding lab experiments, comprises the classical introduction to Electrical and Computer Engineering (ECE), starting from the basics of the electric phenomenon, its fundamental elements (charge, current, potential, energy, etc.), its interaction with materials (conductivity, capacitance, inductance, etc.) and its manipulation by man-made structures (electronic components and circuits). The module then develops into a wide set of general principles, laws and analytical tools to understand electric circuits and electric systems in general. The module also offers a solid foundation on which specialization areas in EE (e.g. Communications, Control, etc.) are built. The emphasis is the analysis of circuits in DC steady state and transient modes. Classic material include (but are not limited to): Kirchhoff's Laws, Volta's Law (capacitance), Faraday's Law (inductance), Thevenin and Norton's Theorem, Tellegen's Theorem, delty-wye transformation, source transformations, basics of non-linear electronic components (diodes and transistors), OpAmp circuits, State-space Method, Laplace Transform applied to the analysis of higher-order circuits, Laplace impedances and transfer functions. In the lab portion of the module, users will familiarize themselves with electronic components (resistors, capacitors, inductors, diodes, OpAmps, transistors, etc.) and circuits, and learn how to utilize typical lab equipment (such as breadboards, digital multimeters, voltage and current sources and function generators) required for the assembly and analysis of electric circuits.

Intended Learning Outcomes
By the end of this module, students should be able to 1. describe the fundamental physical principles of electric quantities (charge, current, potential, energy and its conservation, etc.); 2. explain how the aforementioned quantities relate to each other and interact with matter, including corresponding mathematical models; 3. explain how the aforementioned models can be utilized to manipulate electric quantities and phenomenon in the form of electric and electronic circuits or machines that perform several tasks and functions according to intended designs; 4. employ various theoretical and practical tools to analyze electric circuits including resistive circuits, reactive circuits, and OpAmp circuits, both in DC steady-state and transient modes. In addition to the aforementioned outcomes, fundamental to a career in ECE, students will also have acquired: 5. analytical and mathematical modeling skills useful to study other physical systems (e.g. in other areas of Engineering, Physics, Robotics, etc.) 6. the ability to work in a lab environment and operate lab equipment, as required in other professions (e.g. Physics, Biology, Chemistry etc.).
Usability and Relationship to other Modules
Indicative Literature Charles K. Alexander and Matthew N. O. Sadiku, Fundamentals of Electric Circuits, 3rd ed., McGraw-Hill, 2008 (Primary Textbook). J. David Irwin and R. Mark Nelms, Basic Engineering Circuit Analysis, 10th ed., Wiley, 2010 (Recommended Reference). James Nilsson and Susan Riedel, Electric Circuits, 10th ed., Pearson, 2015 (Extra Reference). A. Agarwal and J. Lang, Foundations of Analog and Digital Electronic Circuits, 1st ed., Elsevier, 2005 (Advanced Reference for selected topics).
Examination Type: Module Component Examinations **Module Component 1: Lecture** Assessment Type: Written examination — Duration: 120 min Weight: 67% Scope: Intended learning outcomes of the lecture (1-3,5) **Module Component 2: Lab** Assessment Type: Lab reports — Length: 5-10 pages per experiment session Weight: 33% Scope: Intended learning outcomes of the lab (3-4, 6). Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.2 General Electrical Engineering II

Module Name	Module Code	Level (type)	CP

General Electrical Engineering II	CH-211	Year 1 (CHOICE)	7.5

Module Components

Number	Name	Type	CP
CH-211-A	General Electrical Engineering II	Lecture	5
CH-211-B	General Electrical Engineering Lab II	Lab	2.5

Module Coordinator	**Program Affiliation**	**Mandatory Status**
Prof. Dr. Giuseppe Abreu	• Electrical and Computer Engineering (ECE)	Mandatory for ECE, and minor in ECE

Entry Requirements			**Frequency**	**Forms of Learning and Teaching**
Pre-requisites	Co-requisites	Knowledge, Abilities, or Skills	Annually (Spring)	• Lecture (35 hours) • Lab (25.5 hours) • Private Study (127)
☒ CH-210 General Electrical Engineering I	☒ None	• Basic mathematics, including notions of Calculus and Linear Algebra	**Duration** 1 semester	**Workload** 187.5 hours

Recommendations for Preparation

Review Basic mathematics, including notions of Calculus and Linear Algebra.

Content and Educational Aims

This module continues with the classical introduction to Electrical and Computer Engineering (ECE), developing beyond the contents introduced in CH10-GenEE11, towards building the foundations upon which modern specialization areas in ECE such as Signal Processing, Communications, and Control are based. We start with the concepts of Impedance and Phasors, followed by the introduction of the Fourier Trigonometric and Exponential Series, and later, the Fourier Transform. Using these tools as a basis, we revise various elementary circuits first studied in CH10-GenEE1 under the Laplace framework, this time emphasizing the notions of frequency (oscillation rate) and phase (rotation), thus establishing the fundamental concepts required to understand Signals and Systems, and Digital Signal Processing, to be studied in the second year. Besides the already mentioned fundamental tools of Fourier analysis, some of the classical material covered in the module include, but is not limited to: Impedances and Phasors (in the frequency domain), the Parseval Theorem (in the context of power analysis), magnetic coupling, Bode plots (in amplitude and phase), spectral graphs, the Convolution Integral and more.

Intended Learning Outcomes

By the end of this module, students should be able to

1. explain the fundamental physical principle of oscillation and its frequency representation, in particular in the context of AC circuits;
2. explain how to mathematically model the oscillatory (or periodic) phenomena in the frequency domain, in light of Fourier Analysis;
3. explain how the latter Fourier tool extends beyond periodic phenomena, building the basic framework of general spectral analysis of physical systems, with emphasis on electric systems and signals;
4. design and analyze electronic circuits and their signals (e.g. time-varying voltages and currents) requiring certain tasks and functions according to intended objectives.

In addition to the aforementioned outcomes, fundamental to a career in ECE, students will also have acquired:

5. Analytical and mathematical modeling skills useful to study other physical systems (e.g. in other areas of Engineering, Physics, Robotics, etc.)
6. Ability to work in a lab environment and operate lab equipment, as required in other professions (e.g. Physics, Biology, Chemistry etc.).

Indicative Literature

Charles K. Alexander and Matthew N. O. Sadiku, Fundamentals of Electric Circuits, 3rd ed., McGraw-Hill, 2008 (Primary Textbook).

J. David Irwin and R. Mark Nelms, Basic Engineering Circuit Analysis, 10th ed., Wiley, 2010 (Recommended Reference).

James Nilsson and Susan Riedel, Electric Circuits, 10th ed., Pearson, 2015 (Extra Reference).

A. Agarwal and J. Lang, Foundations of Analog and Digital Electronic Circuits, 1st ed., Elsevier, 2005 (Advanced Reference for selected topics).

Usability and Relationship to other Modules

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination

Duration: 120 min
Weight: 67%

Scope: Intended learning outcomes of the lecture (1-3,5).

Module Component 2: Lab

Assessment Type: Lab reports

Length: 5-10 pages per experiment session
Weight: 33%

Scope: Intended learning outcomes of the lab (4, 6).

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.3 Classical Physics

<table>
<tr><td colspan="2">Module Name

Classical Physics</td><td>Module Code

CH-140</td><td>Level (type)

Year 1
(CHOICE)</td><td>CP

7.5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CH-140-A</td><td colspan="2">Classical Physics</td><td>Lecture</td><td>5</td></tr>
<tr><td>CH-140-B</td><td colspan="2">Classical Physics Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Jürgen Fritz</td><td colspan="2">Program Affiliation

• Physics and Data Science</td><td colspan="2">Mandatory Status

Mandatory for ECE, PHDS, RIS, and minor in Physics
Mandatory elective for MMDA</td></tr>
</table>

<table>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• High school physics
• High school math</td><td>Frequency

Annually

(Fall)</td><td>Forms of Learning and Teaching

• Lecture (35 hours)
• Lab (25.5 hours)
• Homework (42 hours)
• Private study (85 hours)</td></tr>
<tr><td>Duration

1 semester</td><td>Workload

187.5 hours</td></tr>
</table>

Recommendations for Preparation

A revision of high school math (especially calculus, analytic geometry, and vector algebra) and high school physics (basics of motion, forces, and energy) is recommended. The level and content follow standard textbooks for calculus-based first-year university physics such as Young & Freedman: University Physics, Halliday & Resnick & Walker: Fundamentals of Physics, or Tipler & Mosca: Physics.

Content and Educational Aims

A. This module introduces students to basic physical principles, facts, and experimental evidence in the fields of classical mechanics, thermodynamics, and optics. It lays the foundations for more advanced physics modules and for other science and engineering disciplines. It is intended for students who already have reasonably solid knowledge of basic physics and mathematics at the high school level.

B. Emphasis is placed on general physical principles and general mathematical concepts for a thorough understanding of physical phenomena. Calculus and vector analysis will be used to develop a scientifically sound description of physical phenomena. An optional tutorial is offered to discuss homework or topics of interest in more detail.

C. Topics covered in the module include an introduction to mechanics using calculus, vectors, and coordinate systems; concepts of force and energy, momentum and rotational motion, and gravitation and oscillations; and concepts of thermodynamics such as temperature, heat, ideal gas, and kinetic gas theory up to heat engines and entropy. The module content concludes with an introduction to classical optics including refraction and reflection, lenses and optical instruments, waves, interference, and diffraction.

D. The lectures are complemented by hands-on work in a teaching lab where students apply their theoretical knowledge by performing experiments as well as related data analysis and result presentation. The default lab of this module is the Classical Physics Lab offering experiments in mechanics, thermodynamics, and optics. For students majoring in RIS a Technical Mechanics Lab is offered with a focus on technical mechanics experiments.

Intended Learning Outcomes

By the end of the module, students will be able to

- recall basic facts and experimental evidence in classical mechanics, thermodynamics, and optics;
- understand the basic concepts of motion, force, energy, oscillations, heat, and light and apply them to physical phenomena;
- describe and understand natural and technical phenomena in mechanics, thermodynamics, and optics by reducing them to their basic physical principles;
- apply basic calculus and vector analysis to describe physical systems;
- examine basic physical problems, find possible solutions, and assess them critically;
- set up experiments, analyze their outcomes by using error analysis, and present them properly;
- record experimental data using basic experimental techniques and data acquisition tools;
- use the appropriate format and language to describe and communicate the outcomes of experiments and the solutions to theoretical problems.

Indicative Literature

H. Young & R. Freedman: University physics, with modern physics. Upper Saddle River: Prentice Hall.

D. Halliday, R. Resnick, J. Walker: Fundamentals of physics, extended version. Hoboken: John Wiley & Sons Inc.P. Tipler & G. Mosca: Physics for scientists and engineers. New York: WH Freeman.

Usability and Relationship to other Modules

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination (Lecture) — Duration: 120 min; Weight: 67%

Scope: Intended learning outcomes of the lecture (1-5).

Module Component 2: Lab (Classical Physics Lab/ Classical Mechanics Lab)

Assessment Type: Lab Reports (Lab) — Length: 8-12 pages; Weight: 33%

Scope: Intended learning outcomes of the lab (1, 6-8).

A bonus achievement for the lecture module component is offered.

Completion: To pass this module, the examination of each module component has to be passed with at least 45%

7.4 Introduction to Computer Science

Module Name			Module Code	Level (type)	CP
Introduction to Computer Science			CH-232	Year 1 (CHOICE)	7.5
Module Components					
Number	Name			Type	CP
CH-232-A	Introduction to Computer Science			Lecture	7.5
Module Coordinator Prof. Dr. Jürgen Schönwälder	**Program Affiliation** • Computer Science (CS)			**Mandatory Status** Mandatory for CS, ECE and RIS	
Entry Requirements			**Frequency** Every semester (Fall/Spring)	**Forms of Learning and Teaching** • Class (52.5 hours) • Independent study (115 hours) • Exam preparation (20 hours)	
Pre-requisites ☒ None	Co-requisites ☒ None	Knowledge, Abilities, or Skills	**Duration** 1 semester	**Workload** 187.5 hours	

Recommendations for Preparation

It is recommended that students install a Linux system such as Ubuntu on their notebooks and that they become familiar with basic tools such as editors (vim or emacs) and the basics of a shell. The Glasgow Haskell Compiler (GHC) will be used for implementing Haskell programs.

Content and Educational Aims

The module introduces fundamental concepts and techniques of computer science in a bottom-up manner. Based on clear mathematical foundations (which are developed as needed), the course discusses abstract and concrete notions of computing machines, information, and algorithms, focusing on the question of representation versus meaning in Computer Science.

The module introduces basic concepts of discrete mathematics with a focus on inductively defined structures, to develop a theoretical notion of computation. Students will learn the basics of the functional programming language Haskell because it treats computation as the evaluation of pure and typically inductively defined functions. The module covers a basic subset of Haskell that includes types, recursion, tuples, lists, strings, higher-order functions, and finally monads. Back on the theoretical side, the module covers the syntax and semantics of Boolean expressions and it explains how Boolean algebra relates to logic gates and digital circuits. On the technical side, the course introduces the representation of basic data types such as numbers, characters, and strings as well as the von Neuman computer architecture. On the algorithmic side, the course introduces the notion of correctness and elementary concepts of complexity theory (big O notation).

Intended Learning Outcomes By the end of this module, students will be able to 1. explain basic concepts such as the correctness and complexity of algorithms (including the big O notation); 2. illustrate basic concepts of discrete math (sets, relations, functions); 3. recall basic proof techniques and use them to prove properties of algorithms; 4. explain the representation of numbers (integers, floats), characters and strings, and date and time; 5. summarize basic principles of Boolean algebra and Boolean logic; 6. describe how Boolean logic relates to logic gates and digital circuits; 7. outline the basic structure of a von Neumann computer; 8. explain the execution of machine instructions on a von Neumann computer; 9. describe the difference between assembler languages and higher-level programming languages; 10. define the differences between interpretation and compilation; 11. illustrate how an operating system kernel supports the execution of programs; 12. determine the correctness of simple programs; 13. write simple programs in a pure functional programming language.
Indicative Literature Eric Lehmann, F. Thomson Leighton, Albert R. Meyer: Mathematics for Computer Science, online 2018. David A. Patterson, John L Hennessy: Computer Organization and Design: The Hardware/Software Interface, 4th edition, Morgan Kaufmann, 2011. Miran Lipovaca: Learn You a Haskell for Great Good!: A Beginner's Guide, 1st edition, No Starch Press, 2011.
Usability and Relationship to other Modules • This module introduces key mathematical concepts and various notions of computing machines and computing abstractions and is in particularly important for subsequent courses covering theoretical aspects of computer science. This module is also important for courses that require a basic understanding of computer architecture and program execution at the hardware level.
Examination Type: Module Examination Assessment Type: Written examination — Duration: 120 min, Weight: 100% Scope: All intended learning outcomes of the module Module achievement: 50% of the assignments correctly solved This module introduces the functional programming language Haskell. Students develop their functional programming skills by solving programming problems. The module achievement ensures that a sufficient level of practical programming and problem-solving skills has been obtained. Completion: To pass this module, the examination has to be passed with at least 45%

7.5 Programming in C and C++

Module Name		**Module Code**	**Level (type)**	**CP**
Programming in C and C++		CH-230	Year 1 (CHOICE)	7.5
Module Components				
Number	Name		Type	CP
CH-230-A	Programming in C and C++		Lecture	5
CH-230-B	Programming in C and C++ - Tutorial		Tutorial	2.5
Module Coordinator Dr. Kinga Lipskoch	**Program Affiliation** • Computer Science (CS)		**Mandatory Status** Mandatory for CS, RIS, minor CS and minor RIS Mandatory elective for ECE	
Entry Requirements Pre-requisites ☒ None	Co-requisites ☒ None	Knowledge, Abilities, or Skills	**Frequency** Annually (Fall)	**Forms of Learning and Teaching** • Lecture attendance (17,5 hours) • Tutorial attendance (35 hours) • Independent study (115 hours) • Exam preparation (20 hours)
			Duration 1 semester	**Workload** 187.5 hours

Recommendations for Preparation

It is recommended that students install a suitable programming environment on their notebooks. It is recommended to install a Linux system such as Ubuntu, which comes with open-source compilers such as gcc and g++ and editors such as vim or emacs. Alternatively, the open-source Code: Blocks integrated development environment can be installed to solve programming problems.

Content and Educational Aims

This course offers an introduction to programming using the programming languages C and C++. After a short overview of the program development cycle (editing, preprocessing, compiling, linking, executing), the module presents the basics of C programming. Fundamental imperative programming concepts such as variables, loops, and function calls are introduced in a hands-on manner. Afterwards, basic data structures such as multidimensional arrays, structures, and pointers are introduced and dynamically allocated multidimensional arrays and linked lists and trees are used for solving simple practical problems. The relationships between pointers and arrays, pointers and structures, and pointers and functions are described, and they are illustrated using examples that also introduce recursive functions, file handling, and dynamic memory allocation.

The module then introduces basic concepts of object-oriented programming languages using the programming language C++ in a hands-on manner. Concepts such as classes and objects, data abstractions, and information hiding are introduced. C++ mechanisms for defining and using objects, methods, and operators are introduced and the relevance of constructors, copy constructors, and destructors for dynamically created objects is explained. Finally, concepts such as inheritance, polymorphism, virtual functions, and overloading are introduced. The learned concepts are applied by solving programming problems.

Intended Learning Outcomes

By the end of this module, students will be able to

1. explain basic concepts of imperative programming languages such as variables, assignments, loops, and function calls;
2. write, test, and debug programs in the procedural programming language C using basic C library functions;
3. demonstrate how to use pointers to create dynamically allocated data structures such as linked lists;
4. explain the relationship between pointers and arrays;
5. illustrate basic object-oriented programming concepts such as objects, classes, information hiding, and inheritance;
6. give original examples of function and operator overloading and polymorphism;
7. write, test, and debug programs in the object-oriented programming language C++.

Indicative Literature

Brian Kernighan, Dennis Ritchie: The C Programming Language, 2nd edition, Prentice Hall Professional Technical Reference, 1988.

Steve Oualline: Practical C Programming, 3rd edition, O'Reilly Media, 1997.

Bruce Eckel: Thinking in C++: Introduction to Standard C++, Prentice Hall, 2000.

Bruce Eckel, Chuck Allison: Thinking in C++: Practical Programming, Prentice Hall, 2004.

Bjarne Stroustrup: The C++ Programming Language, 4th edition, Addison Wesley, 2013.

Michael Dawson: Beginning C++ Through Game Programming, 4th edition, Delmar Learning, 2014.

Usability and Relationship to other Modules

- This module introduces the programming languages C and C++ and several other modules build on this foundation. Certain features of C++ such as templates and generic data structures and an overview of the standard template library will be covered in the Algorithms and Data Structures module.

Examination Type: Module Component Examinations

Component 1: Lecture

Assessment types: Written examination — Duration: 120 min, Weight: 67%

Scope: All theoretical intended learning outcomes of the module

Component 2: Tutorial

Assessment: Practical assessment (Programming assignments) — Weight: 33%

Scope: All practical intended learning outcomes of the module

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.6 Programming in Python and C++

<table>
<tr><td colspan="3">Module Name

Programming in Python and C++</td><td>Module Code

CH-250</td><td>Level (type)

Year 1
(CHOICE)</td><td>CP

7.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CH-250-A</td><td colspan="3">Programming in Python and C++</td><td>Lectures</td><td>5</td></tr>
<tr><td>CH-250-B</td><td colspan="3">Programming in Python and C++ - Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Aleksandr Omelchenko</td><td colspan="3">Program Affiliation

• Data Science and Software Development (DSSD)</td><td colspan="2">Mandatory Status

Mandatory for DSSD, PHDS, and MMDA

Mandatory elective for ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

<table><tr><td>Pre-requisites

☒ none</td><td>Co-requisites

☒ none</td><td>Knowledge, Abilities, or Skills

☒ none</td></tr></table></td><td>Frequency

Annually

(Fall)</td><td colspan="2">Forms of Learning and Teaching

- Lectures (35 hours)
- Tutorials (17.5 hours)
- Independent study (115 hours)
- Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Set up a suitable programming environment.</td></tr>
<tr><td colspan="6">Content and Educational Aims

This course provides a solid foundation in imperative programming concepts and techniques, with a focus on Python and C++ programming languages. This course enables students to write programs in Python that solve problems and perform various operations using functions, data structures, and control structures, provides a basic introduction to the C++ programming language and its standard library, with a focus on data structures and algorithms, develops students' problem-solving and algorithmic thinking skills through hands-on programming exercises and projects, fosters students' ability to design, write, and test programs that are robust, maintainable, and scalable, encourages students to pursue further studies and practice in the field of programming and data science.

Content:
Introduction to Imperative Programming: Overview of basic concepts of imperative programming languages, including variables, assignments, loops, function calls, data structures, and more.
Python Programming: Writing interactive programs in Python, working with user input, and testing and debugging code.
Object-Oriented Programming in Python: Overview of basic object-oriented programming concepts, such as objects, classes, information hiding, inheritance, and function and operator overloading.
File Input/Output in Python: Retrieving and processing data from/to files, and generating data using Python.</td></tr>
</table>

- Scientific Computing with Python: Using NumPy arrays for vectorized code and SciPy for special functions and black-boxed algorithms (root solvers, quadrature, ODE solvers, and fast Fourier transform).
- Visualization in Python: Visualizing data using Matplotlib.
- Introduction to C++ Programming: Writing basic programs in C++ using standard library functions.
- Pointers in C++: Using pointers to create dynamically allocated data structures, such as linked lists, and understanding the relationship between pointers and arrays.
- Standard Library Data Types in C++: Overview of C++ standard library data types, including vector, string, list, map, set, and sort.
- Risks and Limitations of C/C++: Understanding the risks of C/C++ programming, including implicit type conversions, lack of bounds checking, and manual memory ownership management.

Intended Learning Outcomes

Upon completion of this module, students will be able to:

1. explain basic concepts of imperative programming languages such as variables, assignments, loops, function calls, data structures, etc.;
2. work with user input from the keyboard, write interactive Python programs;
3. write, test, and debug programs;
4. illustrate basic object-oriented programming concepts such as objects, classes, information hiding and inheritance;
5. give original examples of function and operator overloading;
6. retrieve data and process and generate data from/to files;
7. write vectorized code using NumPy arrays
8. use SciPy for special functions and black-boxed algorithms (root solvers, quadrature, ODE solvers, and fast Fourier transform)
9. visualize data in appropriate ways using Matplotlib
10. write basic programs in the programming languages C/C++ using standard library functions
11. demonstrate how to use pointers to create dynamically allocated data structures such as linked lists;
12. explain the relationship between pointers and arrays;
13. use C++ standard library data types (vector, string, list, map, set, sort);
14. describe C/C++ risks (implicit type conversions, lack of bounds checking, manual memory ownership management)

Indicative Literature

Mark Lutz: "Learning Python", 5th edition, O'Reilly Media, 2013.

Lillian Pierson: "Data Science from Scratch: First Principles with Python", 2nd edition, O'Reilly Media, 2019.

Mark Summerfield: "Programming in Python 3: A Complete Introduction to the Python Language", 2nd edition, Addison-Wesley Professional, 2009.

David J. Pine: "Introduction to Python for Science and Engineering", CRC Press, 2019.

John V. Guttag: "Introduction to Computation and Programming Using Python", 2nd edition, MIT Press, 2013.

Bjarne Stroustrup: "Programming -- Principles and Practice Using C++", Second edition, Addison-Wesley Professional, 2014.

Stanley Lippman: "C++ Primer (5th Edition)", 2012

Scott Meyers: "Effective Modern C++", O'Reilly Media, 2014.

H. M. Deitel and P. J. Deitel: "C++ How to Program", 10th edition, Pearson, 2015.

John Zelle: "Python Programming: An Introduction to Computer Science", 3rd edition, Franklin, Beedle & Associates, Inc., 2016.

Usability and Relationship to other Modules

Examination Type: Module Component Examination

Component 1: Lecture

Assessment type: Written examination | Duration: 120 min

Weight: 67%

Scope: All theoretical intended learning outcomes of the module

Component 2: Lab

Assessment type: Practical assessment

Weight: 33%

Scope: All practical intended learning outcomes of the module

Completion: To pass this module, the examination of each module component has to be passed with at least 45%

7.7 Introduction to Robotics and Intelligent Systems

<table>
<tr><td colspan="2">Module Name
Introduction to Robotics and Intelligent Systems</td><td>Module Code
CH-220</td><td>Level (type)
Year 1
(CHOICE)</td><td>CP
7.5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CH-220-A</td><td colspan="2">Introduction to Robotics and Intelligent Systems</td><td>Lecture</td><td>5</td></tr>
<tr><td>CH-220-B</td><td colspan="2">Introduction to Robotics and Intelligent Systems - Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Francesco Maurelli</td><td colspan="2">Program Affiliation

• Robotics and Intelligent Systems (RIS)</td><td colspan="2">Mandatory Status

Mandatory for RIS and CS
Mandatory elective for ECE</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites
☒ None

Co-requisites
☒ None

Knowledge, Abilities, or Skills
None</td><td>Frequency

Annually
(Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lecture (35 hours)
• Lab (17.5 hours)
• Private study (115 hours)
• Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Review basic linear algebra concepts, vector and matrix operations.</td></tr>
<tr><td colspan="5">Content and Educational Aims

This module represents an initial introduction to robotics and intelligent systems, starting from the basics of mathematics and physics applied to simple robotics scenarios. It will cover transformation matrices and quaternions for reference systems. Students will then learn and the basics of trajectory planning and robotic systems. The second part of the module offers an introduction to the modeling and design of linear control systems in terms of ordinary differential equations (ODEs). Students learn how to analyze and solve systems of ODEs using state and frequency space methods. The concepts covered include time and frequency response, stability, and steady-state errors. This part culminates with a discussion on P, PI, PD, and PID controllers. The lab is designed to guide students through practical hands-on work with various components of intelligent systems. It will focus on the interfacing of a microcontroller with commonly used sensors and actuators.</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, successful students will be able to

1. compute 3D transformations;
2. understand and apply quaternion operations;
3. apply trajectory planning techniques;
4. model common mechanical and electrical systems;
5. understand and apply the unilateral Laplace transform and its inverse;
6. explore linear systems and tune their behavior;
7. program the open-source electronic prototyping platform Arduino;
8. interface Arduino to several different sensors and actuators.

Indicative Literature

R. V. Roy, Advanced Engineering Dynamics. R. V. Roy, 2015.

R. N. Jazar, Theory of Applied Robotics. Springer, 2010.

N.S. Nise, Control Systems Engineering. Wiley, 2010.

Usability and Relationship to other Modules

- This module is the foundation of the CORE modules in the following years.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module

Module achievement: Lab report

7.8 Algorithms and Data Structures

Module Name Algorithms and Data Structures			**Module Code** CH-231	**Level (type)** Year 1 (CHOICE)	**CP** 7.5
Module Components					
Number	Name			Type	CP
CH-231-A	Algorithms and Data Structures			Lecture	7.5
Module Coordinator Dr. Kinga Lipskoch	**Program Affiliation** • Computer Science (CS)			**Mandatory Status** Mandatory for CS, minor in CS, and RIS Mandatory elective ECE, PHDS and MMDA	
Entry Requirements Pre-requisites ☒ Programming in C and C++ or Programming in Python and C++	 Co-requisites ☒ None	Knowledge, Abilities, or Skills	**Frequency** Annually (Spring)	**Forms of Learning and Teaching** • Class attendance (52.5 hours) • Independent study (115 hours) • Exam preparation (20 hours)	
			Duration 1 semester	**Workload** 187.5 hours	

Recommendations for Preparation

Students should refresh their knowledge of the C and C++ programming language and be able to solve simple programming problems in C and C++. Students are expected to have a working programming environment.

Content and Educational Aims

Algorithms and data structures are the core of computer science. An algorithm is an effective description for calculations using a finite list of instructions that can be executed by a computer. A data structure is a concept for organizing data in a computer such that data can be used efficiently. This introductory module allows students to learn about fundamental algorithms for solving problems efficiently. It introduces basic algorithmic concepts; fundamental data structures for efficiently storing, accessing, and modifying data; and techniques that can be used for the analysis of algorithms and data structures with respect to their computational and memory complexities. The presented concepts and techniques form the basis of almost all computer programs.

Intended Learning Outcomes

By the end of this module, students will be able to

1. explain asymptotic (time and memory) complexities and respective notations;
2. able to prove asymptotic complexities of algorithms;
3. illustrate basic data structures such as arrays, lists, queues, stacks, trees, and hash tables;
4. describe algorithmic design concepts and apply them to new problems;
5. explain basic algorithms (sorting, searching, graph algorithms, computational geometry) and their complexities;
6. summarize and apply C++ templates and generic data structures provided by the standard C++ template library.

Indicative Literature
• Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein: Introduction to Algorithms, 3rd edition, MIT Press, 2009. • Donald E. Knuth: The Art of Computer Programming: Fundamental Algorithms, volume 1, 3rd edition, Addison Wesley Longman Publishing, 1997.
Usability and Relationship to other Modules
• Familiarity with basic algorithms and data structures is fundamental for almost all advanced modules in computer science. This module additionally introduces advanced concepts of the C++ programming language that are needed in advanced programming-oriented modules in the 2nd and 3rd years of the CS and RIS programs.
Examination Type: Module Examination
Assessment Type: Written examination — Duration: 120 min, Weight: 100% Scope: All intended learning outcomes of the module Completion: To pass this module, the examination of each module component has to be passed with at least 45%

7.9 Core Algorithms & Data Structures

<table>
<tr><td colspan="3">Module Name

Core Algorithms and Data Structures</td><td>Module Code

CH-252</td><td>Level (type)

Year 1
(CHOICE)</td><td>CP

7.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CH-252-A</td><td colspan="3">Core Algorithms and Data Structures</td><td>Lecture</td><td>5</td></tr>
<tr><td>CH-252-B</td><td colspan="3">Core Algorithms and Data Structures - Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Aleksandr Omelchenko</td><td colspan="3">Program Affiliation

• Data Science and Software Development (DSSD)</td><td colspan="2">Mandatory Status

Mandatory for DSSD

Mandatory elective for PHDS, MMDA and ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ Programming in Python and C++ OR Programming in C/C++

Co-requisites: ☒ none

Knowledge, Abilities, or Skills:</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching
• Lecture (35 hours)
• Tutorial (17.5 hours)
• Independent study (115 hours)
• Exam preparation (20 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Students should refresh their knowledge of the C, C++ and Python programming language and be able to solve simple programming problems in C, C++ and Python. Students are expected to have a working programming environment.</td></tr>
<tr><td colspan="6">Content and Educational Aims

Algorithms and data structures are the foundation of computer science and are crucial for the design and implementation of efficient software programs. In this course, students will learn about fundamental algorithms for solving problems and about data structures for storing, accessing, and modifying data in an efficient manner. They will also learn techniques for analyzing the computational and memory complexities of algorithms and data structures. These concepts and techniques form the basis for almost all computer programs and are essential for success in the fields of data science and software development.

Content:

• Introduction (asymptotic analysis of algorithms, analysis of recurrence relations, sums and integrals, time complexity, non-asymptotic optimizations, cache)
• Basic data structures (array, list, stack, queue, vector, hash tables, binary heap, heapsort, etc.)
• Sorting algorithms and heaps (quadratic sorting, stable sorting, mergesort, etc.)
• Graphs: depth-first search (DFS) and breadth-first search (BFS) algorithms.
• Graphs: matchings, colorings, flows, cuts.
• Graphs: shortest paths
• Introduction to Complexity Theory, Probabilistic Algorithms</td></tr>
</table>

- Numerical and Algebraic Algorithms

Intended Learning Outcomes

Upon completion of this module, students will be able to:

1. Analyze the time and space complexity of algorithms and optimize them using asymptotic analysis and non-asymptotic techniques such as cache optimization.
2. Implement and evaluate various data structures including arrays, lists, stacks, queues, vectors, hash tables, binary heaps, and heapsort.
3. Compare and contrast different sorting algorithms, including quadratic sorting, stable sorting, and mergesort, and understand the trade-offs involved in their use.
4. Implement depth-first search (DFS) and breadth-first search (BFS) algorithms and understand their applications in graph theory.
5. Analyze matchings, colorings, flows, and cuts in graphs, and understand the algorithms and mathematical foundations used to solve these problems.
6. Implement shortest path algorithms in graphs and understand their applications in network design and routing.
7. Understand the fundamental concepts of complexity theory and probabilistic algorithms, and apply them in solving computational problems.
8. Analyze and implement numerical and algebraic algorithms and understand their applications in a variety of fields.
9. Develop the ability to analyze, design, and implement algorithms for solving real-world problems and understand the trade-offs involved in their use.

Indicative Literature

Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein: Introduction to Algorithms, 3rd edition, MIT Press, 2009.

Robert Sedgewick and Kevin Wayne: Algorithms, 4th edition, Addison-Wesley, 2011.

Steven Skiena: The Algorithm Design Manual, 2nd edition, Springer, 2008.

Michael T. Goodrich, Roberto Tamassia, and Michael H. Goldwasser: Data Structures and Algorithms in Python, John Wiley & Sons, 2013.

Jon Kleinberg and Éva Tardos: Algorithm Design, 1st edition, Pearson, 2005.

David E. Goldberg: Genetic Algorithms in Search, Optimization, and Machine Learning, Addison-Wesley, 1989.

Donald E. Knuth: The Art of Computer Programming: Fundamental Algorithms, volume 1, 3rd edition, Addison Wesley Longman Publishing, 1997.

Usability and Relationship to other Modules

- This course will provide students with a solid foundation for understanding how to design and analyze algorithms for solving problems, as well as data structures for efficiently storing and manipulating data.

Examination Type: Module Component Examination

Component 1: Lecture

Assessment type: Written examination — Duration: 120 min

Weight: 67%

Scope: All theoretical intended learning outcomes of the module

Component 2: Lab

Assessment type: Practical assessment — Weight: 33%

Scope: All practical intended learning outcomes of the module Completion: To pass this module, the examination of each module component has to be passed with at least 45%

7.10 Modern Physics

Module Name		**Module Code**	**Level (type)**	**CP**
Modern Physics		CH-141	Year 1 (CHOICE)	7.5
Module Components				
Number	Name		Type	CP
CH-141-A	Modern Physics Lecture		Lecture	5
CH-141-B	Modern Physics Lab		Lab	2.5
Module Coordinator Prof. Dr. Veit Wagner, Prof. Dr. Arnulf Materny	**Program Affiliation** • Physics and Data Science		**Mandatory Status** Mandatory for PHDS and minor in Physics Mandatory Elective ECE	
Entry Requirements Pre-requisites ☒ Classical Physics	Co-requisites ☒ None	Knowledge, Abilities, or Skills • High school physics • High school math	**Frequency** Annually (Spring)	**Forms of Learning and Teaching** • Lecture (35 hours) • Lab (25.5 hours) • Homework problem (42 hours) • Private study (85 hours)
			Duration 1 semester	**Workload** 187.5 hours

Recommendations for Preparation

A revision of high school math (especially calculus, analytic geometry, and vector algebra) and high school physics (basics of forces, fields, energy, and atomic physics) is recommended. The level and content follow standard textbooks for calculus-based first-year university physics such as Young & Freedman: University Physics; Halliday & Resnick & Walker: Fundamentals of Physics; or Tipler & Mosca: Physics.

Content and Educational Aims

Modern technology and the understanding of natural systems are heavily based on electromagnetic phenomena and the physics of the 20th century. This module introduces students to basic physical principles, facts, and experimental evidence from electromagnetism and modern physics. It lays foundations for the more advanced physics modules and for other science and engineering disciplines. It is intended for students who already have reasonably solid knowledge of basic physics and mathematics at the high school level.

Emphasis is placed on general physical principles and general mathematical concepts for a thorough understanding of physical phenomena. Lectures are complemented by hands-on work in a teaching lab where students apply their theoretical knowledge by performing experiments as well as related data analysis and presentation. Data acquisition as well as evaluation involve classical as well as computer-based techniques.

Calculus and vector analysis are used to develop a scientifically sound description of physical phenomena. An optional tutorial is offered to discuss homework or topics of interest in more detail.

The electromagnetism part of the module introduces basic electric and magnetic phenomena using the concepts of force, fields, and potentials. This is followed by a discussion of dielectrics and magnetism in matter, electric currents, induction, and Maxwell equations. The modern physics part starts with a short introduction to special relativity. The focus lies on concepts of quantum physics and their use to describe the properties and interactions of particles. This includes a discussion of the particle nature of light and the wave-like nature of particles, Schrödinger's equation, the energy levels of atoms, spin, the basics of molecules and solids, semiconductors and devices, nuclear physics, elementary particles and the standard model of particle physics, and cosmology. The purpose of this module is an overview of important physical concepts. It will prepare students for the in-depth treatment in the second-year courses.

Intended Learning Outcomes

By the end of the module, students will be able to:

1. recall the basic facts and experimental evidence in electromagnetism and modern physics;
2. understand the basic concepts of fields, potential, current, elementary particles and their interactions, and the duality of particles and waves, and apply them to physical phenomena;
3. describe and understand natural and technical phenomena in electromagnetism and modern physics by reducing them to their basic physical principles;
4. apply calculus and vector analysis to describe physical systems;
5. examine basic physical problems, find possible solutions, and assess them critically;
6. set up experiments, analyze their outcomes by using error analysis, and present them properly;
7. record experimental data using computer-assisted techniques and data acquisition tools;
8. use statistical methods for data evaluation;
9. use the appropriate format and language to describe and communicate the outcomes of experiments and the solutions to theoretical problems.

Indicative Literature

H. Young & R. Freedman: University physics, with modern physics. Upper Saddle River: Prentice Hall.

D. Halliday, R. Resnick, J. Walker: Fundamentals of physics, extended version. Hoboken: John Wiley & Sons Inc.

P. Tipler & G. Mosca: Physics for scientists and engineers. New York: WH Freeman.

Usability and Relationship to other Modules

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination (Lecture),

Duration: 120 min
Weight: 67%

Scope: Intended learning outcomes of the lecture (1-5, 9).

A bonus achievement for the lecture module component is offered.

Module Component 2: Lab

Assessment Type: Lab Reports (Lab),

Length: 8-12 pages
Weight: 33%

Scope: Intended learning outcomes of the lab (1, 6-9).

Completion: To pass this module, the examination of each module component has to be passed with at least 45%

7.11 Mathematical Modeling

Module Name	Module Code	Level (type)	CP
Mathematical Modeling	CH-152	Year 1 (CHOICE)	7.5

Module Components

Number	Name	Type	CP
CH-152-A	Mathematical Modeling	Lecture	5
CH-152-B	Mathematical Modeling Lab	Lab	2.5

Module Coordinator	Program Affiliation	Mandatory Status
Prof. Dr. Sören Petrat and Dr. Ivan Ovsyannikov	• Mathematics, Modeling, and Data Analytics (MMDA)	Mandatory for MMDA, PHDS, Minor in Math Mandatory elective ECE

Entry Requirements			Frequency	Forms of Learning and Teaching
Pre-requisites	Co-requisites	Knowledge, Abilities, or Skills	Annually (Spring)	- Lectures (35 hours) - Tutorials (17.5 hours) - Private Study (135 hours)
☒ Matrix Algebra & Advanced Calculus I	☒ none	• Good command of Calculus and basic Linear algebra	**Duration** 1 semester	**Workload** 187.5 hours

Recommendations for Preparation

- Recap basic Calculus and Linear Algebra knowledge

Content and Educational Aims

The idea of this module is to introduce and teach mathematical methods starting with concrete scientific problems (mostly but not exclusively taken from physics). This module thus provides a first introduction to mathematical modeling, with an emphasis of the modeling of phenomena in physics, but also in other fields such as biology, economy, engineering, environmental sciences, finance, and industry. In modeling, we face two difficulties: Firstly, we have to find a good mathematical representation of the problem at hand, and secondly, we need to solve this problem either exactly, or with approximate analytical or numerical techniques. This class focuses mostly on deterministic problems and discusses stochastic problems only briefly. The main mathematical techniques come from Analysis/Calculus, Linear Algebra, Differential Equations, and Probability. In the Mathematical Modeling Lab, the students work independently and in groups to find formulations of modeling problems and their solutions.

The following topics will be covered:

- Population Dynamics
- Fluid Mechanics
- Systems of Linear Equations
- Electrical Networks
- Linear Programming
- The Ideal Gas
- First and Second Laws of Thermodynamics
- Harmonic Oscillator
- ODEs and Phase Space
- Stability of Linear Systems
- Electromagnetism and Wave Equation
- Brownian Motion
- Monte-Carlo Method

The following mathematical skills will be covered and developed:

- derivatives and integration in one variable
- derivatives and integration in many variables
- integral theorems: Gauß and Stokes
- extreme value problems
- Taylor series
- Fourier series
- ODEs
- elementary introduction to PDEs
- elementary probability and stochastic processes

Intended Learning Outcomes

Upon completion of this module, students will be able to:

1. formulate mathematical models of problems from the sciences
2. describe solution methods to modeling problems
3. explain the usage of analysis and linear algebra techniques in modeling
4. recognize different solution methods for modeling problems
5. illustrate the use of ODEs and PDEs to describe phenomena in physics
6. solve simple stochastic modeling problems

Indicative Literature

- Eck, Garcke, Knaber – Mathematical Modeling

Usability and Relationship to other Modules

- This module is part of the core education in MMDA and PHDS.
- It is also valuable for students in Computer Science, RIS, and ECE, either as part of a minor in Mathematics, or as an elective module.

Examination Type: Module Component Examination

Module Component 1: Mathematical Modeling
Assessment Type: Written examination — Duration: 120 min
Weight: 67%
Scope: All intended learning outcomes of this module

Module Component 2: Mathematical Modeling Lab
Assessment Type: Practical assessment (Homework assignments)
Weight: 33%
Scope: All intended learning outcomes of this module

Completion: To pass this module, the examination of each module component has to be passed with at least 45%

7.12 Signals and Systems

<table>
<tr><td colspan="3">Module Name
Signals and Systems</td><td>Module Code
CO-520</td><td>Level (type)
Year 2 (CORE)</td><td>CP
7.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-520-A</td><td colspan="3">Signals and Systems</td><td>Lecture</td><td>5</td></tr>
<tr><td>CO-520-B</td><td colspan="3">Signals and Systems - Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Werner Henkel</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE and minor in ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ General Electrical Engineering I General Electrical Engineering II
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Linear Circuits
• Complex description for sinusoidal sources
• Some concepts of linear transforms / convolution
• Matlab</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lecture (35 hours)
• Lab (25.5 hours)
• Private Study (127)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Revise linear circuits and transforms and Matlab from your 1st year, and get textbook & lab material. See dedicated Module Web pages for details (links on CampusNet).</td></tr>
<tr><td colspan="6">Content and Educational Aims

This module offers a comprehensive exploration of signals and systems which is the key knowledge for almost all electrical engineering tasks. Continuous-time and discrete-time concepts/methods are developed in parallel, highlighting their similarities and differences. Central is the coverage of all linear transforms.
Introductory treatments of the applications of these basic methods in such areas as filtering, communication, sampling, discrete-time processing of continuous-time signals, and feedback, will be discussed. We are also covering stability, minimum and maximum phase, delay, group delay and characteristic impedance of two-ports to build cascades of filter blocks. The module contains also a short treatment of analog modulation methods, such as amplitude, single-sideband and vestigial-sideband, frequency, and phase modulation.

The practical lab contains experiments addressing transient and frequency response with some RLC circuits, Fourier series and transform, sampling, AM and FM modulation.</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, students should be able to

1. explain all linear transforms with all their properties and the links between them;
2. apply linear transforms to time-continuous and time-discrete problems;
3. describe the function of poles and zeros, and the meaning of stability, minimum phase, delay and group delay functions;
4. describe the link between pole and zero locations and the resulting transfer function;
5. apply the major concepts of the module (such as time and frequency-domain, sampling, and analog modulation) to practical problems using function generators, digital scopes, and Matlab.

Indicative Literature

Alan V. Oppenheim, Alan S. Willsky, with S. Hamid Nawab, Signals and Systems, 2nd ed., Pearson, 2017.

Usability and Relationship to other Modules

- This module builds on the GenEE1 and GenEE2 modules and prepares the students for advanced modules in their 2nd & 3rd year

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination

Duration: 120 min
Weight: 67%

Scope: Intended learning outcomes of the lecture (1-4).

Module Component 2: Lab

Assessment Type: Lab reports

Length: 5-10 pages per experiment session
Weight: 33%

Scope: Intended learning outcomes of the lab (2,5).

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.13 Digital Signal Processing

<table>
<tr><td colspan="2">Module Name
Digital Signal Processing</td><td>Module Code
CO-521</td><td>Level (type)
Year 2 (CORE)</td><td>CP
7.5</td></tr>
<tr><td colspan="5">Module Components</td></tr>
<tr><td>Number</td><td colspan="2">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-521-A</td><td colspan="2">Digital Signal Processing</td><td>Lecture</td><td>5</td></tr>
<tr><td>CO-521-B</td><td colspan="2">Digital Signal Processing Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Werner Henkel</td><td colspan="2">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE and minor in ECE</td></tr>
<tr><td colspan="2" rowspan="2">Entry Requirements

Pre-requisites: ☒ General Electrical Engineering I; ☒ General Electrical Engineering II; ☒ Signals and Systems

Co-requisites: ☒ None

Knowledge, Abilities, or Skills:
• Signal description with linear transforms,
• Linear circuits and their description with linear transforms
• Familiarity with bilateral and unilateral Laplace transforms
• Matlab and C programming</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lecture (35 hours)
• Private study for lecture (90 hours)
• Lab (24 hours)
• Private Study for lab (38.5)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

187.5 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation

Revise linear transforms, especially Laplace transforms, get textbook & lab material. See dedicated module Web pages for details (links on CampusNet).</td></tr>
<tr><td colspan="5">Content and Educational Aims

The module is a combination of standard Digital Signal Processing (DSP) contents and applications in digital communications. The standard DSP contents are linear transforms, sampling theorem, quantization, networks with delay elements, difference equations, filter structures (implementations in C/Matlab), z-transform, frequency-domain characterization (Parseval), DFT, window functions, frequency response of frequency-selective filters, fast convolution (overlap save, overlap add), power spectral density, periodogram, design of poles and zeros, least squares identification and prediction (LPC, Toeplitz algorithms), design of digital filters (short introduction to wave digital filters), sampling rate conversion, subband coding, FFT algorithms, quadrature mirror filters, filter banks, two-dimensional transforms, discrete cosine transform, (wavelets) and an introduction to video coding. The communications part is essentially an introduction to digital communications with channel properties, passband and complex baseband description, PAM, QAM, matched filter, whitened matched filter, equalizer structures and its adaptation with LMS and ZF. An introduction to multicarrier transmission (OFDM, DMT) and the relation to filter banks will be given, too. OFDM and DMT are the transmission methods used in every current wireless and wireline system (LTE, DSL, DVB-t, etc.). Overall, the module provides a complete coverage of digital signal processing and the essential basics of digital communications. The module is hence mandatory for ECE and central for students with a focus towards signal processing, video and audio, and communications.</td></tr>
</table>

This lab component compliments the lecture by providing hands-on experience in practical development of a communications system using Digital Signal Processors. Note that although the focus is on DSP in this module, many of the concepts learned also apply to embedded development, which is also becoming increasingly important in our electronic world.

Intended Learning Outcomes

By the end of this module, students should be able to

1. model and analyze signals mathematically, enable their manipulation (filtering, recovery, sampling, etc.) and design various engineering applications;
2. apply digital signal processing methods to speech, audio, and video signal processing, automation, and control systems;
3. understand all major digital communications methods, be it baseband, single-carrier, multi-carrier, or spread spectrum;
4. understand the essential components of a transmission chain from the transmitter to detection at a receiver, including multiple-input and multiple-output systems;
5. implement digital signal processing and digital communications methods;
6. be familiar with digital signal processors.

Indicative Literature

John G. Proakis and Dimitris G. Manolakis, Digital Signal Processing, 3rd ed., Prentice Hall, 1996.

Alan V. Oppenheim, Ronald W. Schafer, Digital Signal Processing, Pearson, 1974.

Edward A. Lee, David G. Messerschmitt, Digital Communication, 2nd ed., Kluwer, 1994.

John G. Proakis and Massoud Salehi, 5th ed., Digital Communications, 2007.

Usability and Relationship to other Modules

- Important basis for all advanced modules in Signal Processing and Communications.
- Wireless Communication (CO-523) together with DSP and the earlier introductory Communications Basics module (CO-522) will provide a wide coverage of analog and digital communications methods.
- In Coding Theory (CA-ECE-802), some interesting links will become visible, e.g., using convolution in so-called convolutional codes, other conceptually similar Toeplitz algorithm, the DFT to define Reed-Solomon codes.
- The Module Control Systems (CO-545 / RIS) is a nice counterpart of Signals and Systems plus Digital Signal Processing, especially, adding aspects of stability from a different angle.
- Mandatory for a major and minor in ECE.

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination | Duration: 120 min
Weight: 67%

Scope: Intended learning outcomes of the lecture (1-4).

Module Component 2: Lab

Assessment Type: Lab reports | Length: 5-10 pages per experiment session
Weight: 33%

Scope: Intended learning outcomes of the lab (5-6).

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.14 Communication Basics

<table>
<tr><td colspan="3">Module Name
Communication Basics</td><td>Module Code
CO-522</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-522-A</td><td colspan="3">Communications Basics</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>CO-522-B</td><td colspan="3">Communications Basics Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator

Dr. Mathias Bode</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE students</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites | Co-requisites | Knowledge, Abilities, or Skills

☒ General Electrical Engineering I&II | ☒ None | • Linear Transforms (Fourier) • Matlab</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lecture (35 hours)
• Lab (25.5 hours)
• Private study (64.5)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Revise linear transforms and Matlab from your 1st year, and get textbook & lab material. See dedicated module Web pages for details (links on CampusNet).</td></tr>
<tr><td colspan="6">Content and Educational Aims

The module comprises the basis for analog and digital communication, and prepares the students for more advanced modules on wireless communication and information theory. Starting from first steps to understand modulation and demodulation procedures with and without noise, students will learn the basics of binary data transmission. The lab course provides hands-on experience with practical development of a communications system using Simulink and Matlab simulations. This includes the design and the implementation of the typical building blocks of a digital transmitter and receiver chain. Topics covered are: BPSK, QPSK, pulse shape, up-conversion, matched filter, PLL, carrier recovery, symbol timing recovery, and demodulation.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes

By the end of this module, students should be able to

1. explain fundamental blocks of a communication chain;
2. model the blocks based on Matlab and Simulink;
3. characterize wide sense stationary random (noise) processes and their transformation by LTI systems;
4. analyze and design basic linear and nonlinear modulation and demodulation blocks;
5. analytically compare different designs with regard to their performance figures like required bandwidth and signal-to-noise ratio;</td></tr>
</table>

6. numerically evaluate performance figures of simulated communication chains.

Indicative Literature

Rodger E. Ziemer, William H. Tranter, Principles of Communications, 7th ed., Wiley 2014.

Usability and Relationship to other Modules

- This module builds on the Gen EE I+II modules and prepares the students for advanced modules in their 2nd & 3rd year
-

Examination Type: Module Component Examinations

Module Component 1: Lecture

Assessment Type: Written examination

Duration: 120 min
Weight: 50%

Scope: Intended learning outcomes of the lecture (1,3,4,5).

Module Component 2: lab

Assessment Type: Lab reports

Length: 5-10 pages per experiment session
Weight: 50%

Scope: Intended learning outcomes of the lab (2,4,5).

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.15 Wireless Communication I

<table>
<tr><td colspan="3">Module Name
Wireless Communication I</td><td>Module Code
CO-523</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-523-A</td><td colspan="3">Wireless Communication I</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Giuseppe Abreu</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ Signals & Systems, Comm. Lecture & Lab, Electromagnetics
Co-requisites: ☒ Data Signal Processing, Information Theory
Knowledge, Abilities, or Skills: • Notions of signals and systems, digital communications, and probability.</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private Study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

It is recommended that students are in good standing with respect to the listed pre-requistite modules and are capable of writing simple programs, as well as to perform basic operations, in Matlab.</td></tr>
<tr><td colspan="6">Content and Educational Aims

This module builds upon the knowledge gained in Signals and Systems, Electromagnetics, and Communications, developing those further into the set of required tools to analyze and design wireless communications systems. Starting from notions of propagating waves learned in Electromagnetics, and relying on tools studied in Probability, the dedicated theory to mathematically model the various complex phenomena undergone by signals as they propagate in an open medium (e.g. vacuum, air, or water) is described. Within such a theory, the various forms of distortion and impairments suffered by wireless signals, including, e.g., noise, propagation losses, polarization, spectral and temporal dispersion, selectivity and fading, as well as interference are studied, and techniques to engineer signals so as to withstand such hindrances while retaining the ability to convey information are described. Overall, the focus is on classical narrowband point-to-point wireless communications, but occasional incursions into modern methods such as multiple-input multiple-output (MIMO) systems and ultra-wideband communications (UWB) – to cite only a few – are also made. Topics covered include, but are not limited to, statistical characterization of fading (Rayleigh, Rice, Hoyt, and Nakagami) channels, coherent and differential digital modulation, pairwise, symbol and bit-error probabilities, water-filling transmit power optimization, and more. In the process, several tools including probability bounds (e.g. the union bound, Gaussian Q-functions, Chernoff, Chebychev, and Bonferroni bounds) and optimization methods (e.g. Lagrange Multiplier Method, Maximum Ratio Combining, Kullback Leibler Divergence minimization, and Maximum-Entropy Methods) are also introduced, which are useful not only to Wireless Communications, but to the analysis and design of virtually any system afflicted by uncertainties.</td></tr>
</table>

Intended Learning Outcomes

Scope: All intended learning outcomes of the module.

- explain the physical nature of, and the corresponding mathematical/statistical models suitable to describe, the fundamental phenomena afflicting wireless signals;
- describe qualitatively, and quantify statistically, the effects of the aforementioned phenomena on the ability to convey information over various kinds of wireless channels;
- perform essential design steps for modern wireless communications systems taking into account the aforementioned properties and phenomena of wireless communcation.

In addition to the aforementioned outcomes, fundamental to a career in ECE, students will also have acquired:

- analytical and mathematical tools useful to study various systems in which statistical uncertainty plays a major role, examples of which are hypothesis testing methods widely used in experimental sciences (also, e.g., in Biology and Psychology).

Indicative Literature

A. Goldsmith, Wireless Communications, 3rd ed., Cambridge, 2005.

D. Tse and P. Vishawanath, Fundamentals of Wireless Communications, Cambridge University Press, 2005.

J. Proakis, Digital Communications, McGraw-Hill Education, 2007.

M. Simon and M.-S. Alouini, Digital Communication over Fading Channels, Willey-IEEE Press, 2004.

T. Rappaport, Wireless Communications: Principles and Practice, Pearson, 2014.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 120 min, Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

7.16 Electromagnetics

<table>
<tr><td colspan="3">Module Name
Electromagnetics</td><td>Module Code
CO-524</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-524-A</td><td colspan="3">Electromagnetics</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator
Prof. Dr.-Ing. Werner Henkel</td><td colspan="3">Program Affiliation
• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status
Mandatory for ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements</td><td>Frequency
Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching
• Lectures (35 hours)
• Private Study (90 hours)</td></tr>
<tr><td>Duration
1 semester</td><td colspan="2">Workload
125 hours</td></tr>
<tr><td>Pre-requisites</td><td>Co-requisites</td><td>Knowledge, Abilities, or Skills</td><td></td><td colspan="2"></td></tr>
<tr><td>☒ General Electrical Engineering I
☒ General Electrical Engineering II</td><td>☒ None</td><td>• Basic knowledge of electrical and magnetical fields
• Description of resistor, capacitor, inductor</td><td></td><td colspan="2"></td></tr>
<tr><td colspan="6">Recommendations for Preparation
Students should come with a sound understanding of electromagnetic fields and elementary passive components.</td></tr>
<tr><td colspan="6">Content and Educational Aims
Unlike other engineering disciplines, the complete theory of electrical engineering can be summarized in four fundamental equations known as Maxwell's equations. This module gives an introduction to the electric and magnetic field theory, leading to Maxwell's equations. The theory is applied to wave propagation problems and guided waves on transmission lines. This knowledge enables us to understand the physics behind electrical signals travelling through lines and electronic devices.
Contents:
• Electric Field: Electric charge, charge distributions, Coulomb's law, electric field, dipoles, electric flux, Gauss' law, potential, capacitance;
• Currents: current density, conductance, superconductors, semiconductors;
• Magnetic Field: magnetic force, magnetic flux, Ampere's law, inductance, Faraday's law, Lenz' law, displacement current, boundary conditions;
• Electromagnetic Waves: Maxwell's equations, electromagnetic waves, radiation, waves on transmission lines.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes
By the end of this module, students should be able to
1. apply Maxwell‘s equations in integral and differential form;
2. use vector operators grad, div, curl;
3. compute capacity and inductance for given geometries using symmetries and possibly coordinate transformations;</td></tr>
</table>

4. explain and apply the principle of waves on wave guides (cables and hollow wave guides) and emitted from dipole antennas.

Indicative Literature

Md. Abdus Salam, Electromagnetic Field Theories for Engineering, Springer, 2014.

Nathan Ida, Engineering Electromagnetics, 2nd ed., Springer, 2004.

William H. Hayt and John A. Buck, Engineering Electromagnetics, 8th ed., McGraw-Hill, 2012.

Constantine A. Balanis, Advanced Engineering Electromagnetics, 2nd Edition, Wiley, 2012.

David Grifiths, Introduction to Electrodynamics, 4th ed., Cambridge University Press, 2017.

Matthew Sadiku, Elements of Electromagnetics, 6th ed., Oxford Press, 2014.

Fawwaz T. Ulaby, Eric Michielssen, and Umberto Ravaioli. Fundamentals of Applied Electromagnetism, 6th ed., Prentice Hall, 2010.

Usability and Relationship to other Modules

- The module conveys basic knowledge for the lab "PCB design and measurement automation" and for RF-oriented specialization modules
-

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

7.17 Information Theory

<table>
<tr><td colspan="2">Module Name
Information Theory</td><td colspan="2">Module Code
CO-525</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-525-A</td><td colspan="3">Information Theory</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Prof. Dr.-Ing. Werner Henkel</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE
Mandatory elective for CS, RIS and PHDS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ None
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Signals and Systems contents, such as DFT and convolution
• Notion of probability, combinatorics basics as taught in Methods module “Probability and Random Processes"</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private Study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Some basic knowledge of communications and sound understanding of probability is recommended. Hence, it is strongly advised to take the methods and skills course Probability and Random Processes prior to this module. Nevertheless, probability basics will also be revised within the module.</td></tr>
<tr><td colspan="6">Content and Educational Aims

Information theory serves as the most important foundation for communication systems. The module provides an analytical framework for modeling and evaluating point-to-point and multi-point communication. After a short rehearsal of probability and random variables and some excursion to random number generation, the key concept of information content of a signal source and information capacity of a transmission medium are precisely defined, and their relationships to data compression algorithms and error control codes are examined in detail. The module aims to install an appreciation for the fundamental capabilities and limitations of information transmission schemes and to provide the mathematical tools for applying these ideas to a broad class of communications systems.
The module contains also a coverage of different source-coding algorithms like Huffman, Lempel-Ziv-(Welch), Shannon-Fano-Elias, Arithmetic Coding, Runlength Encoding, Move-to-Front transform, PPM, and Context Tree Weighting. In Channel coding, finite fields, some basic block and convolutional codes, and the concept of iterative decoding will be introduced. Aside from source and channel aspects, an introduction to security is given, including public-key cryptography. Information theory is a standard module in every communications-oriented Bachelor’s program.</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, students should be able to

1. explain what is understood as the information content of data and the corresponding limits of data compression algorithms;
2. design and apply fundamental algorithms in data compression;
3. explain the information theoretic limits of data transmission;
4. apply the mathematical basics of channel coding and cryptography;
5. implement some channel coding schemes;
6. differentiate the principles of encryption and authentication schemes and implement discussed procedures.

Indicative Literature

Thomas M. Cover, Joy A. Thomas, Elements of Information Theory, 2nd ed., Wiley, Sept. 2006.

David Salomon, Data Compression, The Complete Reference, 4th ed., Springer, 2007.

Usability and Relationship to other Modules

- Although not a mandatory prerequisite, this module is ideally taken before Coding Theory (CA-ECE-802)
- All communications-related modules are naturally based on information theory
- Students from Computer Science or related programs, also students taking Bio-informatics modules, profit from information-theoretic knowledge and source coding (compression) algorithms. Students from Computer Science would also be interested in the algebraic basics for error-correcting codes and cryptology, fields which area also introduced shortly.

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

7.18 Electronics

Module Name	**Module Code**	**Level (type)**	**CP**
Electronics	CO-526	Year 2 (CORE)	5

Module Components

Number	Name	Type	CP
CO-526-A	Electronics	Lecture	2.5
CO-526-B	Electronics Lab	Lab	2.5

Module Coordinator	**Program Affiliation**	**Mandatory Status**
Dr. Mathias Bode	• Electrical and Computer Engineering (ECE)	Mandatory for ECE Mandatory elective for PHDS

Entry Requirements

Pre-requisites	Co-requisites	Knowledge, Abilities, or Skills
☒ General Electrical Engineering I&II Or ☒Electrodynamics & Relativity (PHDS)	☒ None	• Linear circuits • Basic Calculus • Basic Linear Algebra

Frequency	**Forms of Learning and Teaching**
Annually (Fall)	• Lecture (17,5 hours) • Lab (25.5 hours) • Private Study (82.00)

Duration	**Workload**
1 semester	125 hours

Recommendations for Preparation

Revise linear circuits from your 1st year, and get textbook & lab material. See dedicated module Web pages for details (links on CampusNet).

Content and Educational Aims

Electronics and circuits are at the core of modern technology. This module comprises a lecture and a lab component. It builds on the 1st year General Electrical Engineering modules and provides a more in-depth coverage of the analysis and, in particular, the design of linear and nonlinear analog circuits. After a recap on linear circuits techniques, the lecture gives an introduction to fundamental nonlinear electronic devices, and electronic circuits. Starting from semiconductor properties, the operation principles and various applications of diodes, bipolar junction transistors (BJTs), and field-effect transistors (MOSFETs) are discussed. Different electronic circuits are analyzed and designed including rectifiers, voltage doublers, single- and multi-stage amplifiers, and operational amplifier (OpAmp) stages. While the lecture emphasizes theoretical concepts, the lab provides practical experience and allows the students to relate concrete hardware to device and circuit models. LTSpice are used for the simulation of the basic components and circuits. Experiments include RLC circuits, filters and resonators, diodes, pn-junctions and their application, bipolar junction transistors (BJT) and elementary transistor circuits including amplifiers, differential amplifiers and the basics of operational amplifiers, application of operational amplifiers. MOS field effect transistors and their application in amplifiers and inverter circuits.

Intended Learning Outcomes

By the end of this module, students should be able to

1. explain fundamental electronic devices;
2. analyze and design electronic circuits, in particular linear networks, amplifiers, and operational amplifier circuits, based on a modular approach;
3. compare different designs with regard to their performance figures like voltage gain, current gain, band width;
4. operate lab equipment (oscilloscopes, electric sources, voltmeters) to investigate DC and AC circuits.

Indicative Literature

David Comer and Donald Comer, Fundamentals of Electronic Circuit Design, Wiley, 2002.

Usability and Relationship to other Modules

- This module builds on the GenEE1 and GenEE2 modules (as well as on physics CORE module Electrodynamics) and prepares the students for practical specializations in their 3rd year.

Examination Type: Module Component Examination

Module Component 1: Lecture

Assessment Type: Written examination

Duration: 120 min
Weight: 50%

Scope: Intended learning outcomes of the lecture (1-3).

Module Component 2: Lab

Assessment Type: Lab reports

Length: 5-10 pages per experiment session
Weight: 50%

Scope: Intended learning outcomes of the lab (2-4).

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

7.19 PCB design and measurement automation

<table>
<tr><td colspan="3">Module Name
PCB Design and Measurement Automation</td><td>Module Code
CO-527</td><td>Level (type)
Year 2 (CORE)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CO-527-A</td><td colspan="3">PCB Design and Measurement Automation</td><td>Lab</td><td>5</td></tr>
<tr><td>Module Coordinator

Prof. Dr.-Ing. Werner Henkel</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory for ECE
Mandatory elective for RIS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ General Electrical Engineering I; ☒ General Electrical Engineering II
OR
☒ Introduction to RIS (RIS)

Co-requisites: ☒ None

Knowledge, Abilities, or Skills:
• Knowledge of Fourier series and transforms
• Basic knowledge of electronics components and circuits
• Matlab</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lab (59.5 hours)
• Private Study (65.5 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Download material from corresponding Web pages and get to know the tasks and how the tools and equipment works.</td></tr>
<tr><td colspan="6">Content and Educational Aims
The module (lab) covers mainly two aspects that are seen to be important for employability. One share of the lab deals with measurement automation. Similar tasks, one also finds in industrial automation or monitoring, sometimes using the same tools. Students will learn to use Matlab and Labview for measurement automation tasks. In there, students will also get acquainted with more advanced measurement equipment, like high-end digital scopes, network, and spectrum analyzers. The students will measure standard telephone cables in their properties, which will require a treatment of transmission line theory and transformers/baluns. These theoretical aspects will also be covered.

The second major aspect handled in the lab makes students aware that electrical/electronic components have non-ideal behaviors, e.g., that a capacitor can act as an inductor in some frequency range. It makes students also aware of the problems in selecting the right component for a certain function inside a circuit, caring not just for the frequency range and the variation of properties with frequency, but also power, current, and voltage limits.
Then, a typical circuit design path will be taught, starting from schematics to placement of components and routing. Important aspects of printed circuit board design are treated, like how analog and digital power supplies have to be realized, how mass connections should look like, what measures have to be taken to block unwanted signal coupling is avoided, e.g., blocking capacitors, star-like power supply wiring.

Students also practice scientific writing in line with scientific writing rules as a preparation for their BSc thesis.</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, students should be able to

1. use vector network analyzers, spectrum analyzers, and more advanced digital scopes;
2. learn how to program with LabVIEW;
3. remotely control measurement equipment using Matlab or LabVIEW;
4. describe principles of remote control;
5. know transmission line theory and how transformers/baluns are modeled;
6. measure and determine line parameters;
7. taking non-ideal behavior of passive and active components into account and be able to select components according to their parameters and limitations;
8. design printed circuit boards (PCB) with typical tools and a typical design cycle consisting of schematics, placement, and routing;
9. design analog and digital power routes, shielding ground connections, use measures to block unwanted ingress and coupling;
10. organize work contributions of group members in the lab and in reporting;
11. write reports in line with scientific writing rules as a preparation for their BSc thesis.

Usability and Relationship to other Modules

- This module builds on previous electronics knowledge and rounds this knowledge up with the final PCB design.
- Having learned to use Matlab in earlier modules, mostly for signal processing tasks, this module shows another application and provides a view into graphical programming as another option which they have seen earlier in the form of Simulink
- The module prepares students for a thesis with PCB design aspects.
-

Indicative Literature

Hank Zumbahlen Ed., Basic Linear Design, Analog Devices, 2007.

Walt Jung Ed., Op Amp Applications, Analog Devices, 2005.

Tim Williams, The Circuit Designer's Companion, 3rd ed., Newnes, 2012.

National Instruments, LabVIEW, Getting Started with LabVIEW, 2007.

Examination Type: Module Examination

Assessment Component 1: Written examination — Duration: 120 min, Weight: 50%

Scope: Intended learning outcomes of the lecture/theory component (4, 5, 7, 9).

Assessment Component 2: Lab reports — Length: 5-10 pages per experiment session, Weight: 50%

Scope: Intended learning outcomes of the lab (1-3, 6-11).

Completion: This module is passed with an assessment-component weighted average grade of 45% or higher.

7.20 Wireless Communication II

<table>
<tr><td colspan="3">Module Name
Wireless Communication II</td><td>Module Code
CA-S-ECE-801</td><td>Level (type)
Year 3 (Specialization)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-ECE-801</td><td colspan="3">Wireless Communication II</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Prof. Dr. Giuseppe Abreu</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory elective for ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ Probability and Random Process
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Notions of signals and systems and of digital communications</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

At a minimum, it is recommended that students are in good standing with respect to the contents of Signals and Systems, Communications, and Probability. In addition, it is desirable that students are capable of writing simple programs, as well as to perform basic operations, in Matlab.</td></tr>
<tr><td colspan="6">Content and Educational Aims

This complements the knowledge gained in Signals and Systems, Communications, and Wireless Communications I, focusing on the multi-access aspect of wireless systems. To elaborate, while Wireless Communications I is mostly concerning the fundamental technologies to design and optimize modern communications systems from a single user (point-to-point) perspective, this module focuses on techniques employed to enable multiple users to communicate simultaneously. Specifically, the module covers the mechanisms to mitigate or manage interference that arises when multiple users share the same wireless channel. Within this general theme, the 3 classical multi-access methods, namely: time division multiple access (TDMA), code division multiple access (CDMA), and orthogonal frequency division multiple access (OFDMA) are covered. As part of the latter, various mathematical tools essential to the understanding of multi-access schemes are also introduced (at the depth allowed by time), including, but not limited to: optimization theory, queueing theory, graph theory, fast-Fourier transform and more. In passing, modern technologies based on the extension or combination of the latter with multi-antenna systems (i.e. MIMO) are also touched upon. With the complementation of the preceding Wireless Communications I, the module brings the student to the level required to understand research articles on modern Wireless Communications, helping lay the foundation for a Bachelor's Thesis towards a specialization in the area.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes

By the end of this module, students should be able to

• describe the key features and principles of the three classic multi-access approaches (TDMA, CDMA, and OFDMA) for wireless systems;</td></tr>
</table>

- explain qualitatively, and quantify statistically, the effects of limitations particular to each of the aforementioned approaches (e.g. packet collision in TDMA, out-of-phase and cross-correlation in CDMA, and frequency offset and sampling mismatch in OFDMA) on the performance of multi-access wireless schemes;
- describe the techniques utilized to design modern wireless communications systems so as to circumvent the aforementioned effects;

In addition to the aforementioned outcomes, fundamental to a career in ECE, students will also acquire:

- Analytical and mathematical tools useful to study various systems in which similar problems appear. A case in point is Markov Chains, which find applications in a wide range of sciences, including Physics, Chemistry, Computer Science, and Social Sciences.

Indicative Literature

J. H. Schiller, Mobile Communications, Pearson Education, 2003.

D. Bertsekas and R. Gallager, Data Networks, Prentice Hall, 1992.

M. K. Simon, J. K. Okumura, R. A. Scholtz, and B. K. Levitt, Spread Spectrum Communications Handbook,

Mc-Graw-Hill, 2002.

A. J. Viterbi, Principles of Spread Spectrum Communications, Addison-Wesley, 1995.

Y. G. Li and G. Stuber, Orthogonal Frequency Division Multiplexing for Wireless Communications, Springer, 2006.

Usability and Relationship to other Modules

•

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 120 min
Scope: All intended outcomes of the module — Weight: 100%

Completion: To pass this module, the examination has to be passed with at least 45%

7.21 Coding Theory

Module Name Coding Theory			Module Code CA-S-ECE-802	Level (type) Year 3 (Specialization)	CP 5
Module Components					
Number	Name			Type	CP
CA-ECE-802	Coding Theory			Lecture	5
Module Coordinator Prof. Dr.-Ing. Werner Henkel	**Program Affiliation** • Electrical and Computer Engineering (ECE)			**Mandatory Status** Mandatory elective for ECE	
Entry Requirements Pre-requisites ☒ Signals and Systems ☒ Digital Signal Processing ☒ Probability	 Co-requisites ☒ None	 Knowledge, Abilities, or Skills • Signals and Systems contents, such as DFT and convolution • Notion of probability, combinatorics basics	**Frequency** Annually (Fall) **Duration** 1 semester	**Forms of Learning and Teaching** • Lectures (35 hours) • Private study (90 hours) **Workload** 125 hours	
Recommendations for Preparation At a minimum, it is recommended that students are in good standing with respect to the contents of Signals and Systems, Communications and Probabilities. Although not a mandatory pre-requisite, having heard a Digital Signal Processing course provides some additional insights and links. Information Theory is, of course, the underlying basis of Coding Theory and should have been taken, but the module will be self-contained introducing major information-theoretic concepts where needed.					
Content and Educational Aims Error correcting codes (convolutional codes, block codes, Turbo codes, LDPC codes, etc.) play an essential role in modern digital high data-rate transmission systems. They are part of almost every modern communication, storage, or recording device, like a CD player, your DSL home Internet access, and your mobile phone, to name just a few. This module will focus on theory, construction, and algorithms for error correcting codes, and will highlight the application in communication systems. For modern communications, coding knowledge is a must.					

Intended Learning Outcomes

By the end of this module, students will be able to

1. understand all major code classes, like convolutional, Block, Turbo, LDPC, and Polar codes, rateless coding and network coding;
2. to compute in finite fields, the mathematical structure used in coding and cryptology;
3. understand the interplay between blocks of the transmission chain, especially, between modulation and coding;
4. understand that lattices can be obtained from coding schemes;
5. realize that information theoretic results define practical solutions, e.g., that the optimum distribution for a Gaussian channel is Gaussian as well, which is then practically obtained by Shaping methods;
6. understand the limits of code design and application;
7. select and optimize codes for a certain application;
8. implement coding schemes.
9. implement encoding and decoding algorithms and evaluate code performances.

Indicative Literature

William E. Ryan and Shu Lin, Channel Codes, Classical and Modern, Cambridge, 2009.

Shu Lin and Danial J, Costello, Error Control Coding: Fundamentals and Applications, Prentice-Hall, 1983.

Richard E. Blahut, Theory and Practice of Error Control Codes, Addison-Wesley, 1984.

Tom Richardson and Rüdiger Urbanke, Modern Coding Theory, Cambridge, 2008.

Usability and Relationship to other Modules

- All Communications modules (Communications Basics/ Communications Lab, Wireless Communications, Wireless Communications II) are naturally linked to Coding Theory
- Digital Signal Processing (CO-521) has many links to Coding Theory
- Information Theory (CO-525) is the theoretical foundation of Coding Theory
- In some computer science programs, coding theory is considered a branch of theoretical computer science and hence, the module is also a possibly choice for computer scientists

Examination Type: Module Examination

Assessment Type: Written examination

Duration: 120 min
Weight: 100 %

Scope: All intended learning outcomes of the module

Completion: To pass this module, the examination has to be passed with at least 45%

7.22 Digital Design

Module Name Digital Design			**Module Code** CA-S-ECE-803	**Level (type)** Year 3 (Specialization)	**CP** 5
Module Components					
Number	Name			Type	CP
CA-ECE-803	Digital Design			Lecture/Lab	5
Module Coordinator Dr. Fangning Hu	**Program Affiliation** • Electrical and Computer Engineering (ECE)			**Mandatory Status** Mandatory elective for CS, ECE and RIS	
Entry Requirements Pre-requisites ☒ None	Co-requisites ☒ None	Knowledge, Abilities, or Skills	**Frequency** Annually (Fall)	**Forms of Learning and Teaching** • Lecture/Lab (35 hours) • Private study (90 hours)	
			Duration 1 semester	**Workload** 125 hours	

Recommendations for Preparation

Students may prepare themselves with books like "Brent E. Nelson, Designing Digital Systems, 2005" and "Pong P. Chu, RTL Hardware Design Using VHDL, A John Wiley & Sons, Inc, Publication, 2006"

Content and Educational Aims

The current trend of digital system design is towards hardware description languages (HDLs) that allow compact description of very complex hardware constructs. The module provides a sound introduction to basic components of a digital system such as logic gates, multiplexers, decoders, flip-flops and registers as well as VHDLs such as types, signals, sequential and concurrent statements. Methods and principle of designing complex digital systems such as finite state machines, hierarchical design, pipelined design, RTL design methodology and parameterized design will also be introduced. Students will learn VHDL for programming FPGA boards to realize small digital systems in hardware (i.e. on FPGA boards). Such digital systems could be adders, multiplexers, control units, multipliers, asynchronous serial communication modules (UART). At the end of the module, the students should be able to design a simple digital system by VHDL on an FPGA board.

Intended Learning Outcomes

By the end of this module, students will be able to

1. understand the principle of digital system design based on standard building blocks and components;
2. design a complex digital system;
3. understand the limitations of a given hardware platform (here FPGAs), modify algorithms where necessary, and structure them suitably in order to optimize performance and complexity;
4. use a typical development system;
5. program in VHDL;
6. program an FPGA board.

Indicative Literature

Brent E. Nelson, Designing Digital Systems with SystemVerilog, 2018, ISBN-13: 978-1980926290

Pong P. Chu, RTL Hardware Design Using VHDL, Wiley-IEEE Press, 2006, ISBN-13: 978-0471720928

Usability and Relationship to other Modules

- This module introduces how to design digital systems and how to realize them on a FPGA board which could also serve as a specialization module for students from Computer Science and Robotics and Intelligent Systems.

Examination Type: Module Examination

Assessment Type: written examination   Duration: 120 min
Scope: All intended learning outcomes of the module   Weight: 100%

Completion: To pass this module, the examination has to be passed with at least 45%

7.23 Radio-Frequency (RF) Design

<table>
<tr><td colspan="3">Module Name
Radio-Frequency (RF) Design</td><td>Module Code
CA-S-ECE-804</td><td>Level (type)
Year 3
(Specialization)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-ECE-804</td><td colspan="3">Radio-Frequency (RF) Design</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Prof. Dr.-Ing. Werner Henkel</td><td colspan="3">Program Affiliation

• Electrical and Computer Engineering (ECE)</td><td colspan="2">Mandatory Status

Mandatory elective for ECE</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ Electromagnetics
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• Knowledge of electric and magnetic fields
• Knowledge of wave propagation and transmission line theory</td><td>Frequency

Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching

• Lectures (35 hours)
• Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Student should come with a good understanding of fields and wave propagation covered in an Electromagnetics module.</td></tr>
<tr><td colspan="6">Content and Educational Aims

The objective of this module is to gain an understanding of today's design process of active and passive microwave circuits. After a review of the transmission line theory and microwave-related network theory, the operational principles of basic building block of microwave circuits are discussed. Additionally, the module provides an overview of typical microwave circuit applications for modern wireless communication systems. Especially, the module will cover
• Transmission-line theory (recap)
• Skin effect
• Network theory for microwave circuits
• Microstrip circuit design
• Smith diagram and its application
• Couplers and power splitters
• Non-reciprocal components
• Noise in microwave circuits
• Active components
• Large-signal effects
• Antennas and free space propagation</td></tr>
</table>

Intended Learning Outcomes

By the end of this module, students will be able to:

1. characterize passive and active RF components;
2. understand and apply RF circuit design methods;
3. design antennas and characterize their radiation patterns;
4. understand wave propagation;
5. understand and design the interface between baseband signal processing and actual RF transmission;
6. realize analog front-end circuitry.

Indicative Literature

Ludwig, G. Bogdanov, RF Circuit Design: Theory and Practice, 2nd ed., Prentice Hall, 2009.

David M. Pozar, Microwave and RF Design of Wireless Systems, Wiley, 1st ed., 2000.

Behzad Razavi, RF Microelectronics, Prentice Hall, 2nd ed., 2011.

Cotter Sayre, Complete Wireless Design, McGraw-Hill Professional, 2008.

Sorin Voinigescu, High-Frequency Integrated Circuits, Cambridge University Press, 2013.

Usability and Relationship to other Modules

- The module rounds up the knowledge from the earlier Electromagnetics module (CO-524) and completes the contents of the wireless communications module (CO-523) from an RF perspective.

Examination Type: Module Examination

Assessment Type: Written examination	Duration: 120 min
Scope: All intended learning outcomes of the module	Weight: 100 %

Completion: To pass this module, the examination has to be passed with at least 45%

7.25 Internship / Startup and Career Skills

<table>
<tr><td colspan="3">Module Name
Internship / Startup and Career Skills</td><td>Module Code
CA-INT-900</td><td>Level (type)
Year 3 (CAREER)</td><td>CP
15</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-INT-900-0</td><td colspan="3">Internship</td><td>Internship</td><td>15</td></tr>
<tr><td>Module Coordinator

Sinah Vogel & Dr. Tanja Woebs (SCS Organization); SPC / Faculty Startup Coordinator (Academic responsibility)</td><td colspan="3">Program Affiliation
CAREER module for undergraduate study programs</td><td colspan="2">Mandatory Status

Mandatory for all undergraduate study programs except IEM</td></tr>
<tr><td rowspan="2">Entry Requirements

Pre-requisites

☒ at least 15 CP from CORE modules in the major</td><td rowspan="2">

Co-requisites

☒ None</td><td rowspan="2">

Knowledge, Abilities, or Skills
Information provided on SCS pages (see below)
Major specific knowledge and skills</td><td>Frequency

Annually (Spring/Fall)</td><td colspan="2">Forms of Learning and Teaching
Internship/Start-up
Internship event
Seminars, info-sessions, workshops and career events
Self-study, readings, online tutorials</td></tr>
<tr><td>Duration
1 semester</td><td colspan="2">Workload

375 Hours consisting of:
Internship (308 hours)
Workshops (33 hours)
Internship Event (2 hours)
Self-study (32 hours)</td></tr>
<tr><td colspan="6">Recommendations for Preparation
Please see the section “Knowledge Center” at JobTeaser Career Center for information on Career Skills seminar and workshop offers and for online tutorials on the job market preparation and the application process. For more information, please see https://www.jacobs-university.de/employability/career-services
Participating in the internship events of earlier classes</td></tr>
<tr><td colspan="6">Content and Educational Aims

The aims of the internship module are reflection, application, orientation, and development: for students to reflect on their interests, knowledge, skills, their role in society, the relevance of their major subject to society, to apply these skills and this knowledge in real life whilst getting practical experience, to find a professional orientation, and</td></tr>
</table>

to develop their personality and in their career. This module supports the programs' aims of preparing students for gainful, qualified employment and the development of their personality.

The full-time internship must be related to the students' major area of study and extends lasts a minimum of two consecutive months, normally scheduled just before the 5th semester, with the internship event and submission of the internship report in the 5th semester. Upon approval by the SPC and CSC, the internship may take place at other times, such as before teaching starts in the 3rd semester or after teaching finishes in the 6th semester. The Study Program Coordinator or their faculty delegate approves the intended internship a priori by reviewing the tasks in either the Internship Contract or Internship Confirmation from the respective internship institution or company. Further regulations as set out in the Policies for Bachelor Studies apply.

Students will be gradually prepared for the internship in semesters 1 to 4 through a series of mandatory information sessions, seminars, and career events.

The purpose of the Career Services Information Sessions is to provide all students with basic facts about the job market in general, and especially in Germany and the EU, and services provided by the Career Services Center.

In the Career Skills Seminars, students will learn how to engage in the internship/job search, how to create a competitive application (CV, Cover Letter, etc.), and how to successfully conduct themselves at job interviews and/or assessment centers. In addition to these mandatory sections, students can customize their skill set regarding application challenges and their intended career path in elective seminars.

Finally, during the Career Events organized by the Career Services Center (e.g. the annual Constructor Career Fair and single employer events on and off campus), students will have the opportunity to apply their acquired job market skills in an actual internship/job search situation and to gain their desired internship in a high-quality environment and with excellent employers.

As an alternative to the full-time internship, students can apply for the StartUp Option. Following the same schedule as the full-time internship, the StartUp Option allows students who are particularly interested in founding their own company to focus on the development of their business plan over a period of two consecutive months. Participation in the StartUp Option depends on a successful presentation of the student's initial StartUp idea. This presentation will be held at the beginning of the 4th semester. A jury of faculty members will judge the student's potential to realize their idea and approve the participation of the students. The StartUp Option is supervised by the Faculty StartUp Coordinator. At the end of StartUp Option, students submit their business plan. Further regulations as outlined in the Policies for Bachelor Studies apply.

The concluding Internship Event will be conducted within each study program (or a cluster of related study programs) and will formally conclude the module by providing students the opportunity to present on their internships and reflect on the lessons learned within their major area of study. The purpose of this event is not only to self-reflect on the whole internship process, but also to create a professional network within the academic community, especially by entering the Alumni Network after graduation. It is recommended that all three classes (years) of the same major are present at this event to enable networking between older and younger students and to create an educational environment for younger students to observe the "lessons learned" from the diverse internships of their elder fellow students.

Intended Learning Outcomes

By the end of this module, students should be able to

1. describe the scope and the functions of the employment market and personal career development;
2. apply professional, personal, and career-related skills for the modern labor market, including self-organization, initiative and responsibility, communication, intercultural sensitivity, team and leadership skills, etc.;
3. independently manage their own career orientation processes by identifying personal interests, selecting appropriate internship locations or start-up opportunities, conducting interviews, succeeding at pitches or assessment centers, negotiating related employment, managing their funding or support conditions (such as salary, contract, funding, supplies, work space, etc.);
4. apply specialist skills and knowledge acquired during their studies to solve problems in a professional environment and reflect on their relevance in employment and society;
5. justify professional decisions based on theoretical knowledge and academic methods;
6. reflect on their professional conduct in the context of the expectations of and consequences for employers and their society;
7. reflect on and set their own targets for the further development of their knowledge, skills, interests, and values;

8. establish and expand their contacts with potential employers or business partners, and possibly other students and alumni, to build their own professional network to create employment opportunities in the future;
9. discuss observations and reflections in a professional network.

Indicative Literature

Not specified

Usability and Relationship to other Modules

- This module applies skills and knowledge acquired in previous modules to a professional environment and provides an opportunity to reflect on their relevance in employment and society. It may lead to thesis topics.

Examination Type: Module Examination

Assessment Type: Internship Report or Business Plan and Reflection	Length: approx. 3.500 words
Scope: All intended learning outcomes	Weight: 100%

7.26 Bachelor Thesis and Seminar

<table>
<tr><td colspan="3">Module Name
Bachelor Thesis and Seminar ECE</td><td>Module Code
CA-ECE-800</td><td>Level (type)
Year 3 (CAREER)</td><td>CP
15</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CA-ECE-800-T</td><td colspan="3">Thesis ECE</td><td>Thesis</td><td>12</td></tr>
<tr><td>CA-ECE-800-S</td><td colspan="3">Thesis Seminar ECE</td><td>Seminar</td><td>3</td></tr>
<tr><td>Module Coordinator
Study Program Chair</td><td colspan="3">Program Affiliation
• All undergraduate programs</td><td colspan="2">Mandatory Status
Mandatory for all undergraduate programs</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements
Pre-requisites: ☒ Students must have taken and successfully passed 30 CP from advanced modules.
Co-requisites: ☒ None
Knowledge, Abilities, or Skills:
• comprehensive knowledge of the subject and deeper insight into the chosen topic;
• ability to plan and undertake work independently;
• skills to identify and critically review literature.</td><td>Frequency
Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching
• Self-study/lab work (350 hours)
• Seminars (25 hours)</td></tr>
<tr><td>Duration
1 semester</td><td colspan="2">Workload
375 hours</td></tr>
</table>

Recommendations for Preparation

- Identify an area or a topic of interest and discuss this with your prospective supervisor in a timely manner.
- Create a research proposal including a research plan to ensure timely submission.
- Ensure you possess all required technical research skills or are able to acquire them on time.
- Review the University's Code of Academic Integrity and Guidelines to Ensure Good Academic Practice.

Content and Educational Aims

This module is a mandatory graduation requirement for all undergraduate students to demonstrate their ability to address a problem from their respective major subject independently using academic/scientific methods within a set time frame. Although supervised, this module requires students to be able to work independently and systematically and set their own goals in exchange for the opportunity to explore a topic that excites and interests them personally and that a faculty member is interested in supervising. Within this module, students apply their acquired knowledge about their major discipline and their learned skills and methods for conducting research, ranging from the identification of suitable (short-term) research projects, preparatory literature searches, the realization of discipline-specific research, and the documentation, discussion, interpretation, and communication of research results.

This module consists of two components, an independent thesis and an accompanying seminar. The thesis component must be supervised by a Jacobs University faculty member and requires short-term research work, the results of which must be documented in a comprehensive written thesis including an introduction, a justification of the methods, results, a discussion of the results, and a conclusion. The seminar provides students with the opportunity to practice their ability to present, discuss, and justify their and other students' approaches, methods, and results at various stages of their research in order to improve their academic writing, receive and reflect on formative feedback, and therefore grow personally and professionally.

Intended Learning Outcomes

On completion of this module, students should be able to

1. independently plan and organize advanced learning processes;
2. design and implement appropriate research methods, taking full account of the range of alternative techniques and approaches;
3. collect, assess, and interpret relevant information;
4. draw scientifically-founded conclusions that consider social, scientific, and ethical factors;
5. apply their knowledge and understanding to a context of their choice;
6. develop, formulate, and advance solutions to problems and debates within their subject area, and defend these through argument;
7. discuss information, ideas, problems, and solutions with specialists and non-specialists.

Indicative Literature

Justin Zobel, Writing for Computer Science, 3rd edition, Springer, 2015.

Usability and Relationship to other Modules

- This module builds on all previous modules in the undergraduate program. Students apply the knowledge, skills, and competencies they have acquired and practiced during their studies, including research methods and their ability to acquire additional skills independently as and if required.

Examination Type: Module Component Examinations

Module Component 1: Thesis
Assessment type: Thesis
Scope: All intended learning outcomes, mainly 1-6.
Weight: 80%

Length: approx. 10,000 – 14,000 words (25–35 pages), excluding front and back matter.

Module Component 2: Seminar
Assessment type: Presentation

Duration: approx. 15 to 30 minutes
Weight: 20%

Scope: The presentation focuses mainly on ILOs 6 and 7, but by nature of these ILOs it also touches on the others.

Completion: To pass this module, the examination of each module component has to be passed with at least 45%.

Two separate assessments are justified by the size of this module and the fact that the justification of solutions to problems and arguments (ILO 6) and discussion (ILO 7) should at least have verbal elements. The weights of the types of assessments are commensurate with the sizes of the respective module components.

8 CONSTRUCTOR Track Modules

8.1 Methods Modules

8.1.1 Matrix Algebra and Advanced Calculus I

<table>
<tr><td colspan="3">Module Name

Matrix Algebra and Advanced Calculus I</td><td>Module Code

CTMS-MAT-09</td><td>Level (type)

Year 1
(Methods)</td><td>CP

5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CTMS-09</td><td colspan="3">Matrix Algebra and Advanced Calculus I</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Dr. Keivan Mallahi-Karai</td><td colspan="3">Program Affiliation

• CONSTRUCTOR Track Area</td><td colspan="2">Mandatory Status

Mandatory for ECE and DSSD MMDA, PHDS.

Mandatory elective for CS, and RIS</td></tr>
<tr><td rowspan="2" colspan="3">Entry Requirements

Pre-requisites: ☒ none

Co-requisites: ☒ none

Knowledge, Abilities, or Skills
• Knowledge of pre-calculus ideas (sets and functions, elementary functions, polynomials) and analytic geometry (equations of lines, systems of linear equations, dot product, polar coordinates) at High School level. Familiarity with ideas of calculus is helpful.</td><td>Frequency

Annually

(Spring/Fall)</td><td colspan="2">Forms of Learning and Teaching</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Review of high school mathematics.</td></tr>
<tr><td colspan="6">Content and Educational Aims

This module is the first in a sequence including advanced mathematical methods at the university level at a level higher than the course Calculus and Linear Algebra I. The course comprises the following topics:

• Number systems, complex numbers
• The concept of function, composition of functions, inverse functions
• Basic ideas of calculus: Archimedes to Newton
• The notion of limit for functions and sequences and series
• Continuous function and their basic properties</td></tr>
</table>

- Derivatives: rate of change, velocity and applications
- Mean value theorem and estimation, maxima and minima, convex functions
- Integration, change of variables, Fundamental Theorem of Calculus
- Applications of the integral: work, area, average value, centre of mass
- Improper Integrals, Mean value theorem for integrals
- Taylor series
- Ordinary differential equations, examples, solving first order linear differential equations
- Basic ideas of numerical analysis, Newton's method, asymptotic formulas
- Review of elementary analytic geometry, lines, conics
- Vector spaces, linear independence, bases, coordinates
- Linear maps, matrices and their algebra, matrix inverses
- Gaussian elimination, solution space
- Determinants

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. apply the methods described in the content section of this module description to the extent that they can
2. solve standard text-book problems reliably and with confidence;
3. recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;
4. recognize common mathematical terminology used in textbooks and research papers in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module.

Indicative Literature

Advanced Calculus, G.B. Folland (Pearson, 2002)

Linear Algebra, S. Lang (Springer Verlag, 1986)

Mathematical Methods for Physics and Engineering,

K. Riley, M. Hobson, S. Bence (Cambridge University Press, 2006)

Usability and Relationship to other Modules

- Calculus and Linear Algebra I can be substituted with this module after consulting academic advisor
- A more advanced treatment of multi-variable Calculus, in particular, its applications in Physics and Mathematics, is provided in the second-semester module “Applied Mathematics”. All students taking “Applied Mathematics” are expected to take this module as well as the module topics are closely synchronized.
- The second-semester module “Linear Algebra” provides a complete proof-driven development of the theory of Linear Algebra. Diagonalization is covered more abstractly, with particular emphasis on degenerate cases. The Jordan normal form is also covered in “Linear Algebra”, not in this module.

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

8.1.2 Matrix Algebra and Advanced Calculus II

Module Name			**Module Code**	**Level (type)**	**CP**
Matrix Algebra and Advanced Calculus II			CTMS-MAT-10	Year 1 (Methods)	5
Module Components					
Number	Name			Type	CP
CTMS-10	Matrix Algebra and Advanced Calculus II			Lecture	5
Module Coordinator Dr. Keivan Mallahi Karai	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory for DSSD, ECE, MMDA and PHDS Mandatory elective for CS and RIS	
Entry Requirements Pre-requisites ☒ Matrix Algebra and Advanced Calculus I	 Co-requisites ☒ none	 Knowledge, Abilities, or Skills • None beyond formal pre-requisites	**Frequency** Annually (Spring) **Duration** 1 semester	**Forms of Learning and Teaching** • Lectures (35 hours) • Private study (90 hours) **Workload** 125 hours	
Recommendations for Preparation Review the content of Matrix Algebra and Advanced Calculus I					

Content and Educational Aims

- Coordinate systems, functions of several variables, level curves, polar coordinates
- Continuity, directional derivatives, partial derivatives, chain rule (version I)
- derivative as a matrix, chain rule (version II), tangent planes and linear approximation, gradient, repeated partial derivatives
- Minima and Maxima of functions of several variables, Lagrange multipliers
- Multiple integrals, iterated integrals, integration over standard regions, change of variables formula
- Vector fields, parametric representation of curves, line integrals and arc length, conservative vector fields
- Potentials, Green's theorem in the plane
- Parametric representation of surfaces
- Vector products and normal surface integrals
- Integral theorems by Stokes and Gauss, physical interpretations
- Basics of differential forms and their calculus, connection to gradient, curl, and divergence
- Eigenvalues and eigenvectors, diagonalisable matrices
- Inner product spaces, Hermitian and unitary matrices
- Matrix factorizations: Singular value decomposition with applications, LU decomposition, QR decomposition
- Linear constant-coefficient ordinary differential equations, application to mechanical vibrations and electrical oscillations
- Periodic functions, Fourier series

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. understand the definitions of continuity, derivative of a function as a linear transformation, multivariable integrals, eigenvalues and eigenvectors and associated notions.
2. apply the methods described in the content section of this module description to the extent that they can
3. evaluate multivariable integrals using definitions or by applying Green and Stokes theorem.
4. evaluate various decompositions of matrices

5. solve standard text-book problems reliably and with confidence;
6. recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;
7. recognize common mathematical terminology used in textbooks and research papers in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module.

Indicative Literature

Advanced Calculus, G.B. Folland (Pearson, 2002)

Linear Algebra, S. Lang (Springer Verlag, 1986)

Mathematical Methods for Physics and Engineering,

K. Riley, M. Hobson, S. Bence (Cambridge University Press, 2006)

Vector Calculus, Linear Algebra, and Differential Forms: A Unified

Approach, J.H. Hubbard, B. Hubbard (Pearson, 1998)

Usability and Relationship to other Modules

- This module can substitute Calculus and Linear Algebra II after consulting academic advisor.
- Methods of this course are applied in the module Mathematical Modeling.
- The second-semester module Linear Algebra provides a more rigorous and more abstract treatment of some of the notions discussed in this module.

Examination Type: Module Examination

Assessment type: Written examination Length/duration: (120min)
Weight: 100 %

Scope: All intended learning outcomes of this module

Completion: To pass this module, the examination has to be passed with at least 45%

8.1.3 Probability and Random Processes

<table>
<tr><td colspan="3">Module Name
Probability and Random Processes</td><td>Module Code
CTMS-MAT-12</td><td>Level (type)
Year 2
(Methods)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CTMS-12</td><td colspan="3">Probability and random processes</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator

Dr. Keivan Mallahi Karai</td><td colspan="3">Program Affiliation

• CONSTRUCTOR Track Area</td><td colspan="2">Mandatory Status

Mandatory for CS, DSSD, ECE, MMDA, PHDS and RIS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ Matrix Algebra and Advanced Calculus II or Calculus and Linear Algebra II

Co-requisites: ☒ None

Knowledge, Abilities, or Skills:
• Knowledge of calculus at the level of a first year calculus module (differentiation, integration with one and several variables, trigonometric functions, logarithms and exponential functions).
• Knowledge of linear algebra at the level of a first-year university module (eigenvalues and eigenvectors, diagonalization of matrices).
• Some familiarity with elementary probability theory at the high school level.</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

Lectures (35 hours)
Private study (90 hours)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation

Review all of the first-year calculus and linear algebra modules as indicated in “Entry Requirements – Knowledge, Ability, or Skills” above.</td></tr>
</table>

Content and Educational Aims

This module aims to provide a basic knowledge of probability theory and random processes suitable for students in engineering, Computer Science, and Mathematics. The module provides students with basic skills needed for formulating real-world problems dealing with randomness and probability in mathematical language, and methods for applying a toolkit to solve these problems. Mathematical rigor is used where appropriate. A more advanced treatment of the subject is deferred to the third-year module Stochastic Processes.

The lecture comprises the following topics

- Brief review of number systems, elementary functions, and their graphs
- Outcomes, events and sample space.
- Combinatorial probability.
- Conditional probability and Bayes' formula.
- Binomials and Poisson-Approximation
- Random Variables, distribution and density functions.
- Independence of random variables.
- Conditional Distributions and Densities.
- Transformation of random variables.
- Joint distribution of random variables and their transformations.
- Expected Values and Moments, Covariance.
- High dimensional probability: Chebyshev and Chernoff bounds.
- Moment-Generating Functions and Characteristic Functions,
- The Central limit theorem.
- Random Vectors and Moments, Covariance matrix, Decorrelation.
- Multivariate normal distribution.
- Markov chains, stationary distributions.

Intended Learning Outcomes

By the end of the module, students will be able to

1. command the methods described in the content section of this module description to the extent that they can solve standard text-book problems reliably and with confidence;
2. recognize the probabilistic structures in an unfamiliar context and translate them into a mathematical problem statement;
3. recognize common mathematical terminology used in textbooks and research papers in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module.

Indicative Literature

J. Hwang and J.K. Blitzstein (2019). Introduction to Probability, second edition. London: Chapman & Hall.

S. Ghahramani. Fundamentals of Probability with Stochastic Processes, fourth edition. Upper Saddle River: Prentice Hall.

Usability and Relationship to other Modules

- Students taking this module are expected to be familiar with basic tools from calculus and linear algebra.

Examination Type: Module Examination

Assessment type: Written examination Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

Completion: To pass this module, the examination has to be passed with at least 45%.

8.1.4 Numerical Methods

Module Name			**Module Code**	**Level (type)**	**CP**
Numerical Methods			CTMS-MAT-13	Year 2 (Methods)	5
Module Components					
Number	Name			Type	CP
CTMS-13	Numerical Methods			Lecture	5
Module Coordinator NN	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory for ECE, Mandatory elective for CS and RIS	
Entry Requirements			**Frequency** Annually (Spring)	**Forms of Learning and Teaching** • Lectures (35 hours) • Private study (90 hours)	
Pre-requisites ☒ None	Co-requisites ☒ None	Knowledge, Abilities, or Skills • Knowledge of Calculus (functions, inverse functions, sets, real numbers, sequences and limits, polynomials, rational functions, trigonometric functions, logarithm and exponential function, parametric equations, tangent lines, graphs, derivatives, anti-derivatives, elementary techniques for solving equations) • Knowledge of Linear Algebra (vectors, matrices, lines, planes, n-dimensional Euclidean vector space, rotation, translation, dot product (scalar product), cross product, normal vector, eigenvalues, eigenvectors, elementary techniques for solving systems of linear equations)	**Duration** 1 semester	**Workload** 125 hours	
Recommendations for Preparation Taking Calculus and Elements of Linear Algebra II before taking this module is recommended, but not required. A thorough review of Calculus and Elements of Linear Algebra, with emphasis on the topics listed as "Knowledge, Abilities, or Skills" is recommended.					

Content and Educational Aims

This module covers calculus-based numerical methods, in particular root finding, interpolation, approximation, numerical differentiation, numerical integration (quadrature), and a first introduction to the numerical solution of differential equations.

The lecture comprises the following topics

- number representations
- Gaussian elimination
- LU decomposition
- Cholesky decomposition
- iterative methods
- bisection method
- Newton's method
- secant method
- polynomial interpolation
- Aitken's algorithm
- Lagrange interpolation
- Newton interpolation
- Hermite interpolation
- Bezier curves
- De Casteljau's algorithm
- piecewise interpolation
- Spline interpolation
- B-Splines
- Least-squares approximation
- polynomial regression
- difference schemes
- Richardson extrapolation
- Quadrature rules
- Monte Carlo integration
- time stepping schemes for ordinary differential equations
- Runge Kutta schemes
- finite difference method for partial differential equations

Intended Learning Outcomes

By the end of the module, students will be able to

1. describe the basic principles of discretization used in the numerical treatment of continuous problems;
2. command the methods described in the content section of this module description to the extent that they can solve standard text-book problems reliably and with confidence;
3. recognize mathematical terminology used in textbooks and research papers on numerical methods in the quantitative sciences, engineering, and mathematics to the extent that they fall into the content categories covered in this module;
4. implement simple numerical algorithms in a high-level programming language;
5. understand the documentation of standard numerical library code and understand the potential limitations and caveats of such algorithms.

Indicative Literature

D. Kincaid and W. Cheney (1991). Numerical Analysis: Mathematics of Scientific Computing. Pacific Grove: Brooks/Cole Publishing.

W. Boehm and H. Prautzsch (1993). Numerical Methods. Natick: AK Peters.

Usability and Relationship to other Modules

- This module is a co-recommendation for the module "Applied Dynamical Systems Lab", in which the actual implementation in a high-level programming language of the learned methods will be covered.

Examination Type: Module Examination

Assessment type: Written examination Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module.

Completion: To pass this module, the examination has to be passed with at least 45%.

8.2 New Skills Modules

8.2.1 Logic (perspective I)

Module Name		**Module Code**	**Level (type)**	**CP**
Logic (perspective I)		CTNS-NSK-01	Year 2 (New Skills)	2.5
Module Components				
Number	Name		Type	CP
CTNS-01	Logic (perspective I)		Lecture (online)	2.5
Module Coordinator Jules Coleman	**Program Affiliation** • CONSTRUCTOR Track Area		**Mandatory Status** Mandatory elective for all UG students (one perspective must be chosen)	
Entry Requirements Pre-requisites: ☒ none	Co-requisites: ☒ none Knowledge, Abilities, or Skills: •	**Frequency** Annually (Fall)	**Forms of Learning and Teaching** Online lecture (17.5h) Private study (45h)	
		Duration 1 semester	**Workload** 62.5 hours	
Recommendations for Preparation				

Content and Educational Aims

Suppose a friend asks you to help solve a complicated problem? Where do you begin? Arguably, the first and most difficult task you face is to figure out what the heart of the problem actually is. In doing that you will look for structural similarities between the problem posed and other problems that arise in different fields that others may have addressed successfully. Those similarities may point you to a pathway for resolving the problem you have been asked to solve. But it is not enough to look for structural similarities. Sometimes relying on similarities may even be misleading. Once you've settled tentatively on what you take to be the heart of the matter, you will naturally look for materials, whether evidence or arguments, that you believe is relevant to its potential solution. But the evidence you investigate of course depends on your formulation of the problem, and your formulation of the problem likely depends on the tools you have available – including potential sources of evidence and argumentation. You cannot ignore this interactivity, but you can't allow yourself to be hamstrung entirely by it. But there is more. The problem itself may be too big to be manageable all at once, so you will have to explore whether it can be broken into manageable parts and if the information you have bears on all or only some of those parts. And later you will face the problem of whether the solutions to the particular sub problems can be put together coherently to solve the entire problem taken as a whole.

What you are doing is what we call engaging in computational thinking. There are several elements of computational thinking illustrated above. These include: Decomposition (breaking the larger problem down into smaller ones); Pattern recognition (identifying structural similarities); Abstraction (ignoring irrelevant particulars of the problem): and Creating Algorithms), problem-solving formulas.

But even more basic to what you are doing is the process of drawing inferences from the material you have. After all, how else are you going to create a problem-solving formula, if you draw incorrect inferences about what information has shown and what, if anything follows logically from it. What you must do is apply the rules of logic to the information to draw inferences that are warranted.

We distinguish between informal and formal systems of logic, both of which are designed to indicate fallacies as well as warranted inferences. If I argue for a conclusion by appealing to my physical ability to coerce you, I prove nothing about the truth of what I claim. If anything, by doing so I display my lack of confidence in my argument. Or if the best I can do is berate you for your skepticism, I have done little more than offer an ad hominem instead of an argument. Our focus will be on formal systems of logic, since they are at the heart of both scientific argumentation and computer developed algorithms. There are in fact many different kinds of logic and all figure to varying degrees in scientific inquiry. There are inductive types of logic, which purport to formalize the relationship between premises that if true offer evidence on behalf of a conclusion and the conclusion and are represented as claims about the extent to which the conclusion is confirmed by the premises. There are deductive types of logic, which introduce a different relationship between premise and conclusion. These variations of logic consist in rules that if followed entail that if the premises are true then the conclusion too must be true.

There are also modal types of logic which are applied specifically to the concepts of necessity and possibility, and thus to the relationship among sentences that include either or both those terms. And there is also what are called deontic logic, a modification of logic that purport to show that there are rules of inference that allow us to infer what we ought to do from facts about the circumstances in which we find ourselves. In the natural and social sciences most of the emphasis has been placed on inductive logic, whereas in math it is placed on deductive logic, and in modern physics there is an increasing interest in the concepts of possibility and necessity and thus in modal logic. The humanities, especially normative discussions in philosophy and literature are the province of deontic logic.

This module will also take students through the central aspects of computational thinking, as it is related to logic; it will introduce the central concepts in each, their relationship to one another and begin to provide the conceptual apparatus and practical skills for scientific inquiry and research.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students will be able to

apply the various principles of logic and expand them to computational thinking.
understand the way in which logical processes in humans and in computers are similar and different at the same time.
apply the basic rules of first-order deductive logic and employ them rules in the context of creating a scientific or social scientific study and argument.
employ those rules in the context of creating a scientific or social scientific study and argument.

Indicative Literature

- Frege, Gottlob (1879), Begriffsschrift, eine der arithmetischen nachgebildete Formelsprache des reinen Denkens [Translation: A Formal Language for Pure Thought Modeled on that of Arithmetic],Halle an der Salle: Verlag von Louis Nebert.
- Gödel, Kurt (1986), Russels mathematische Logik. In: Alfred North Whitehead, Bertrand Russell: Principia Mathematica. Vorwort, S. V–XXXIV. Suhrkamp.
- Leeds, Stephen. "George Boolos and Richard Jeffrey. Computability and logic. Cambridge University Press, New York and London1974, x+ 262 pp." The Journal of Symbolic Logic 42.4 (1977): 585-586.
- Kubica, Jeremy. Computational fairy tales. Jeremy Kubica, 2012.
- McCarthy, Timothy. "Richard Jeffrey. Formal logic: Its scope and limits. of XXXVIII 646. McGraw-Hill Book Company, New York etc. 1981, xvi+ 198 pp." The Journal of Symbolic Logic 49.4 (1984): 1408-1409.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written Examination — Duration: 60 min, Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.2 Logic (perspective II)

<table>
<tr><td colspan="3">Module Name
Logic (perspective II)</td><td>Module Code
CTNS-NSK-02</td><td>Level (type)
Year 2
(New Skills)</td><td>CP
2.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CTNS-02</td><td colspan="3">Logic (perspective II)</td><td>Lecture (online)</td><td>2.5</td></tr>
<tr><td>Module Coordinator

NN</td><td colspan="3">Program Affiliation

• CONSTRUCTOR Track Area</td><td colspan="2">Mandatory Status

Mandatory elective for all UG students (one perspective must be chosen)</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements

Pre-requisites: ☒ none
Co-requisites: ☒ none
Knowledge, Abilities, or Skills</td><td>Frequency

Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching

Online lecture (17.5h)
Private study (45h)</td></tr>
<tr><td>Duration

1 semester</td><td colspan="2">Workload

62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation</td></tr>
</table>

Content and Educational Aims

The focus of this module is on formal systems of logic, since they are at the heart of both scientific argumentation and computer developed algorithms. There are in fact many kinds of logic and all figure to varying degrees in scientific inquiry. There are inductive types of logic, which purport to formalize the relationship between premises that if true offer evidence on behalf of a conclusion and the conclusion and are represented as claims about the extent to which the conclusion is confirmed by the premises. There are deductive types of logic, which introduce a different relationship between premise and conclusion. These variations of logic consist in rules that if followed entail that if the premises are true then the conclusion too must be true.

This module introduces logics that go beyond traditional deductive propositional logic and predicate logic and as such it is aimed at students who are already familiar with basics of traditional formal logic. The aim of the module is to provide an overview of alternative logics and to develop a sensitivity that there are many different logics that can provide effective tools for solving problems in specific application domains.

The module first reviews the principles of a traditional logic and then introduces many-valued logics that distinguish more than two truth values, for example true, false, and unknown. Fuzzy logic extends traditional logic by replacing truth values with real numbers in the range 0 to 1 that are expressing how strong the believe into a proposition is. Modal logics introduce modal operators expressing whether a proposition is necessary or possible. Temporal logics deal with propositions that are qualified by time. Once can view temporal logics as a form of modal logics where propositions are qualified by time constraints. Interval temporal logic provides a way to reason about time intervals in which propositions are true.

The module will also investigate the application of logic frameworks to specific classes of problems. For example, a special subset of predicate logic, based on so-called Horn clauses, forms the basis of logic programming languages such as Prolog. Description logics, which are usually decidable logics, are used to model relationships and they have applications in the semantic web, which enables search engines to reason about resources present on the Internet.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students will be able to

1. apply the various principles of logic

2. explain practical relevance of non-standard logic
3. describe how many-valued logic extends basic predicate logic
4. apply basic rules of fuzzy logic to calculate partial truth values
5. sketch basic rules of temporal logic
6. implement predicates in a logic programming language
7. prove some simple non-standard logic theorems

Indicative Literature

- Bergmann, Merry. “An Introduction to Many-Valued and Fuzzy Logic: Semantics, Algebras, and Derivation Systems”, Cambridge University Press, April 2008.
- Sterling, Leon S., Ehud Y. Shapiro, Ehud Y. "The Art of Prolog", 2nd edition, MIT Press, March 1994.
- Fisher, Michael. “An Introduction to Practical Formal Methods Using Temporal Logic”, Wiley, Juli 2011.
- Baader, Franz. "The Description Logic Handbook: Theory Implementation and Applications", Cambridge University Press, 2nd edition, May 2010.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written Examination

Duration: 60 min
Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.3 Causation and Correlation (perspective I)

Module Name		Module Code	Level (type)	CP
Causation and Correlation (perspective I)		CTNS-NSK-03	Year 2 (New Skills)	2.5
Module Components				
Number	Name		Type	CP
CTNS-03	Causation and Correlation		Lecture (online)	2.5
Module Coordinator Prof. Dr. Jules Coleman	**Program Affiliation** • CONSTRUCTOR Track Area		**Mandatory Status** Mandatory elective for all UG students (one perspective must be chosen)	
Entry Requirements Pre-requisites ☒ none	Co-requisites ☒ none	Knowledge, Abilities, or Skills •	**Frequency** Annually (Spring)	**Forms of Learning and Teaching** Online lecture (17.5h) Private study (45h)
			Duration 1 semester	**Workload** 62.5 hours
Recommendations for Preparation				

Content and Educational Aims

In many ways, life is a journey. And also, as in other journeys, our success or failure depends not only on our personal traits and character, our physical and mental health, but also on the accuracy of our map. We need to know what the world we are navigating is actually like, the how, why and the what of what makes it work the way it does. The natural sciences provide the most important tool we have developed to learn how the world works and why it works the way it does. The social sciences provide the most advanced tools we have to learn how we and other human beings, similar in most ways, different in many others, act and react and what makes them do what they do. In order for our maps to be useful, they must be accurate and correctly reflect the way the natural and social worlds work and why they work as they do.

The natural sciences and social sciences are blessed with enormous amounts of data. In this way, history and the present are gifts to us. To understand how and why the world works the way it does requires that we are able to offer an explanation of it. The data supports a number of possible explanations of it. How are we to choose among potential explanations? Explanations, if sound, will enable us to make reliable predictions about what the future will be like, and also to identify many possibilities that may unfold in the future. But there are differences not just in the degree of confidence we have in our predictions, but in whether some of them are necessary future states or whether all of them are merely possibilities? Thus, there are three related activities at the core of scientific inquiry: understanding where we are now and how we got here (historical); knowing what to expect going forward (prediction); and exploring how we can change the paths we are on (creativity).

At the heart of these activities are certain fundamental concepts, all of which are related to the scientific quest to uncover immutable and unchanging laws of nature. Laws of nature are thought to reflect a causal nexus between a previous event and a future one. There are also true statements that reflect universal or nearly universal connections between events past and present that are not laws of nature because the relationship they express is that of a correlation between events. A working thermostat accurately allows us to determine or even to predict the temperature in the room in which it is located, but it does not explain why the room has the temperature it has. What then is the core difference between causal relationships and correlations? At the same time, we all recognize that given where we are now there are many possible futures for each of us, and even had our lives gone just the slightest bit differently than they have, our present state could well have been very different than it is.

The relationship between possible pathways between events that have not materialized but could have is expressed through the idea of counterfactual.

Creating accurate roadmaps, forming expectations we can rely on, making the world a more verdant and attractive place requires us to understand the concepts of causation, correlation, counterfactual explanation, prediction, necessity, possibility, law of nature and universal generalization. This course is designed precisely to provide the conceptual tools and intellectual skills to implement those concepts in our future readings and research and ultimately in our experimental investigations, and to employ those tools in various disciplines.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students will be able to

1. formulate testable hypotheses that are designed to reveal causal connections and those designed to reveal interesting, important and useful correlations.
2. distinguish scientifically interesting correlations from unimportant ones.
3. apply critical thinking skills to evaluate information.
4. understand when and why inquiry into unrealized possibility is important and relevant.

Indicative Literature

Thomas S. Kuhn: The Structure of Scientific Revolutions, Nelson, fourth edition 2012;

Goodman, Nelson. Fact, fiction, and forecast. Harvard University Press, 1983;

Quine, Willard Van Orman, and Joseph Silbert Ullian. The web of belief. Vol. 2. New York: Random house, 1978.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written Examination

Duration/Length: 60 min
Weight: 100%

Scope: All intended learning outcomes of the module

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.4 Causation and Correlation (perspective II)

Module Name			Module Code	Level (type)	CP
Causation and Correlation (perspective II)			CTNS-NSK-04	Year 2 (New Skills)	2.5
Module Components					
Number	Name			Type	CP
CTNS-04	Causation and Correlations (perspective II)			Lecture (online)	2.5
Module Coordinator Dr. Keivan Mallahi-Karai Dr. Eoin Ryan Dr. Irina Chiaburu	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective for all UG students (one perspective must be chosen)	
Entry Requirements Pre-requisites ☒ none	Co-requisites ☒ none	Knowledge, Abilities, or Skills • Basic probability theory	**Frequency** Annually (Spring)	**Forms of Learning and Teaching** Online lecture (17.5h) Private study (45h)	
			Duration 1 semester	**Workload** 62.5 hours	
Recommendations for Preparation					
Content and Educational Aims					

Causality or causation is a surprisingly difficult concept to understand. David Hume famously noted that causality is a concept that our science and philosophy cannot do without, but it is equally a concept that our science and philosophy cannot describe. Since Hume, the problem of cause has not gone away, and sometimes seems to get even worse (e.g., quantum mechanics confusing previous notions of causality). Yet, ways of doing science that lessen our need to explicitly use causality have become very effective (e.g., huge developments in statistics). Nevertheless, it still seems that the concept of causality is at the core of explaining how the world works, across fields as diverse as physics, medicine, logistics, the law, sociology, and history – and ordinary daily life – through all of which, explanations and predictions in terms of cause and effect remain intuitively central.

Causality remains a thorny problem but, in recent decades, significant progress has occurred, particularly in work by or inspired by Judea Pearl. This work incorporates many 20th century developments, including statistical methods – but with a reemphasis on finding the why, or the cause, behind statistical correlations –, progress in understanding the logic, semantics and metaphysics of conditionals and counterfactuals, developments based on insights from the likes of philosopher Hans Reichenbach or biological statistician Sewall Wright into causal precedence and path analysis, and much more. The result is a new toolkit to identify causes and build causal explanations. Yet even as we get better at identifying causes, this raises new (or old) questions about causality, including metaphysical questions about the nature of causes (and effects, events, objects, etc), but also questions about what we really use causality for (understanding the world as it is or just to glean predictive control of specific outcomes), about how causality is used differently in different fields and activities (is cause in physics the same as that in history?), and about how other crucial concepts relate to our concept of cause (space and time seem to be related to causality, but so do concepts of legal and moral responsibility).

This course will introduce students to the mathematical formalism derived from Pearl's work, based on directed acyclic graphs and probability theory. Building upon previous work by Reichenbach and Wright, Pearl defines a "a calculus of interventions" of "do-calculus" for talking about interventions and their relation to causation and counterfactuals. This model has been applied in various areas ranging from econometrics to statistics, where acquiring knowledge about causality is of great importance.

At the same time, the course will not forget some of the metaphysical and epistemological issues around cause, so that students can better critically evaluate putative causal explanations in their full context. Abstractly, such issues involve some of the same philosophical questions Hume already asked, but more practically, it is important to see how metaphysical and epistemological debates surrounding the notion of cause affect scientific practice, and equally if not more importantly, how scientific practice pushes the limits of theory. This course will look at various ways in which empirical data can be transformed into explanations and theories, including the variance approach to causality (characteristic of the positivistic quantitative paradigm), and the process theory of causality (associated with qualitative methodology). Examples and case studies will be relevant for students of the social sciences but also students of the natural/physical world as well.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students will

1. have a clear understanding of the history of causal thinking.
2. be able to form a critical understanding of the key debates and controversies surrounding the idea of causality.
3. be able to recognize and apply probabilistic causal models.
4. be able to explain how understanding of causality differs among different disciplines.
5. be able demonstrate how theoretical thinking about causality has shaped scientific practices.

Indicative Literature

Paul, L. A. and Ned Hall. Causation: A User's Guide. Oxford University Press 2013.

Pearl, Judea. Causality: Models, Reasoning and Inference. Cambridge University Press 2009

Pearl, Judea, Glymour Madelyn and Jewell, Nicolas. Causal Inference in Statistics: A Primer. Wiley 2016

Ilari, Phyllis McKay and Federica Russo. Causality: Philosophical Theory Meets Scientific Practice. Oxford University Press 2014.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment: Written examination

Duration/Length: 60 min

Weight: 100 %

Scope: All intended learning outcomes of the module

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.5 Linear Model and Matrices

Module Name			Module Code	Level (type)	CP
Linear Model and Matrices			CTNS-NSK-05	Year 3 (New Skills)	5
Module Components					
Number	Name			Type	CP
CTNS-05	Linear models and matrix			Seminar (online)	5
Module Coordinator Prof. Dr. Marc-Thorsten Hütt	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective	
Entry Requirements			**Frequency** Annually (Fall)	**Forms of Learning and Teaching** Online lecture (35h) Private Study (90h)	
Pre-requisites Logic Causation & Correlation	Co-requisites ☒ none	Knowledge, Abilities, or Skills •	**Duration** 1 Semester	**Workload** 125 hours	
Recommendations for Preparation					

Content and Educational Aims

There are no universal 'right skills'. But the notion of linear models and the avenue to matrices and their properties can be useful in diverse disciplines to implement a quantitative, computational approach. Some of the most popular data and systems analysis strategies are built upon this framework. Examples include principal component analysis (PCA), the optimization techniques used in Operations Research (OR), the assessment of stable and unstable states in nonlinear dynamical systems, as well as aspects of machine learning.

Here we introduce the toolbox of linear models and matrix-based methods embedded in a wide range of transdisciplinary applications (part 1). We describe its foundation in linear algebra (part 2) and the range of tools and methods derived from this conceptual framework (part 3). At the end of the course, we outline applications to graph theory and machine learning (part 4). Matrices can be useful representations of networks and of system of linear equations. They are also the core object of linear stability analysis, an approach used in nonlinear dynamics. Throughout the course, examples from neuroscience, social sciences, medicine, biology, physics, chemistry, and other fields are used to illustrate these methods.

A strong emphasis of the course is on the sensible usage of linear approaches in a nonlinear world. We will critically reflect the advantages as well as the disadvantages and limitations of this method. Guiding questions are: How appropriate is a linear approximation of a nonlinear system? What do you really learn from PCA? How reliable are the optimal states obtained via linear programming (LP) techniques?

This debate is embedded in a broader context: How does the choice of a mathematical technique confine your view on the system at hand? How, on the other hand, does it increase your capabilities of analyzing the system (due to software available for this technique, the ability to compare with findings from other fields built upon the same technique and the volume of knowledge about this technique)?

In the end, students will have a clearer understanding of linear models and matrix approaches in their own discipline, but they will also see the full transdisciplinarity of this topic. They will make better decisions in their choice of data analysis methods and become mindful of the challenges when going from a linear to a nonlinear thinking.

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. apply the concept of linear modeling in their own discipline
2. distinguish between linear and nonlinear interpretation strategies and understand the range of applicability of linear models
3. make use of data analysis / data interpretation strategies from other disciplines, which are derived from linear algebra
4. be aware of the ties that linear models have to machine learning and network theory

   Note that these four ILOs can be loosely associated with the four parts of the course indicated above

Indicative Literature

Part 1:

material from Linear Algebra for Everyone, Gilbert Strang, Wellesley-Cambridge Press, 2020

Part 2:

material from Introduction to Linear Algebra (5th Edition), Gilbert Strang, Cambridge University Press, 2021

Part 3:

Mainzer, Klaus. "Introduction: from linear to nonlinear thinking." Thinking in Complexity: The Computational Dynamics of Matter, Mind and Mankind (2007): 1-16.

material from Mathematics of Big Data: Spreadsheets, Databases, Matrices, and Graphs, Jeremy Kepner, Hayden Jananthan, The MIT Press, 2018

material from Introduction to Linear Algebra (5th Edition), Gilbert Strang, Cambridge University Press, 2021

Part 4:

material from Linear Algebra and Learning from Data, Gilbert Strang, Wellesley-Cambridge Press, 2019

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment: Written examination Duration/Length: 120 min

Weight: 100 %

Scope: All intended learning outcomes of the module

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.6 Complex Problem Solving

Module Name			Module Code	Level (type)	CP
Complex Problem Solving			CTNS-NSK-06	Year 3 (New Skills)	5
Module Components					
Number	Name			Type	CP
CTNS-06	Complex Problem Solving			Lecture (online)	5
Module Coordinator Marco Verweij	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective	
Entry Requirements Pre-requisites Logic Causation & Correlation	Co-requisites ☒ none	Knowledge, Abilities, or Skills • Being able to read primary academic literature • Willingness to engage in teamwork	**Frequency** Annually (Fall)	**Forms of Learning and Teaching** Online Lectures (35h) Private Study (90h)	
			Duration 1 semester	**Workload** 125 hours	

Recommendations for Preparation

Please read: Camillus, J. (2008). Strategy as a wicked problem. Harvard Business Review 86: 99-106; Rogers, P. J. (2008). Using programme theory to evaluate complicated and complex aspects of interventions. Evaluation, 14, 29–48.

Content and Educational Aims

Complex problems are, by definition, non-linear and/or emergent. Some fifty years ago, scholars such as Herbert Simon began to argue that societies around the world had developed an impressive array of tools with which to solve simple and even complicated problems, but still needed to develop methods with which to address the rapidly increasing number of complex issues. Since then, a variety of such methods has emerged. These include 'serious games' developed in computer science, 'multisector systems analysis' applied in civil and environmental engineering, 'robust decision-making' proposed by the RAND Corporation, 'design thinking' developed in engineering and business studies, 'structured problem solving' used by McKinsey & Co., 'real-time technology assessment' advocated in science and technology studies, and 'deliberative decision-making' emanating from political science.

In this course, students first learn to distinguish between simple, complicated and complex problems. They also become familiar with the ways in which a particular issue can sometimes shift from one category into another. In addition, the participants learn to apply several tools for resolving complex problems. Finally, the students are introduced to the various ways in which natural and social scientists can help stakeholders resolve complex problems. Throughout the course examples and applications will be used. When possible, guest lectures will be offered by experts on a particular tool for tackling complex issues. For the written, take-home exam, students will have to select a specific complex problem, analyse it and come up with a recommendation – in addition to answering several questions about the material learned.

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. Identify a complex problem;
2. Develop an acceptable recommendation for resolving complex problems.
3. Understand the roles that natural and social scientists can play in helping stakeholders resolve complex problems;

Indicative Literature

Chia, A. (2019). Distilling the essence of the McKinsey way: The problem-solving cycle. Management Teaching Review 4(4): 350-377.

Den Haan, J., van der Voort, M.C., Baart, F., Berends, K.D., van den Berg, M.C., Straatsma, M.W., Geenen, A.J.P., & Hulscher, S.J.M.H. (2020). The virtual river game: Gaming using models to collaboratively explore river management complexity, Environmental Modelling & Software 134, 104855,

Folke, C., Carpenter, S., Elmqvist, T., Gunderson, L., Holling, C.S., & Walker, B. (2002). Resilience and sustainable development: Building adaptive capacity in a world of transformations. AMBIO: A Journal of the Human Environment 31(5): 437-440.

Ostrom, E. (2010). Beyond markets and states: Polycentric governance of complex economic systems. American Economic Review 100(3): 641-72.

Pielke, R. Jr. (2007). The honest broker: Making sense of science in policy and politics. Cambridge: Cambridge University Press.

Project Management Institute (2021). A guide to the project management body of knowledge (PMBOK® guide).

Schon, D. A., & Rein, M. (1994). Frame reflection: Toward the resolution of intractable policy controversies. New York: Basic Books.

Simon, H. A. (1973). The structure of ill structured problems. Artificial Intelligence 4(3-4): 181-201.

Verweij, M. & Thompson, M. (Eds.) (2006). Clumsy solutions for a complex world. London: Palgrave Macmillan.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written examination — Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.7 Argumentation, Data Visualization and Communication (perspective I)

<table>
<tr><td colspan="3">Module Name
Argumentation, Data Visualization and Communication (perspective I)</td><td>Module Code
CTNS-NSK-07</td><td>Level (type)
Year 3
(New Skills)</td><td>CP
5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3">Name</td><td>Type</td><td>CP</td></tr>
<tr><td>CTNS-07</td><td colspan="3">Argumentation, Data Visualization and Communication (perspective I)</td><td>Lecture (online)</td><td>5</td></tr>
<tr><td>Module Coordinator
Prof. Dr. Jules Coleman,
Prof Dr. Arvid Kappas</td><td colspan="3">Program Affiliation
CONSTRUCTOR Track Area</td><td colspan="2">Mandatory Status
Mandatory elective for all UG students (one perspective must be chosen)</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements
Pre-requisites: Logic; Causation & Correlation
Co-requisites: ☒ none
Knowledge, Abilities, or Skills</td><td>Frequency
Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching
Online Lectures (35h)
Private Study (90h)</td></tr>
<tr><td>Duration
1 semester</td><td colspan="2">Workload
125h</td></tr>
<tr><td colspan="6">Recommendations for Preparation</td></tr>
<tr><td colspan="6">One must be careful not to confuse argumentation with being argumentative. The latter is an unattractive personal attribute, whereas the former is a requirement of publicly holding a belief, asserting the truth of a proposition, the plausibility of a hypothesis, or a judgment of the value of a person or an asset. It is an essential component of public discourse. Public discourse is governed by norms and one of those norms is that those who assert the truth of a proposition or the validity of an argument or the responsibility of another for wrongdoing open themselves up to good faith requests to defend their claims. In its most general meaning, argumentation is the requirement that one offer evidence in support of the claims they make, as well as in defense of the judgments and assessments they reach. There are different modalities of argumentation associated with different contexts and disciplines. Legal arguments have a structure of their own as do assessments of medical conditions and moral character. In each case, there are differences in the kind of evidence that is thought relevant and, more importantly, in the standards of assessment for whether a case has been successfully made. Different modalities of argumentation require can call for different modes of reasoning. We not only offer reasons in defense of or in support of beliefs we have, judgments we make and hypotheses we offer, but we reason from evidence we collect to conclusions that are warranted by them.

Reasoning can be informal and sometimes even appear unstructured. When we recognize some reasoning as unstructured yet appropriate what we usually have in mind is that it is not linear. Most reasoning we are familiar with is linear in character. From A we infer B, and from A and B we infer C, which all together support our commitment to D. The same form of reasoning applies whether the evidence for A, B or C is direct or circumstantial. What changes in these cases is perhaps the weight we give to the evidence and thus the confidence we have in drawing inferences from it.</td></tr>
</table>

Especially in cases where reasoning can be supported by quantitative data, wherever quantitative data can be obtained either directly or by linear or nonlinear models, the visualization of the corresponding data can become key in both, reasoning and argumentation. A graphical representation can reduce the complexity of argumentation and is considered a must in effective scientific communication. Consequently, the course will also focus on smart and compelling ways for data visualization - in ways that go beyond what is typically taught in statistics or mathematics lectures. These tools are constantly developing, as a reflection of new software and changes in state of the presentation art. Which graph or bar chart to use best for which data, the use of colors to underline messages and arguments, but also the pitfalls when presenting data in a poor or even misleading manner. This will also help in readily identifying intentional mis-representation of data by others, the simplest to recognize being truncating the ordinate of a graph in order to exaggerate trends. This frequently leads to false arguments, which can then be readily countered.

There are other modalities of reasoning that are not linear however. Instead they are coherentist. We argue for the plausibility of a claim sometimes by showing that it fits in with a set of other claims for which we have independent support. The fit is itself the reason that is supposed to provide confidence or grounds for believing the contested claim.

Other times, the nature of reasoning involves establishing not just the fit but the mutual support individual items in the evidentiary set provide for one another. This is the familiar idea of a web of interconnected, mutually supportive beliefs. In some cases, the support is in all instances strong; in others it is uniformly weak, but the set is very large; in other cases, the support provided each bit of evidence for the other is mixed: sometimes strong, sometimes weak, and so on.

There are three fundamental ideas that we want to extract from this segment of the course. These are (1) that argumentation is itself a requirement of being a researcher who claims to have made findings of one sort or another; (2) that there are different forms of appropriate argumentation for different domains and circumstances; and (3) that there are different forms of reasoning on behalf of various claims or from various bits of evidence to conclusions: whether those conclusions are value judgments, political beliefs, or scientific conclusions. Our goal is to familiarize you with all three of these deep ideas and to help you gain facility with each.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students will be able to

1. Distinguish among different modalities of argument, e.g. legal arguments, vs. scientific ones.
2. Construct arguments using tools of data visualization.
3. Communicate conclusions and arguments concisely, clearly and convincingly.

Indicative Literature

- Tufte, E.R. (1985). The visual display of quantitative information. The Journal for Healthcare Quality (JHQ), 7(3), 15.
- Cairo, A (2012). The Functional Art: An introduction to information graphics and visualization. New Ridders.
- Knaflic, C.N. (2015). Storytelling with data: A data visualization guide for business professionals. John Wiley & Sons.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written Examination

Duration/Length: 120 (min)
Weight: 100%

Scope: All intended learning outcomes of the module

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.8 Argumentation, Data Visualization and Communication (perspective II)

Module Name			**Module Code**	**Level (type)**	**CP**
Argumentation, Data Visualization and Communication (perspective II)			CTNS-NSK-08	Year 3 (New Skills)	5
Module Components					
Number	Name			Type	CP
CTNS-08	Argumentation, Data Visualization and Communication (perspective II)			Lecture (online)	5
Module Coordinator Prof. Dr. Jules Coleman, Prof Dr. Arvid Kappas	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective for all UG students (one perspective must be chosen)	
Entry Requirements Pre-requisites Logic Causation & Correlation	Co-requisites ☒ none	Knowledge, Abilities, or Skills • ability and openness to engage in interactions • media literacy, critical thinking and a proficient handling of data sources • own research in academic literature	**Frequency** Annually (Spring)	**Forms of Learning and Teaching** • Online Lecture (35 hours) • Tutorial of the lecture (10 hours) • Private study for the lecture (80 hours)	
			Duration 1 semester	**Workload** 125 hours	
Recommendations for Preparation					

Content and Educational Aims

Humans are a social species and interaction is crucial throughout the entire life span. While much of human communication involves language, there is a complex multichannel system of nonverbal communication that enriches linguistic content, provides context, and is also involved in structuring dynamic interaction. Interactants achieve goals by encoding information that is interpreted in the light of current context in transactions with others. This complexity implies also that there are frequent misunderstandings as a sender's intention is not fulfilled. Students in this course will learn to understand the structure of communication processes in a variety of formal and informal contexts. They will learn what constitutes challenges to achieving successful communication and to how to communicate effectively, taking the context and specific requirements for a target audience into consideration. These aspects will be discussed also in the scientific context, as well as business, and special cases, such as legal context – particularly with view to argumentation theory.

Communication is a truly transdisciplinary concept that involves knowledge from diverse fields such as biology, psychology, neuroscience, linguistics, sociology, philosophy, communication and information science. Students will learn what these different disciplines contribute to an understanding of communication and how theories from these fields can be applied in the real world. In the context of scientific communication, there will also be a focus on visual communication of data in different disciplines. Good practice examples will be contrasted with typical errors to facilitate successful communication also with view to the Bachelor's thesis.

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. Analyze communication processes in formal and informal contexts.
2. Identify challenges and failures in communication.
3. Design communications to achieve specified goals to specific target groups.
4. Understand the principles of argumentation theory.
5. Use data visualization in scientific communications.

Indicative Literature

- Joseph A. DeVito: The Interpersonal Communication Book (Global edition, 16th edition), 2022
- Steven L. Franconeri, Lace M. Padilla, Priti Shah, Jeffrey M. Zacks, and Jessica Hullman: The Science of Visual Data Communication: What Works Psychological Science in the Public Interest, 22(3), 110–161, 2022
- Douglas Walton: Argumentation Theory – A Very Short Introduction. In: Simari, G., Rahwan, I. (eds) Argumentation in Artificial Intelligence. Springer, Boston, MA, 2009

Examination Type: Module Examination

Assessment Type: Digital submission of asynchronous presentation, including reflection

Duration/Length: Asynchronous/Digital submission

Weight: 100%

Scope: All intended learning outcomes of the module

Module achievement: Asynchronous presentation on a topic relating to the major of the student, including a reflection including concept outlining the rationale for how arguments are selected and presented based on a particular target group for a particular purpose. The presentation shall be multimedial and include the presentation of data

The module achievement ensures sufficient knowledge about key concepts of effective communication including a reflection on the presentation itself

Completion: To pass this module, the examination has to be passed with at least 45%%.

8.2.9 Agency, Leadership, and Accountability

Module Name	**Module Code**	**Level (type)**	**CP**
Agency, Leadership, and Accountability	CTNS-NSK-09	Year 3 (New Skills)	5

Module Components

Number	Name	Type	CP
CTNS-09	Agency, Leadership, and Accountability	Lecture	5

Module Coordinator	**Program Affiliation**	**Mandatory Status**
Prof. Dr. Jules Coleman	• CONSTRUCTOR Track Area	Mandatory for CSSE Mandatory elective for all other UG study programs

Entry Requirements			**Frequency**	**Forms of Learning and Teaching**
Pre-requisites	Co-requisites	Knowledge, Abilities, or Skills	Annually (Spring)	Online Lectures (35h) Private Study (90h)
☒ none	☒ none		**Duration**	**Workload** 125 hours

Recommendations for Preparation

Content and Educational Aims

Each of us is judged by the actions we undertake and held to account for the consequences of them. Sometimes we may be lucky and our bad acts don't have harmful effects on others. Other times we may be unlucky and reasonable decisions can lead to unexpected or unforeseen adverse consequences for others. We are therefore held accountable both for choices and for outcomes. In either case, accountability expresses the judgment that we bear responsibility for what we do and what happens as a result. But our responsibility and our accountability in these cases is closely connected to the idea that we have agency.

Agency presumes that we are the source of the choices we make and the actions that result from those choices. For some, this may entail the idea that we have free will. But there is scientific world view that holds that all actions are determined by the causes that explain them, which is the idea that if we knew the causes of your decisions in advance, we would know the decision you would make even before you made it. If that is so, how can your choice be free? And if it is not free, how can you be responsible for it? And if you cannot be responsible, how can we justifiably hold you to account for it?

These questions express the centuries old questions about the relationship between free will and a determinist world view: for some, the conflict between a scientific world view and a moral world view.

But we do not always act as individuals. In society we organize ourselves into groups: e.g. tightly organized social groups, loosely organized market economies, political societies, companies, and more. These groups have structure. Some individuals are given the responsibility of leading the group and of exercising authority. But one can exercise authority over others in a group merely by giving orders and threatening punishment for non-compliance.

Exercising authority is not the same thing as being a leader? For one can lead by example or by encouraging others to exercise personal judgment and authority. What then is the essence of leadership?

The module has several educational goals. The first is for students to understand the difference between actions that we undertake for which we can reasonably held accountable and things that we do but which we are not responsible for. For example, a twitch is an example of the latter, but so too may be a car accident we cause as a result of a heart attack we had no way of anticipating or controlling. This suggests the importance of control to responsibility. At the heart of personal agency is the idea of control. The second goal is for students to understand what having control means. Some think that the scientific view is that the world is deterministic, and if it is then we cannot have any personal control over what happens, including what we do. Others think that the quantum scientific view entails a degree of indeterminacy and that free will and control are possible, but only in the sense of being unpredictable or random. But then random outcomes are not ones we control either. So, we will devote most attention to trying to understand the relationships between control, causation and predictability.

But we do not only exercise agency in isolation. Sometimes we act as part of groups and organizations. The law often recognizes ways in which groups and organizations can have rights, but is there a way in which we can understand how groups have responsibility for outcomes that they should be accountable for. We need to figure out then whether there is a notion of group agency that does not simply boil down to the sum of individual actions. We will explore the ways in which individual actions lead to collective agency.

Finally we will explore the ways in which occupying a leadership role can make one accountable for the actions of others over which one has authority.

Intended Learning Outcomes

Students acquire transferable and key skills in this module.

By the end of this module, the students will be able to

1. Understand and reflect how the social and moral world views that rely on agency and responsibility are compatible, if they are, with current scientific world views.
2. understand how science is an economic sector, populated by large powerful organizations that set norms and fund research agendas.
3. identify the difference between being a leader of others or of a group – whether a research group or a lab or a company – and being in charge of the group.
4. learn to be a leader of others and groups. Understand that when one graduates one will enter not just a field of work but a heavily structured set of institutions and that one's agency and responsibility for what happens, what work gets done, its quality and value, will be affected accordingly.

Indicative Literature

Hull, David L. "Science as a Process." Science as a Process. University of Chicago Press, 2010;

Feinberg, Joel. "Doing & deserving; essays in the theory of responsibility." (1970).

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written examination

Duration/Length: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module

Completion: To pass this module, the examination has to be passed with at least 45%

8.2.10 Community Impact Project

Module Name	**Module Code**	**Level (type)**	**CP**
Community Impact Project	CTCI-CI-950	Year 3 (New Skills)	5

Module Components

Number	Name	Type	CP
CTCI-950	Community Impact Project	Project	5

Module Coordinator	**Program Affiliation**	**Mandatory Status**
CIP Faculty Coordinator	• CONSTRUCTOR Track Area	Mandatory elective

Entry Requirements

Pre-requisites	Co-requisites	Knowledge, Abilities, or Skills
☒ at least 15 CP from CORE modules in the major	☒ None	1 Basic knowledge of the main concepts and methodological instruments of the respective disciplines

Frequency	**Forms of Learning and Teaching**
Annually (Fall / Spring)	• Introductory, accompanying, and final events: 10 hours • Self-organized teamwork and/or practical work in the community: 115 hours

Duration	**Workload**
1 semester	125 hours

Recommendations for Preparation

Develop or join a community impact project before the 5th or 6th semester based on the introductory events during the 4th semester by using the database of projects, communicating with fellow students and faculty, and finding potential companies, organizations, or communities to target.

Content and Educational Aims

CIPs are self-organized, major-related, and problem-centered applications of students' acquired knowledge and skills. These activities will ideally be connected to their majors so that they will challenge the students' sense of practical relevance and social responsibility within the field of their studies. Projects will tackle real issues in their direct and/or broader social environment. These projects ideally connect the campus community to other communities, companies, or organizations in a mutually beneficial way.
Students are encouraged to create their own projects and find partners (e.g., companies, schools, NGOs), but will get help from the CIP faculty coordinator team and faculty mentors to do so. They can join and collaborate in interdisciplinary groups that attack a given issue from different disciplinary perspectives.
Student activities are self-organized but can draw on the support and guidance of both faculty and the CIP faculty coordinator team.

Intended Learning Outcomes

The Community Impact Project is designed to convey the required personal and social competencies for enabling students to finish their studies at Constructor University as socially conscious and responsible graduates (part of the Constructor University's mission) and to convey social and personal abilities to the students, including a practical awareness of the societal context and relevance of their academic discipline.

By the end of this project, students will be able to

- understand the real-life issues of communities, organizations, and industries and relate them to concepts in their own discipline;
- enhance problem-solving skills and develop critical faculty, create solutions to problems, and communicate these solutions appropriately to their audience;

- apply media and communication skills in diverse and non-peer social contexts;
- develop an awareness of the societal relevance of their own scientific actions and a sense of social responsibility for their social surroundings;
- reflect on their own behavior critically in relation to social expectations and consequences;
- work in a team and deal with diversity, develop cooperation and conflict skills, and strengthen their empathy and tolerance for ambiguity.

Indicative Literature

Not specified

Usability and Relationship to other Modules

- Students who have accomplished their CIP (6th semester) are encouraged to support their fellow students during the development phase of the next year's projects (4th semester).

Examination Type: Module Examination

Project, not numerically graded (pass/fail)
Scope: All intended learning outcomes of the module

8.3 Language and Humanities Modules

8.3.1 Languages

The descriptions of the language modules are provided in a separate document, the "Language Module Handbook" that can be accessed from the Constructor University's Language & Community Center internet sites (https://constructor.university/student-life/language-community-center/learning-languages).

8.3.2 Humanities

8.3.2.1 Introduction to Philosophical Ethics

Module Name Introduction to Philosophical Ethics			**Module Code** CTHU-HUM-001	**Level (type)** Year 1	**CP** 2.5
Module Components					
Number	Name			Type	CP
CTHU-001	Introduction to Philosophical Ethics			Lecture (online)	2.5
Module Coordinator Dr. Eoin Ryan	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective	
Entry Requirements Pre-requisites ☒ none	Co-requisites ☒ none	Knowledge, Abilities, or Skills •	**Frequency** Annually (Fall)	**Forms of Learning and Teaching** Online lectures (17.5 h) Private Study (45h)	
			Duration 1 semester	**Workload** 62.5 hours	
Recommendations for Preparation					
Content and Educational Aims The nature of morality – how to lead a life that is good for yourself, and how to be good towards others – has been a central debate in philosophy since the time of Socrates, and it is a topic that continues to be vigorously discussed. This course will introduce students to some of the key aspects of philosophical ethics, including leading normative theories of ethics (e.g. consequentialism or utilitarianism, deontology, virtue ethics, natural law ethics, egoism) as well as some important questions from metaethics (are useful and generalizable ethical claims even possible; what do ethical speech and ethical judgements actually do or explain) and moral psychology (how do abstract ethical principles do when realized by human psychologies). The course will describe ideas that are key factors in ethics (free will, happiness, responsibility, good, evil, religion, rights) and indicate various routes to progress in understanding ethics, as well as some of their difficulties.					

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. Describe normative ethical theories such as consequentialism, deontology and virtue ethics.
2. Discuss some metaethical concerns.
3. Analyze ethical language.
4. Highlight complexities and contradictions in typical ethical commitments.
5. Indicate common parameters for ethical discussions at individual and social levels.
6. Analyze notions such as objectivity, subjectivity, universality, pluralism, value.

Indicative Literature

Simon Blackburn, Being Good (2009)

Russ Shafer-Landay, A Concise Introduction to Ethics (2019)

Mark van Roojen, Metaethicas: A Contemporary Introduction (2015)

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment Type: Written Examination

Duration/Length: 60 min
Weight: 100%

Scope: All intended learning outcomes of the module.

Completion: To pass this module, the examination has to be passed with at least 45%

8.3.2.2 Introduction to the Philosophy of Science

Module Name			Module Code	Level (type)	CP
Introduction to the Philosophy of Science			CTHU-HUM-002	Year 1	2.5
Module Components					
Number	Name			Type	CP
CTHU-002	Introduction to the Philosophy of Science			Lecture (online)	2.5
Module Coordinator Dr. Eoin Ryan	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective	
Entry Requirements Pre-requisites ☒ none	Co-requisites ☒ none	Knowledge, Abilities, or Skills	**Frequency** Annually (Spring)	**Forms of Learning and Teaching** Online lectures (17.5h) Private Study (45h)	
			Duration 1 semester	**Workload** 62.5 hours	
Recommendations for Preparation					

Content and Educational Aims

This humanities module will introduce students to some of the central ideas in philosophy of science. Topics will include distinguishing science from pseudo-science, types of inference and the problem of induction, the pros and cons of realism and anti-realism, the role of explanation, the nature of scientific change, the difference between natural and social sciences, scientism and the values of science, as well as some examples from philosophy of the special sciences (e.g., physics, biology).
The course aims to give students an understanding of how science produces knowledge, and some of the various contexts and issues which mean this process is never entirely transparent, neutral, or unproblematic. Students will gain a critical understanding of science as a human practice and technology; this will enable them both to better understand the importance and success of science, but also how to properly critique science when appropriate.

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. Understand key ideas from the philosophy of science.
2. Discuss different types of inference and rational processes.
3. Describe differences between how the natural sciences, social sciences and humanities discover knowledge.
4. Identify ways in which science can be more and less value-laden.
5. Illustrate some important conceptual leaps in the history of science.

Indicative Literature

Peter Godfrey-Smith, Theory and Reality (2021)

James Ladyman, Understanding Philosophy of Science (2002)

Paul Song, Philosophy of Science: Perspectives from Scientists (2022)

Usability and Relationship to other Modules	
Examination Type: Module Examination	
Assessment Type: Written Examination	Duration/Length: 60 min Weight: 100%
Scope: All intended learning outcomes of the module.	
Completion: To pass this module, the examination has to be passed with at least 45%	

8.3.2.3 Introduction to Visual Culture

Module Name Introduction to Visual Culture			Module Code CTHU-HUM-003	Level (type) Year 1	CP 2.5
Module Components					
Number	Name			Type	CP
CTHU-003	Introduction to Visual Culture			Lecture (online)	2.5
Module Coordinator Irina Chiaburu	**Program Affiliation** • CONSTRUCTOR Track Area			**Mandatory Status** Mandatory elective	
Entry Requirements			**Frequency** Annually (Spring/Fall)	**Forms of Learning and Teaching** Online Lecture	
Pre-requisites ☒ none	Co-requisites ☒ none	Knowledge, Abilities, or Skills	**Duration** 1 semester	**Workload** 62.5 h	
Recommendations for Preparation					

Content and Educational Aims

Of the five senses, the sense of sight has for a long time occupied the central position in human cultures. As John Berger has suggested this could be because we can see and recognize the world around us before we learn how to speak. Images have been with us since the earliest days of the human history. In fact, the earliest records of human history are images found on cave walls across the world. We use images to capture abstract ideas, to catalogue and organize the world, to represent the world, to capture specific moments, to trace time and change, to tell stories, to express feelings, to better understand, to provide evidence and more. At the same time, images exert their power on us, seducing us into believing in their 'innocence', that is into forgetting that as representations they are also interpretations, i.e., a particular version of the world.

The purpose of this course is to explore multiple ways in which images and the visual in general mediate and structure human experiences and practices from more specialized discourses, e.g., scientific discourses, to more informal and personal day-to-day practices, such as self-fashioning in cyberspace. We will look at how social and historical contexts affect how we see, as well as what is visible and what is not. We will explore the centrality of the visual to the intellectual activity, from early genres of scientific drawing to visualizations of big data. We will examine whether one can speak of visual culture of protest, look at the relationship between looking and subjectivity and, most importantly, ponder the relationship between the visual and the real.

Intended Learning Outcomes

Upon completion of this module, students will be able to

1. Understand a range of key concepts pertaining to visual culture, art theory and cultural analysis
2. Understand the role visuality plays in development and maintenance of political, social, and intellectual discourses
3. Think critically about images and their contexts
4. Reflect critically on the connection between seeing and knowing

Indicative Literature

- Berger, J., Blomberg, S., Fox, C., Dibb, M., & Hollis, R. (1973). Ways of seeing.
- Foucault, M. (2002). The order of things: an archaeology of the human sciences (Ser. Routledge classics). Routledge.
- Hunt, L. (2004). Politics, culture, and class in the French revolution: twentieth anniversary edition, with a new preface (Ser. Studies on the history of society and culture, 1). University of California Press.
- Miller, V. (2020). Understanding digital culture (Second). SAGE.

- Thomas, N. (1994). Colonialism's culture: anthropology, travel and government. Polity Press.

Usability and Relationship to other Modules

Examination Type: Module Examination

Assessment: Written examination — Duration/Length: 60 min. Weight: 100%

Scope: all intended learning outcomes

Completion: To pass this module, the examination has to be passed with at least 45%

9 Appendix

9.1 Intended Learning Outcomes Assessment Matrix

Electrical and Computer Engineering (ECE) B.Sc	A	E	P	S	General Electrical Engineering I	General Electrical Engineering II	Classical Physics	Introduction to Computer Science	Programming in C and C++	Programming in Python and C++	Introduction to Robotics and Intelligent Systems	Algorithms and Data Structures	Core Algorithms and Data Structures	Modern Physics	Mathematical Modelling	Signals and Systems	Digital Signal Processing	Communications Basics	Wireless Communication I	Electromagnetics	Information Theory	Electronics	PCB Design and Measurement Automation	SPEC: Wireless Communication II	SPEC Coding Theory	SPEC Digital Design	SPEC Radio-Frequency (RF) Design	Internship	Bachelor Thesis	CT Methods	CT Langauge and Humanities	CT New Skills
Semester					1	2	1	2	1	1	2	2	2	2	2	3	4	3	4	3	4	5	4	5/6	5/6	5/6	5/6	5	6	1-4	1-2	5/6
Mandatory/ optional					m	m	m	me	me	me	me	me	me	me	me	m	m	m	m	m	m	m	m	me	me	me	me	m	m	m	m	m
Credits					7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	7.5	5	5	5	5	5	5	5	5	5	5	15	15	20	5	20
	Competencies*																															
Program Learning Outcomes	A	E	P	S																												
describe the underlying natural physical foundation, especially Maxwell' equations; describe and apply mathematical basics and tools	x	x			x	x	x	x			x			x	x	x	x	x	x	x	x	x	x				x		x	x		
describe the underlying theoretical concepts of deterministic and random signals in time and frequency domain	x	x			x	x										x	x	x			x			x	x				x			
compare results to theoretical limits, e.g., provided by Information Theory	x	x	x														x	x	x	x	x	x	x	x	x				x			
explain and implement signal processing components, methods, and algorithms, having studied the theoretical foundation and having learned programming languages Matlab, C, C++, assembler, VHDL for general-purpose, signal processor platforms, or FPGAs	x	x							x	x	x					x	x	x	x		x	x	x	x	x	x			x			
treat signals with dedicated algorithms, be it audio, video, or from other origin, e.g., by filtering, prediction, compression	x	x															x	x	x		x		x	x	x	x			x			
design suitable transmission methods for diverse channels, wireline and wireless on the basis of channel properties and models, knowing an almost complete set of transmission methods	x	x	x													x	x	x	x	x	x			x	x	x	x		x			
know typical electronic components and their standard base circuits and to implement dedicated circuitry, be it analog or digital, including the printed circuit board layout	x	x	x		x	x										x	x			x		x	x			x	x		x			
use advanced measurement equipment, like high-end scopes, spectrum and network analyzers including their remote control	x	x			x	x										x	x	x				x	x			x	x		x			
design MAC and higher protocols, error correcting codes, and compression schemes, also know major security schemes and their implementation	x	x																			x			x	x	x	x		x			
use academic or scientific methods as appropriate in the field of Electrical and Computer Engineering such as defining research questions, justifying methods, collecting, assessing and interpreting relevant information, and drawing scientifically-founded conclusions that consider social, scientific, and ethical insights	x	x																					x						x			
develop and advance solutions to problems and arguments in Electrical and Computer Engineering and defend these in discussions with specialists and non-specialists	x	x			x	x						x	x	x	x	x	x	x					x						x			x
engage ethically with academic, professional and wider communities and to actively contribute to a sustainable future, reflecting and respecting different views	x	x	x	x	x	x			x	x						x	x	x					x					x	x		x	x
take responsibility for their own learning, personal and professional development, and role in society, evaluating critical feedback and self-analysis	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x		x	x
apply their knowledge and understanding to a professional context	x	x			x	x	x									x	x	x										x	x		x	x
take on responsibility in a diverse team		x	x		x	x	x		x	x				x	x	x	x	x					x					x			x	x
adhere to and defend ethical, scientific, and professional standards	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Assessment Type																																
Oral examination																																
Written examination					x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x			x		x
Project													x																x			x
Term paper																													x			
Lab report					x	x	x			x				x	x	x	x	x					x					x				
Poster presentation																																
Presentation																													x			
Various																															x	x
Module achievements/bonus achievements							x				x																				x	

*Competencies: A-scientific/academic proficiency; E-competence for qualified employment; P-development of personality; S-competence for engagement in society

Figure 5: Intended Learning Outcomes Assessment-Matrix