# Study Program Handbook

## Physics

Bachelor of Science

**Subject-specific Examination Regulations for Physics (Fachspezifische Prüfungsordnung)**

The subject-specific examination regulations for Physics 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 (for specifics see Chapter 6 of this handbook).

| Version | Valid as of | Decision | Details |
|---|---|---|---|
| Fall 2021 – V1 | Sep 01, 2021 | Jun 26, 2019 | V1 Originally approved by the Academic Senate |

# Contents

# 1 Program Overview

## 1.1 Concept

### 1.1.1 The Jacobs University Educational Concept

Jacobs University aims to educate students for both an academic and a professional career by emphasizing four core objectives: academic quality, self-development/personal growth, internationality and the ability to succeed in the working world (employability). Hence, study programs at Jacobs University offer a comprehensive, structured approach 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.

In this context, it is Jacobs 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 in the democratic, peaceful, and sustainable development of the societies in which they live. This is achieved through high-quality teaching, 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 Jacobs University, both in terms of actual disciplinary subject matter and also of social skills and intercultural competence. Study-program-specific modules and additional specializations provide the necessary depth, interdisciplinary offerings and the minor option provide breadth while the university-wide general foundation and methods modules, mandatory German language requirements, 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 complements students' education. In addition, Jacobs University offers professional advising and counseling.

Jacobs 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, 2020 and 2021. 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

Physics has shaped our view of the universe by studying the basic concepts of space, time, and matter. Physics not only lays the foundation for other natural sciences and many engineering disciplines, but is also a fundamental part of modern technology such as transistors, lasers, or global positioning systems. Physics is also of fundamental importance for global challenges such as global warming, E-mobility, or renewable energies.

Physicists describe our world by using only a few basic principles and together with mathematical methods connect and apply these principles. As in any natural science, physicists check their theoretical outcomes by performing appropriate experiments. The qualification aims for a physics bachelor degree therefore include on one side a solid knowledge about the basic physical concepts and how they can be used to explain natural phenomena or technical devices. On the other side, physicists will be able to design, perform, and evaluate experiments to investigate unknown phenomena or to verify new theories. To do so, a physics BSc is trained in a thorough understanding of mathematical methods, computational tools, and other quantitative problem-solving skills to describe physical phenomena and complex systems.

The Jacobs University physics major is a three-year BSc program. Its content is oriented along the guidelines of the Konferenz der Fachbereiche der Physik (KFP) in Germany, the Institute of Physics (Britain) for BSc in Physics, and the topics required for the Graduate Record Examination (GRE) physics test. The physics program is frequently optimized and fine-tuned by feedback from students and instructors and developments in research and teaching.

The first year starts with a broad introduction to classical and modern physics and their mathematical foundations, complemented by a choice of other subjects. The emphasis is on an overview of physical phenomena. The second year of study features a thorough and advanced education in the foundations of physics (analytical mechanics, electrodynamics, quantum mechanics, and statistical physics), and in fields of recent interest such as computational physics or renewable energy. Lectures and interactive seminars with constant learning feedback by means of weekly homework are complemented by hands-on work in teaching labs. Motivated and interested students are encouraged to join a research group even before their thesis work. Between the fourth and fifth semester, students will perform an internship in a company or an academic institution. The third year finally features a varying selection of specialization courses (such as condensed matter physics and particles, fields, and quanta) and guided research leading to the BSc thesis.

A Jacobs University BSc in Physics provides a solid and simultaneously flexible foundation for careers in diverse fields, from basic research in academia to engineering in industry or in the educational sector. The broad training in analytical skills, technical thinking and the appreciation of complexity and subtlety allows physicists to also work often with additional qualification in finance and consulting/management. Physicists are the all-rounders among the natural scientists. The physics curriculum at Jacobs University is designed to ensure that graduates will be well prepared for postgraduate programs in physics and related fields at global leading universities.

The scientific knowledge, the international network of physics alumni, and the problem solving and social skills acquired during studies of physics at Jacobs University guarantee success in our increasingly technology-driven society, as demonstrated by our many very successful graduates.

## 1.2 Specific Advantages of Physics at Jacobs University

The institutional framework of the three-year Jacobs University Physics BSc program is unique in its internationality and research experience. Students gain extra learning and research experience through an internship and by working in research groups of professors for their BSc thesis work or even before. The level of courses is on par with physics programs at leading international universities.

Since students live on our residential campus, they are immersed in a stimulating international and academic community, supporting and enhancing their learning. This provides an ideal preparation for postgraduate studies of physics and related fields at leading international universities.

Our physics graduates are very successful in either being admitted to top postgraduate programs (MSc/PhD) in physics and related fields, directly entering employment, or starting their own businesses. We use feedback from our graduates to continuously improve our study program, and the graduates themselves benefit from our international alumni network.

For students with a strong interdisciplinary interest, the program easily allows the pursuit of a minor in some of the other bachelor programs at Jacobs University in addition to their regular physics major.

## 1.3 Program-Specific Educational Aims

### 1.3.1 Qualification Aims

Our main objective is to provide a broad and thorough education in physics with some advanced topics and exposure to research. Students learn the foundations and advanced concepts of classical and modern physics. In lab courses and research projects, they are provided with hands-on training in experimental methods and techniques in physics, but also in computational approaches. By giving presentations, writing lab reports, term papers, and the BSc thesis, they gain familiarity with tools and approaches to access and communicate scientific information. The BSc education in physics at Jacobs University is designed to serve as an excellent foundation for graduate programs in physics and related fields. As such, it contains the core topics of any serious physics program: analytical mechanics, electrodynamics, quantum mechanics, statistical physics, as well as condensed matter physics and specialization topics such as biophysics, computational physics, particles and fields, and electronic devices. The analysis of complex systems, logical and quantitative thinking, solid mathematical skills, and a broad background in diverse physical phenomena is an asset for any profession in modern society.

### 1.3.2 Intended Learning Outcomes

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

- recall and understand the basic facts, principles, formulas, and experimental evidence from the major fields of physics, namely, classical physics (mechanics, thermodynamics, optics, and electrodynamics), modern physics (including atomic physics, quantum mechanics, relativity, and elementary particle physics), and statistical physics;
- describe and understand natural and technical phenomena by reducing them to basic physical principles from the various fields of physics;
- analyze complex systems to extract underlying and organizing principles;
- apply a variety of mathematical methods and tools especially from analysis and linear algebra to describe physical systems;
- use numerical and computational methods to describe and analyze physical systems;

- examine physical problems and apply their mathematical skills and knowledge from different fields in physics to find possible solutions and assess them critically;
- conceive and apply analogies, approximations, estimates, or extreme cases to test the plausibility of ideas or solution to physical problems;
- set up and perform experiments, analyze their outcomes with the pertinent precision, and present them properly;
- work responsibly in a team on a common task, with the necessary preparation, planning, communication, and work organization;
- use the appropriate language of the scientific community to communicate, discuss, and defend scientific findings and ideas in physics;
- familiarize themselves with a new field in physics by finding, reviewing, and digesting the relevant scientific information to work independently or as a team member on a physics-related problem or on a scientific research project;
- apply their knowledge and understanding from their BSc Physics education to advance their personal career either by professional employment or by further academic or professional education;
- take on responsibility for their own personal and professional role in society by critical self-evaluation and self-analysis;
- adhere to and defend ethical, scientific, and professional standards, but also reflect on and respect different views;
- act as a scientifically literate citizen to provide sound evidence-based solutions and arguments especially when communicating with specialists or laymen, or when dealing with technology or science issues;
- appreciate the importance of education, community, and diversity for personal development and a peaceful and sustainable world.

## 1.4 Career Options

Physicists are the all-rounders of the natural scientists. About two-thirds work on advancing our scientific knowledge or develop new technologies, products, and processes. Research positions are found in research centers, scientific institutes, and universities. In industry, physicists work in fields like IT, software development, electronics, lasers, optics, and semiconductors. An increasing demand for physicists also comes from the medical technology sector. Another large fraction of physicists holds faculty positions at universities and colleges or work in other branches of education.

A Jacobs University BSc in Physics provides a solid and simultaneously flexible foundation for careers in diverse fields, from basic research to engineering and life sciences, to finance and management. The scientific knowledge, the problem-solving skills, and the social skills acquired during studies of physics at Jacobs University guarantee success in our increasingly technology-driven society, as demonstrated by our many very successful graduates.

The physics curriculum at Jacobs University is designed to ensure that graduates will be well prepared for postgraduate programs in physics and related fields at leading international universities. The physics program is oriented along the guidelines of the Konferenz der Fachbereiche der Physik (KFP) in Germany, the Institute of Physics (Britain) for BSc in Physics, and the topics required for the Graduate Record Examination (GRE) physics test.

The broad training in analytical skills, technical thinking, and the appreciation of complexity and subtlety allows physicists to work—often with additional qualifications—as management consultants, patent attorneys, market analysts, or risk managers. Many BSc degree recipients go on to graduate in physics and other fields, as careers in research and development usually require a postgraduate degree.

Jacobs University Physics BSc graduates have an excellent placement record in top graduate programs. Very helpful for career development is also the opportunity for international network building with Jacobs University students coming from more than one hundred different nations. Good communication skills are essential, since many physicists work as part of a team, have contact with clients with non-physics backgrounds, and need to write research papers and proposals. These skills are particularly well developed in the broad and multidisciplinary undergraduate program at Jacobs University.

The Career Services Center (CSC) as well as the Jacobs Alumni Office help students in their career development. The CSC provides students with high-quality training and coaching in CV creation, cover letter formulation, interview preparation, effective presenting, business etiquette, and employer research, as well as in many other aspects, thus helping students identify and follow up on rewarding careers after their time at Jacobs University. Furthermore, the Alumni Office helps students establish a long-lasting and worldwide network which is useful when exploring job options in academia, industry, and elsewhere.

## 1.5 Admission Requirements

Admission to Jacobs University is selective and based on a candidate's school and/or university achievements, recommendations, self-presentation, and performance on required standardized tests. Students admitted to Jacobs 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
- Official or certified copies of high school/university transcripts
- Educational History Form
- Standardized test results (SAT/ACT/TestAS) if applicable
- ZeeMee electronic resume (optional)
- Language proficiency test results (TOEFL, IELTS or equivalent)

German language proficiency is not required; rather all applicants need to submit proof of English proficiency.

For any student who has acquired the right to study at a university in the country where s/he has acquired the higher education entrance qualification Jacobs University accepts the common international university entrance tests as a replacement for the entrance examination. Applicants who have a subject-related entrance qualification (fachgebundene Hochschulreife) may be admitted only to respective study programs.

For more detailed information visit:

https://www.jacobs-university.de/study/undergraduate/application-information

## 1.6 More Information and Contact

For more information, please contact the study program chairs:

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or visit our program website: www.jacobs-university.de/physics

# 2 The Curricular Structure

## 2.1 General

The curricular structure provides multiple elements for enhancing employability, interdisciplinarity, and internationality. The unique Jacobs 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 opportunities 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 Jacobs 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 as well as minor study interests and complete their studies within the regular period.

The framework policies and procedures regulating undergraduate study programs at Jacobs University can be found on the website (https://www.jacobs-university.de/academic-policies).

## 2.2 The Jacobs University 3C Model

Jacobs 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 3C-Model - that groups the disciplinary content of the three study years according to overarching themes:

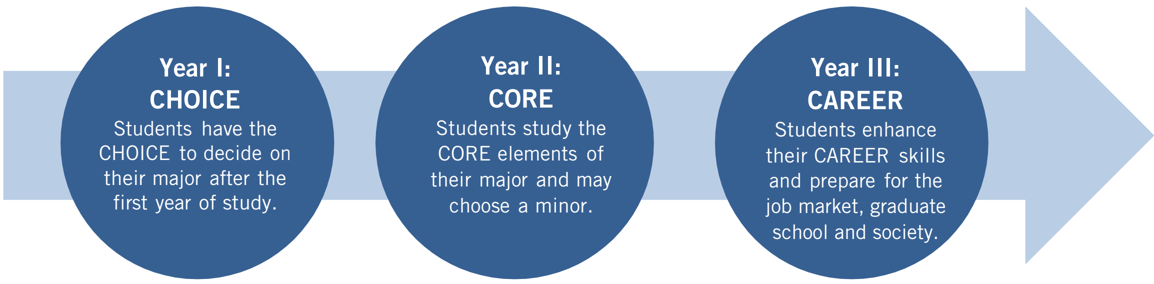


*Figure 1: The Jacobs University 3C-Model*

### 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 15-30 CP will belong to their intended major. A unique feature of our curricular structure allows students to select their major freely upon entering Jacobs University. The Academic Advising Coordinator offers curricular counseling to all Bachelor students independently of their major, while Academic Advisors, in their capacity as contact persons from the faculty, support students individually in deciding on their major study program.

To pursue Physics as a major, the following CHOICE modules (15 CP) need to be taken as mandatory modules:

- CHOICE Module: Classical Physics (7.5 CP)
- CHOICE Module: Modern Physics (7.5 CP)

Students can choose between the following mandatory elective modules:

- CHOICE Module: Applied Mathematics (7.5 CP)
- CHOICE Module: Introduction to Robotics and Intelligent Systems (7.5 CP)

The Classical Physics and Modern Physics modules provide physics students with an overview of the major fields in physics such as mechanics, optics, and thermodynamics (in Classical Physics) and electromagnetism and modern physics (in Modern Physics). With a focus on experimental findings and basic concepts, they summarize high school knowledge, go beyond it, and prepare students for in-depth physics studies in the second year. The modules also contain a lab where students are introduced to basic experimental techniques in physics, performing and analyzing experiments. The mathematical foundations for advanced physics studies are laid out in the Applied Mathematics module (in addition to math-specific methods courses). This module is strongly recommended for physics majors, but can be replaced with the Introduction to RIS (with a MATLAB lab) to accommodate students that plan to pursue a major in RIS or CS. Students who do not take the Applied Mathematics module may have to independently catch up on missing mathematics topics relevant to Electrodynamics and other CORE physics courses.

The remaining CHOICE modules (22.5 CP) can be selected in the first year of study according to interest and/or with the aim of allowing a change of major until the beginning of the second year, when the major choices become fixed (see 2.2.1.1 below).

#### 2.2.1.1 Major Change Option

Students can still change to another major at their beginning of the second year of studies, provided they have taken the corresponding mandatory CHOICE modules in their first year of studies. All students must participate in a seminar on the major change options in the O-Week and consult their Academic Advisor during their first year of studies prior to changing their major.

Physics students who would like to retain an option for a major change are strongly recommended to register for the CHOICE modules of one of the following study programs in their first year. The module descriptions can be found in the respective Study Program Handbook.

- Mathematics (Math)
  CHOICE Module: Analysis I (7.5 CP)
  CHOICE Module: Advanced Linear Algebra (7.5 CP)
  *CHOICE Module: Applied Mathematics (7.5 CP)* [1]

- Earth and Environmental Sciences (EES)

CHOICE Module: General Earth & Environmental Sciences (7.5 CP)
CHOICE Module: General Geosciences (7.5 CP)

- Computer Science (CS)
  CHOICE Module: Programming in C and C++ (7.5 CP)
  CHOICE Module: Algorithms and Data Structures (7.5 CP)
  CHOICE Module: Introduction to Computer Science (7.5 CP)
  *CHOICE Module: Introduction to Robotics and Intelligent Systems (7.5 CP)* [1]

- Society, Media and Politics (SMP)
  CHOICE Module: Introduction to the Social Sciences 1: Politics and Society (7.5 CP)
  CHOICE Module: Introduction to the Social Sciences 2: Media and Society (7.5 CP)

- Integrated Social and Cognitive Psychology (ISCP)
  CHOICE Module: Essentials of Cognitive Psychology (7.5 CP)
  CHOICE Module: Essentials of Social Psychology (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 students have already 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.

To pursue Physics as a major, the following 30 CP mandatory CORE modules need to be acquired:

- CORE Module: Analytical Mechanics (5 CP)
- CORE Module: Electrodynamics (5 CP)
- CORE Module: Quantum Mechanics (5 CP)
- CORE Module: Statistical Physics (5 CP)
- CORE Module: Advanced Physics Lab I (5 CP)
- CORE Module: Advanced Physics Lab II (5 CP)

Students can decide to either complement their studies by taking the following mandatory elective CORE modules (15 CP) from Physics:

- CORE Module: Computational Physics (5 CP),
- CORE Module: Renewable Energy (5 CP),
- CORE Module: Advanced Physics Lab III (5 CP),

or they may substitute these modules with CORE modules from a second field of study according to interest and with the aim of pursuing a minor.

The Physics CORE modules contain an advanced discussion of the major fields of physics, as given in their titles. They focus on the theory and mathematical description of the respective

[1] This is one of the two mandatory elective CHOICE modules Physics students have to take in their second semester. Students who would like to retain an option for a change to this study program have to select this option.

fields, but also include discussions of additional experimental findings and methods. In Advanced Physics Lab I, students will perform advanced experiments from mechanics and electrodynamics, whereas in Advanced Physics Lab II, they will perform experiments related to quantum mechanics and statistical physics.

#### 2.2.2.1 Minor Option

Physics students can take CORE modules (or more advanced Specialization modules) from a second discipline, which allows them to incorporate a minor study track into their undergraduate education, within the 180 CP required for a bachelor's degree. The educational aims of a minor are to broaden students' knowledge and skills, support a critical reflection on statements in complex contexts, foster an interdisciplinary approach to problem-solving, and to develop an individual academic and professional profile in line with students' strengths and interests. This extra qualification will be highlighted in the transcript.

The Academic Advising Coordinator, Academic Advisor, and the Study Program Chair of the minor study program support students in the realization of the minor option. In addition, the consultation with the Academic Advisor is mandatory when choosing a minor.

As a rule, this requires Physics students to:

- select CHOICE modules (15 CP) from the desired minor program in the first year and
- substitute mandatory elective Physics CORE modules (15 CP) in the second year with the default minor CORE modules of the minor study program.

The requirements for each specific minor are described in the handbook of the study program offering the minor (Chapter 3.2) and are marked in Study and Examination Plans of the respective programs. For an overview of accessible minors, please check the Major/Minor Combination Matrix which is published at the beginning of each academic year.

### 2.2.3 Year 3 – CAREER

During their third year, students prepare for and make decisions about their career after graduation. To explore available choices, and to gain professional experience, students take a mandatory summer internship. The third year of studies allows Physics students to take Specialization modules in their discipline, but it also focuses on the responsibility of students beyond their discipline (see Jacobs Track).

The fifth semester also opens a mobility window for a diverse range of study abroad options. Finally, the sixth 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 Jacobs 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 personal role in employment and society, and develope 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 their business plans.

For further information, please contact the Career Services Center (https://www.jacobs-university.de/career-services).

#### 2.2.3.2 Specialization Modules

In the third year of their study, students take 15 CP from major-specific or major-related, advanced Specialization modules to consolidate their knowledge at the current state of research in areas of their choice. 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 Physics as major, at least 15 CP from the following mandatory elective Specialization modules need to be taken:

Dedicated physics Specialization modules (10 or 15 CP recommended):

- Specialization: Condensed Matter Physics (5 CP)
- Specialization: Particles, Fields and Quanta (5 CP)
- Specialization: Advanced Applied Physics (5 CP)

Alternative Specialization modules from other majors:

- Specialization: Foundations of Mathematical Physics (5 CP)
- CORE: Electronics (5 CP)
- CORE: Physical Chemistry (5 CP)

Please consult a physics SPC for further options.

The Condensed Matter Physics module contains an in-depth discussion of the basic concepts of solid-state physics and electronic devices. Particles, Fields, and Quanta contains topics on elementary particles and fields and advanced quantum physics, whereas Advanced Applied Physics discusses a selection of topics from advanced experimental physics such as biophysics, nanotechnology, advanced optics, or molecular physics. Suitable modules from other majors can also be chosen as Specializations with the written consent of a physics SPC.

#### 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 Jacobs University study abroad procedures. Several exchange programs allow students to directly enroll at prestigious partner institutions worldwide. Jacobs 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://www.jacobs-university.de/study/international-office).

Physics 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 Big Questions modules or the Community Impact Project (see Jacobs 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 Big Questions modules to reach 15 CP in this area. Study abroad students are allowed to substitute the 5 CP Community Impact Project (see Jacobs Track below) with 5 CP of Big Questions modules.

#### 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 Jacobs 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 Jacobs 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 Jacobs Track**

The Jacobs Track is another important feature of Jacobs University's educational model. The Jacobs Track runs parallel to the disciplinary CHOICE, CORE, and CAREER modules across all study years and is an integral part of all undergraduate study programs. It reflects a university-wide commitment to an in-depth training in scientific methods, fosters an interdisciplinary approach, raises awareness of global challenges and societal responsibility, enhances employability, and equips students with augmented skills desirable in the general field of study. Additionally, it integrates (German) language and culture modules.

### 2.3.1 Methods and Skills modules

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

To pursue Physics as a major, the following Methods and Skills modules (10 CP) need to be taken as mandatory modules:

- Methods Module: Calculus and Elements of Linear Algebra I (5 CP)
- Methods Module: Calculus and Elements of Linear Algebra II (5 CP)

For the remaining 10 CP Physics students can choose in each semester among two Methods modules:

- Methods Module: Numerical Methods (5 CP)
- Methods Module: Probability and Random Processes (5 CP)

and

- Methods Module: Programming in Python (5 CP)
- CORE Module: Discrete Mathematics (5 CP)

### 2.3.2 Big Questions modules

The modules in the Big Questions area (10 CP) intend to broaden students' horizons with applied problem solving between and beyond their chosen disciplines. The offerings in this area comprise problem-solving oriented modules that tackle global challenges from the perspectives of different disciplinary backgrounds that allow, in particular, a reflection of acquired disciplinary knowledge in economic, societal, technological, and/or ecological contexts. Working together with students from different disciplines and cultural backgrounds, these modules cross the boundaries of traditional academic disciplines.

Students are required to take 10 CP from modules in the area. This curricular component is offered as a portfolio of modules, from which students can make free selections during their fifth and sixth semester with the aim of being exposed to the full spectrum of economic, societal, technological, and/or ecological contexts. The size of Big Questions modules is either 2.5 or 5 CP.

### 2.3.3 Community Impact Project

In their fifth semester students are required to take a 5 CP Community Impact Project (CIP) module. Students engage in on-campus or off-campus activities that challenge their social responsibility, i.e., they typically work on major-related projects that make a difference in the community life on campus, in the campus neighborhood, Bremen, or on a cross-regional level. The project is supervised by a faculty coordinator and mentors.

Study abroad students are allowed to substitute the 5 CP Community Impact Project with 5 CP of Big Questions modules.

### 2.3.4 Language modules

Communication skills and foreign language abilities foster students' intercultural awareness and enhance their employability in an increasingly globalized and interconnected world. Jacobs University supports its students in acquiring and improving these skills by offering a variety of language modules at all proficiency levels. Emphasis is put on fostering the German language skills of international students as they are an important prerequisite for non-native students to learn about, explore, and eventually integrate into their host country and its professional environment. Students who meet the required German proficiency level (e.g., native speakers) are required to select modules in any other modern foreign language offered (Chinese, French or Spanish). Hence, acquiring 10 CP in language modules, with German mandatory for non-native speakers, is a requirement for all students. This curricular component is offered as a four-semester sequence of foreign language modules. The size of the Language Modules is 2.5 CP.

# 3 Physics as a Minor

Physics not only lays the foundation for other natural sciences and many engineering disciplines, but is also a fundamental part of modern technology. A physics minor is especially interesting for students who want to gain a solid quantitative foundation of the description of nature starting with the concepts of motion, force and energy, particles, and fields. In a physics minor, those topics are discussed in more depth and breadth than it is possible in disciplines such as chemistry, life science, or earth and environmental science. Engineering-oriented students can learn more about the scientific foundations of their engineering discipline. By choosing a physics minor, math-oriented students learn how mathematical and computational methods can be applied to describe real-world phenomena or to solve technical problems.

## 3.1 Qualification Aims

The main objective of a physics minor is a broad overview of the different fields in physics in the first year and a focus on some in-depth topics in the second year. Students will learn the foundations of physics with some advanced concepts of classical and modern physics. In lab courses, they will receive hands-on training in experimental methods and techniques in physics. By writing lab reports, they will gain familiarity with the field-specific language and scientific standards in physics. In the second year, they will focus on a specific topic and use more advanced mathematical tools and advanced physical concepts to describe physical phenomena.

### 3.1.1 Intended Learning Outcomes

With a minor in Physics, students will be able to:

- recall and understand the basic facts, principles and formula, and experimental evidence from the major fields of physics, namely, classical physics (mechanics, thermodynamics, optics, and electrodynamics), and modern physics;
- describe and understand natural and technical phenomena by reducing them to basic physical principles from selected fields of physics;
- apply basic mathematical methods to describe physical systems;

- examine physical problems and apply appropriate mathematical methods and physical knowledge to find possible solutions within a specific field of physics;
- set up and perform basic experiments in physics, analyze their outcomes with the pertinent precision, and present them properly.

### 3.2 Module Requirements

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

- CHOICE Module: Classical Physics (7.5 CP)
- CHOICE Module: Modern Physics (7.5 CP)
- CORE Module: Analytical Mechanics (5 CP)
- CORE Module: Quantum Mechanics (5 CP)
- CORE Module: Computational Physics (5 CP)

The selection of CHOICE modules is fixed to ensure a solid foundation in physics, but to accommodate different interests, the default CORE modules for a physics minor might be replaced by other advanced modules (CORE or Specialization) from the physics major upon consultation with the Academic Advisor and the Physics Study Program Coordinator.

### 3.3 Degree

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

## 4 Physics Undergraduate Program Regulations

### 4.1 Scope of these Regulations

The regulations in this handbook are valid for all students who entered the Physics undergraduate program at Jacobs University in Fall 2021. In case of conflict between the regulations in this handbook and the general Policies for Bachelor Studies, the latter apply (see http://www.jacobs-university.de/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, Jacobs University Bremen reserves therefore the right to change or 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 Physics.

## 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 Study and Examination Plan in Chapter 6 of this handbook.

## 5 Schematic Study Plan for Physics

*Figure 2* schematically shows 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 Plan in following section.

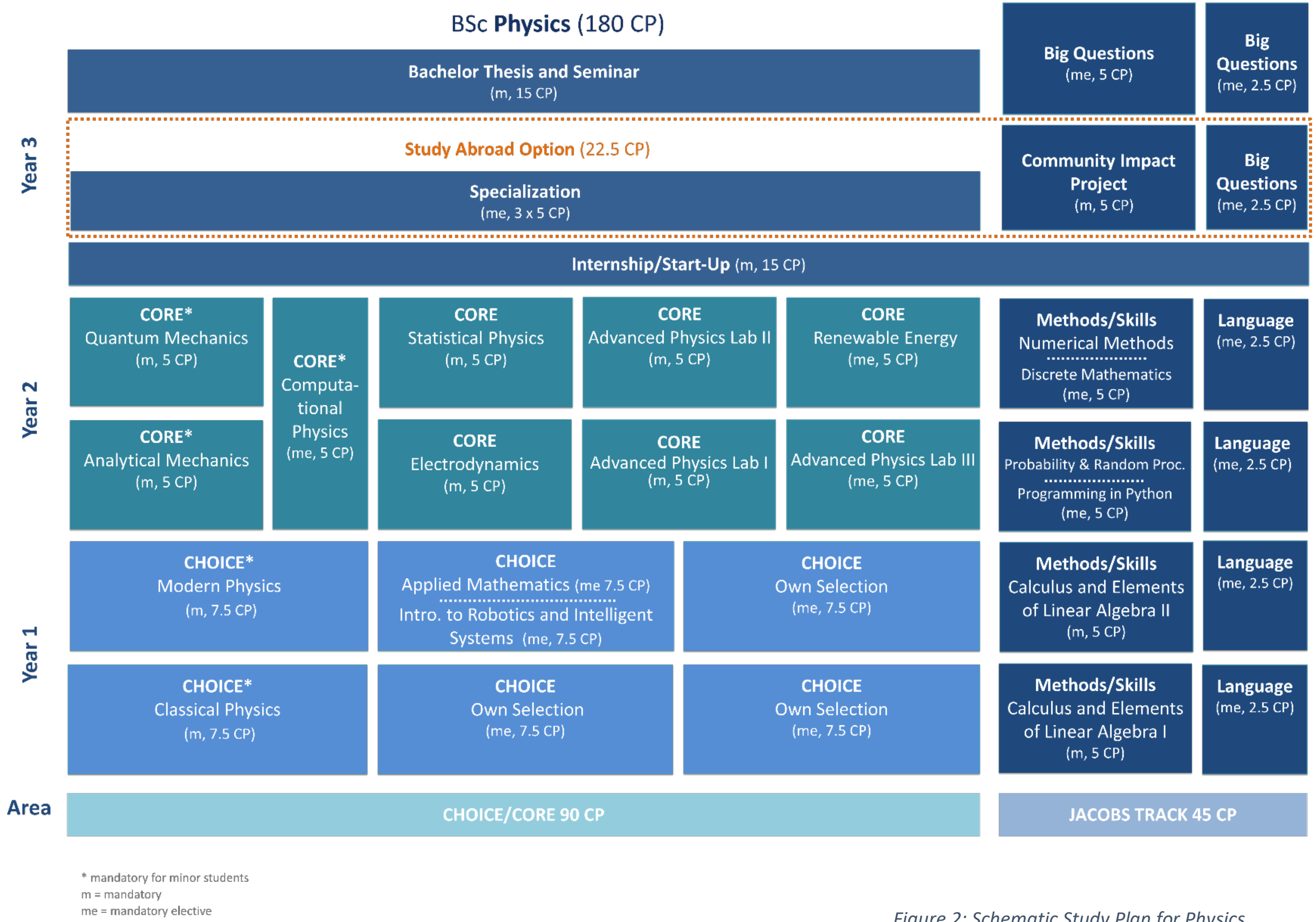


*Figure 2: Schematic Study Plan for Physics*

# 6 Study and Examination Plan

## Physics BSc

**Matriculation Fall 2021**

| | Program-Specific Modules | Type | Assessment | Period | Status[1] | Sem. | CP |
|---|---|---|---|---|---|---|---|
| **Year 1 - CHOICE** | *Take the mandatory CHOICE modules listed below, these are a requirement for the physics program.* | | | | | | **45** |
| | **Unit: Classical and Modern Physics** (default minor) | | | | | | **15** |
| **CH-140** | **Module: Classical Physics** (default minor) | | | | **m** | | **7.5** |
| CH-140-A | Classical Physics | Lecture | Written exam | Examination period | | 1 | 5 |
| CH-140-B | Classical Physics Lab | Lab | Lab report | During the semester | | 1 | 2.5 |
| **CH-141** | **Module: Modern Physics** (default minor) | | | | **m** | | **7.5** |
| CH-141-A | Modern Physics | Lecture | Written exam | Examination period | | 2 | 5 |
| CH-141-B | Modern Physics Lab | Lab | Lab report | During the semester | | 2 | 2.5 |
| *Take one of the two mandatory elective CHOICE modules listed below, these are a requirement for the physics program (see study program handbook).* | | | | | | | |
| **CH-202** | **Module: Applied Mathematics** | | | | **me** | | **7.5** |
| CH-202-A | Advanced Calculus and Methods of Mathematical Physics | Lecture | Written exam | Examination period | | 2 | 5 |
| CH-202-B | Numerical Software Lab | Lab | Lab report | During the semester | | 2 | 2.5 |
| **CH-220** | **Module: Introduction to Robotics and Intelligent Systems** | | | | **me** | | **7.5** |
| CH-220-A | Introduction to Robotics and Intelligent Systems | Lecture | Written examination | Examination period | | 2 | 5 |
| CH-220-B | Intro to RIS - lab | Lab | | | | 2 | 2.5 |
| | **Unit: CHOICE (own selection)** | | | | **me** | **1/2** | **22.5** |
| | *Take **three further CHOICE modules** from those offered for other study programs: Two modules in 1st, one in 2nd semester.* | | | | | | |
| **Year 2 - CORE** | *Take all modules listed below or replace 15 CP of mandatory elective ("me") modules by suitable CORE modules from other study programs[3]* | | | | | | **45** |
| | **Unit: Advanced Physics I** | | | | | | **15** |
| **CO-480** | **Module: Analytical Mechanics** (default minor)[2] | | | | **m** | | **5** |
| CO-480-A | Analytical Mechanics | Lecture | Written exam | Examination period | | 3 | |
| **CO-481** | **Module: Quantum Mechanics** (default minor)[2] | | | | **m** | | **5** |
| CO-481-A | Quantum Mechanics | Lecture | Written exam | Examination period | | 4 | |
| **CO-482** | **Module: Computational Physics** (default minor)[2] | | | | **me** | | **5** |
| CO-482-A | Computational Physics I | Lecture | Project | During the semester | | 3 | 2.5 |
| CO-482-B | Computational Physics II | Lecture | | | | 4 | 2.5 |
| | **Unit: Advanced Physics II** | | | | | | **15** |
| **CO-483** | **Module: Electrodynamics** | | | | **m** | | **5** |
| CO-483-A | Electrodynamics | Lecture | Written exam | Examination period | | 3 | |
| **CO-484** | **Module: Statistical Physics** | | | | **m** | | **5** |
| CO-484-A | Statistical Physics | Lecture | Written exam | Examination period | | 4 | |
| **CO-485** | **Module: Renewable Energy** | | | | **me** | | **5** |
| CO-485-A | Renewable Energy | Lecture | Project | During the semester | | 4 | |
| | **Unit: Advanced Physics Labs** | | | | | | **15** |
| **CO-486** | **Module: Advanced Physics Lab I** | | Oral exam | Before examination period | **m** | | **5** |
| CO-486-A | Advanced Physics Lab I | Lab | Lab report | During the semester | | 3 | |
| **CO-487** | **Module: Advanced Physics Lab II** | | Oral exam | Before examination period | **m** | | **5** |
| CO-487-A | Advanced Physics Lab II | Lab | Lab report | During the semester | | 4 | |
| **CO-488** | **Module: Advanced Physics Lab III** | | Oral exam | Before examination period | **me** | | **5** |
| CO-488-A | Advanced Physics Lab III | Lab | Lab report | During the semester | | 5/3 | |
| **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 | Intersnhip | Report/Business Plan | During the 5th semester | | | |
| **CA-PHY-800** | **Module: Thesis / Seminar Physics** | | | | **m** | **6** | **15** |
| CA-PHY-800-S | Thesis Physics | Project | Thesis and Presentation | 15th of May | | | 12 |
| CA-PHY-800-T | Seminar Physics | Seminar | | During the semester | | | 3 |
| | **Unit: Specialization Physics** (*Take a total of 15 CP of specialization modules*) | | | | | | **15** |
| **CA-S-PHY-801** | **Module: Condensed Matter Physics** | | | | **me** | | **5** |
| CA-PHY-801-A | Condensed Matter and Devices | Lecture | Written exam | Examination period | | 5 | |
| **CA-PHY-802** | **Module: Particles, Fields and Quanta** | | | | **me** | | **5** |
| CA-PHY-802-A | Elementary Particles and Fields | Lecture | Presentation | During the semester | | 6 | 2.5 |
| CA-PHY-802-B | Advanced Quantum Physics | Lecture | | | | 6 | 2.5 |
| **CA-PHY-803** | **Module: Advanced Applied Physics** | | | | **me** | **6** | **5** |
| CA-PHY-803-A | Biophysics / Nanotechnology | Lecture | Presentation | During the semester | | 6 | 2.5 |
| CA-PHY-803-B | Advanced Optics / Atoms and Molecules | Lecture | | | | 6 | 2.5 |
| **Specialization electives from other study programs** (see physics study program handbook) | | | Various | Various | **me** | **5/6** | **5** |
| **Total CP** | | | | | | | **180** |

| | Jacobs Track Modules (General Education) | Type | Assessment | Period | Status[1] | Sem. | CP |
|---|---|---|---|---|---|---|---|
| **Year 1** | | | | | | | **15** |
| | **Unit: Skills / Methods** | | | | | | **10** |
| **JTMS-MAT-09** | **Module: Calculus and Elements of Linear Algebra I** | | | | **m** | **1** | **5** |
| JTMS-09 | Calculus and Elements of Linear Algebra I | Lecture | Written exam | Examination period | | | |
| **JTMS-MAT-10** | **Module: Calculus and Elements of Linear Algebra II** | | | | **m** | **2** | **5** |
| JTMS-10 | Calculus and Elements of Linear Algebra II | Lecture | Written exam | Examination period | | | |
| | **Unit: Language** | | | | | | **5** |
| | German is default language. Native German speakers take modules in another offered language. | | | | | | |
| **JTLA** | **Module: Language 1** | | | | **m** | **1** | **2.5** |
| JTLA-xxx | Language 1 | Seminar | Various | Various | me | | |
| **JTLA** | **Module: Language 2** | | | | **m** | **2** | **2.5** |
| JTLA-xxx | Language 2 | Seminar | Various | Various | me | | |
| **Year 2** | | | | | | | **15** |
| | **Unit: Skills / Methods** (take a total of 10 CP of skills/methods modules, see list below) | | | | | 3+4 | **10** |
| **JTMS-MAT-12** | **Module: Probability and Random Processes** | | | | **me** | **3** | **5** |
| JTMS-12 | Probability and Random Processes | Lecture | Written exam | Examination period | | | 5 |
| **JTMS-MAT-13** | **Module: Numerical Methods** | | | | **me** | **4** | **5** |
| JTMS-13 | Numerical Methods | Lecture | Written exam | Examination period | | | 5 |
| *Alternatives:* | | | | | | | |
| **JTMS-SKI-14** | **Module: Programming in Python** | | | | **me** | **3** | **5** |
| JTMS-14 | Programming in Python | Lecture | Written exam | Examination period | | | 5 |
| **CO-501** | **Module: Discrete Mathematics** | | | | **me** | **4** | **5** |
| CO-501-A | Discrete Mathematics | Lecture | Written exam | Examination period | | | |
| | **Unit: Language** | | | | | | **5** |
| | German is default language. Native German speakers take modules in another offered language. | | | | | | |
| **JTLA** | **Module: Language 3** | | | | **m** | **3** | **2.5** |
| JTLA-xxx | Language 3 | Seminar | Various | Various | me | | |
| **JTLA** | **Module: Language 4** | | | | **m** | **4** | **2.5** |
| JTLA-xxx | Language 4 | Seminar | Various | Various | me | | |
| **Year 3** | | | | | | | **15** |
| | **Unit: Big Questions** | | | | | | **10** |
| **JTBQ** | **Module: Big Questions** | | | | **m** | **5/6** | |
| Take a total of 10 CP of Big Questions modules with each 2.5 or 5 CP | | Lecture | Various | Various | me | | |
| | **Unit: Community Impact Project** | | | | | | **5** |
| **JTCI-CI-950** | **Module: Community Impact Project** | | | | **m** | **5** | **5** |
| JTCI-950 | Community Impact Project | Project | Project | Examination period | | | |

[1] Status (m = mandatory, me = mandatory elective). [2]Alternative module choices for a minor in physics are possible (see physics study program handbook).

[3] For a full listing of all CHOICE / CORE / CAREER / Jacobs Track modules please consult the CampusNet online catalogue and /or the study program handbooks.

*Figure 3: Study and Examination Plan*

# 1 Physics Modules

## 1.1 Classical Physics

<table>
<tr><td colspan="3">Module Name<br>Classical Physics</td><td>Module Code<br>CH-140</td><td>Level (type)<br>Year 1<br>(CHOICE)</td><td>CP<br>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-140-A</td><td colspan="3">Classical Physics</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>CH-140-B</td><td colspan="3">Classical Physics Lab</td><td>Lab</td><td>2.5</td></tr>
<tr><td>CH-140-C</td><td colspan="3">Technical Mechanics Lab (for RIS students only)</td><td>Lab</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>Jürgen Fritz</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physic, ECE and RIS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• High school physics<br>• High school math</td><td>Frequency<br><br>Annually<br>(Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (35 hours)<br>• Lab (25.5 hours)<br>• Homework (42 hours)<br>• Private study (85 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>187.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>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, and Tipler & Mosca: Physics.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br>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.<br>Emphasis is placed on general physical principles and general mathematical concepts for a thorough understanding of physical phenomena. 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 presentation. 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.<br>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.<br>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 presentation. The default lab of this module is the Classical Physics Lab offering experiments in mechanics, thermodynamics, and optics. For students</td></tr>
</table>

majoring in RIS a Technical Mechanics Lab is offered with a focus on technical mechanics experiments. Calculus and vector analysis."

*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 (2011). University Physics, with modern physics. Upper Saddle River: Prentice Hall.

or

D. Halliday, R. Resnick, J. Walker (2018). Fundamentals of Physics, extended version. Hoboken: John Wiley & Sons Inc.

Or

P. Tipler & G. Mosca (2007). Physics for Scientists and Engineers. New York: WH Freeman.

*Usability and Relationship to other Modules*

- Mandatory for a major in Physics, ECE and RIS
- Mandatory for a minor in Physics
- Prerequisite for first year Physics CHOICE module “Modern Physics”
- Prerequisite for second year Physics CORE modules “Analytical Mechanics” and “Renewable Energy”
- Elective for all other undergraduate study programs

*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).

Module achievement: 40% of homework points necessary as prerequisite to take the final exam.

Completion: To pass this module, both module component examinations have to be passed with at least 45%.

## 1.2 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 | 5.0 |
| CH-141-B | Modern Physics Lab | | Lab | 2.5 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Jürgen Fritz, Veit Wagner, Arnulf Materny | • Physics | Mandatory for Physics |

| *Entry Requirements* | | | *Frequency* | *Forms of Learning and Teaching* |
|---|---|---|---|---|
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Annually (Spring) | • Lecture (35 hours)<br>• Lab (25.5 hours)<br>• Homework problem (42 hours)<br>• Private study (85 hours) |
| ☒ Classical Physics | ☒ None | • High school physics<br>• High school math | *Duration* | *Workload* |
| | | | 1 semester | 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, and 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 advance 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. 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. In the modern physics part, the concepts of quantum physics are introduced 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 phenomena, preparing 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:

- recall the basic facts and experimental evidence in electromagnetism and modern physics;
- 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;
- describe and understand natural and technical phenomena in electromagnetism and modern physics by reducing them to their basic physical principles;
- apply 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 (2011). University Physics, with modern physics. Upper Saddle River: Prentice Hall.

or

D. Halliday ,R. Resnick, J. Walker (2018). Fundamentals of Physics, extended version. Hoboken: John Wiley & Sons Inc.

Or

P. Tipler & G. Mosca (2007). Physics for Scientists and Engineers. New York: WH Freeman.

*Usability and Relationship to other Modules*

- Mandatory for a major in Physics
- Mandatory for a minor in Physics
- Prerequisite for second year Physics CORE modules “Advanced Physics Lab 1-3”and “Quantum Mechanics”
- Prerequisite for third year Physics Specialization module “Advanced Applied Physics”
- Elective for all other undergraduate study programs

*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 1: Lecture**

Assessment Type: Lab Reports (Lab),

Length: 8-12 pages
Weight: 33%

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

Module achievement: 40% of homework points necessary as prerequisite to take the final exam.

Completion: To pass this module, both module component examinations have to be passed with at least 45%.

## 1.3 Applied Mathematics

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Applied Mathematics | CH-202 | Year 1 (CHOICE) | *7.5* |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CH-202-A | Advanced Calculus and Methods of Mathematical Physics | Lecture | 5 |
| CH-202-B | Numerical Software Lab | Lab | 2.5 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Marcel Oliver<br>Ulrich Kleinekathöfer | • Mathematics | Mandatory for Mathematics<br>Mandatory elective for ECE and Physics |

*Entry Requirements*

| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* |
|---|---|---|
| ☒ None | ☒ None | • Single-variable Calculus at the level achieved in "Calculus and Elements of Linear Algebra I" |

| *Frequency* | *Forms of Learning and Teaching* |
|---|---|
| Annually (Spring) | • Lectures (35 hours)<br>• Lab (17.5 hours)<br>• Private study (135 hours) |

| *Duration* | *Workload* |
|---|---|
| 1 semester | 187.5 hours |

*Recommendations for Preparation*

Recapitulate single variable Calculus at a level of at least "Calculus and Elements of Linear Algebra I"

*Content and Educational Aims*

This module covers advanced topics from calculus that are part of the core mathematics education of every Physicist and also forms a fundamental part of the mathematics major. It features examples and applications from the physical sciences. The module is designed to be taken with minimal pre-requisites and is tightly coordinated with the parallel module Calculus and Elements of Linear Algebra II. The style of development strives for rigor, but avoids abstraction and prefers simplicity over generality.

Topics covered include:

- Taylor series, power series, uniform convergence
- Advanced concepts from multivariable differential calculus, here mainly the inverse and implicit function theorem; elementary vector calculus and Lagrange multipliers are covered in Calculus and Elements of Linear Algebra II
- Riemann integration in several variables, and line integrals
- The Gauss and Stokes integral theorems
- Change of variables and integration in polar coordinates
- Fourier integrals and distributions

- Applications to partial differential equations that are important in physics (Laplace, Poisson, diffusion, wave equations)
- Very brief introduction to complex analysis (Cauchy formula and residue theorem)

The lecture part is complemented by a lab course in Numerical Software (Scientific Python), which has become an essential tool for numerical computation and data analysis in many areas of mathematics, physics, and other sciences. Topics include:

- Writing vectorized code using NumPy arrays
- An introduction to SciPy for special functions and black-boxed algorithms (root solvers, quadrature, ODE solvers, and fast Fourier transform)
- Visualization using Matplotlib, including a general introduction to the effective visualization of scientific data and concepts
- The lab also includes a very brief comparative introduction to MATLAB, another standard numerical tool.

*Intended Learning Outcomes*

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

1. apply series expansions in a variety of mathematical and scientific contexts;
2. solve, simplify, and transform integrals in several dimensions;
3. explain the intuition behind the major theorems;
4. use the major theorems in an application context;
5. compute Fourier transforms and apply them to problems in Calculus and Partial Differential Equations;
6. distinguish differentiability in a complex from a real variable;
7. use numerical software to support simple numerical tasks and to visualize data.

*Indicative Literature*

S. Kantorovitz (2016). Several Real Variables, Berlin: Springer.
K. Riley, M. Hobson, S. Bence (2006). Mathematical Methods for Physics and Engineering, third edition. Cambridge: Cambridge University Press.
D.J. Pine (2018). Introduction to Python for Science and Engineering. Boca Raton: CRC Press.

*Usability and Relationship to other Modules*

- This module is a mandatory part of the core education in Mathematics.
- Mandatory elective for a major in Physics and ECE
- The curriculum is tightly integrated with the curriculum of the modules “Calculus and Elements of Linear Algebra I and II” .
- It is also valuable for students in Computer Science, RIS, either as part of a minor in Mathematics, or as an elective module.
- This module is an elective for students of all other undergraduate studies.

*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 (5, 7).

*Module Component 2: Lab*

Assessment Type: Lab report — Length: Approx. 30 pages, Weight: 33%

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

Completion: To pass this module, both module component examinations have to be passed with at least 45%.

## 1.4 Introduction to Robotics and Intelligent Systems

| *Module Name* | | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|---|
| Introduction to Robotics and Intelligent Systems | | CH-220 | Year 1 (CHOICE) | 7.5 |
| *Module Components* | | | | |
| *Number* | *Name* | | *Type* | *CP* |
| CH-220-A | Introduction to Robotics and Intelligent Systems | | Lecture | 5 |
| CH-220-B | Introduction to Robotics and Intelligent Systems - Lab | | Lab | 2.5 |
| *Module Coordinator*<br><br>Francesco Maurelli | *Program Affiliation*<br><br>• Robotics and Intelligent Systems (RIS) | | *Mandatory Status*<br><br>Mandatory for RIS, CS, ECE<br>Mandatory elective for Physics | |
| *Entry Requirements*<br><br>*Pre-requisites*<br><br>☒ None | *Co-requisites*<br><br>☒ None | *Knowledge, Abilities, or Skills*<br><br>None | *Frequency*<br><br>Annually (Spring) | *Forms of Learning and Teaching*<br><br>• Lecture (35 hours)<br>• Lab (17.5 hours)<br>• Private study (115 hours)<br>• Exam preparation (20 hours) |
| | | | *Duration*<br><br>1 semester | *Workload*<br><br>187.5 hours |

*Recommendations for Preparation*

Review basic linear algebra concepts, vector and matrix operations.

*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.

*Intended Learning Outcomes*

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

- compute 3D transformations;
- understand and apply quaternion operations;
- apply trajectory planning techniques;
- model common mechanical and electrical systems;
- understand and apply the unilateral Laplace transform and its inverse;
- explore linear systems and tune their behavior;
- program the open-source electronic prototyping platform Arduino;
- 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*

- Mandatory for a major in RIS, CS, ECE
- Mandatory for a minor in RIS.
- Mandatory elective for a major in Physics.
- 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

## 1.5 **Analytical Mechanics**

<table>
<tr><td colspan="3">Module Name<br>Analytical Mechanics</td><td>Module Code<br>CO-480</td><td>Level (type)<br>Year 2 (CORE)</td><td>CP<br>5.0</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-480-A</td><td colspan="3">Analytical Mechanics</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator<br><br>Peter Schupp</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physics</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ Classical Physics<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills: • Mathematics at the level of the Applied Mathematics module</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (35 hours)<br>• Homework exercises (55 hours)<br>• Private study (35 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Review classical mechanics and calculus at the level of the first-year courses.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>Mechanics provides the foundation for all other fields of physics. The analytical techniques developed in mechanics have applications in many other sciences, engineering, mathematics and even economics. This module provides an intensive calculus-based introduction to analytical mechanics and special relativity. Topics include: Newton's laws, the kinematics and dynamics of systems of particles, planetary motion, rigid body mechanics, Lagrangian mechanics, variational techniques, symmetries and conservation laws, Hamiltonian mechanics, canonical transformations, small oscillations, and relativistic mechanics. Additional topics may include continuum mechanics and an outlook to general relativity. The course is part of the core physics education and builds on the foundation of the Classical Physics and Applied Mathematics modules. The course is however also accessible and of interest to students without this prerequisite, but with a sufficiently strong background in mathematics. Essential practical experience in analyzing physical phenomena, formulating mathematical models and solving physics problems will be supported by homework exercises in close coordination with the lectures. The aim of the module is an introduction to the core topics of physics at a level that prepares students for BSc thesis research. At the same time, students' mathematical repertoires and problem-solving skills are developed. The module also serves as a foundation for physics specialization subjects.</td></tr>
</table>

*Intended Learning Outcomes*

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

- understand the classical foundations of physics;
- solve mechanics problems of practical relevance using advanced mathematical techniques;
- analyze mechanical systems using Newton's laws and re-formulate them in terms of Lagrangian and Hamiltonian mechanics;
- formulate physical laws using variational methods and derive the equations of the motion of physical systems;
- derive the equivalence of energy and matter in the framework of the special theory of relativity;
- understand Lorentz transformations and apply them;
- communicate in scientific language using advanced field-specific technical terms.

*Indicative Literature*

D. Morin (2008). Introduction to Classical Mechanics: With Problems and Solutions. Cambridge: Cambridge University Press;

and/or:

L. D. Landau, E. M. Lifshitz (1976). Mechanics. Vol. 1, 3rd ed, *(chapters on Lagrangian and Hamiltonian mechanics).* Oxford: Butterworth-Heinemann

*Usability and Relationship to other Modules*

- Mandatory for a major in Physics.
- One of three default second year CORE modules for a minor in Physics
- Prerequisite for second year Physics CORE module "Statistical Physics"
- Co-requisite for second year Physics CORE module "Advanced Physics Lab 1 and 3"

*Examination Type: Module Examination*

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

Scope: All intended learning outcomes of the module

Bonus achievement: Additional bonus homework as a voluntary task can improve the grade, but is not required to reach the best grade in the module (1.0).

## 1.6 Quantum Mechanics

<table>
<tr><td colspan="3">Module Name<br>Quantum Mechanics</td><td>Module Code<br>CO-481</td><td>Level (type)<br>Year 2 (CORE)</td><td>CP<br>5.0</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-481-A</td><td colspan="3">Quantum Mechanics</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator<br><br>Peter Schupp, Arnulf Materny</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physics</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ Modern Physics<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• Mathematics at the level of the Applied Mathematics Module</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (35 hours)<br>• Homework exercises (55 hours)<br>• Private study (35 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparations<br><br>None.</td></tr>
</table>

***Content and Educational Aims***

At a fundamental microscopic level, our world is governed by quantum phenomena that frequently defy attempts of a common-sense understanding based on our everyday experience of the macroscopic world. Yet modern technology would not be possible without quantum physics. This module provides an intensive introduction to quantum mechanics. We shall emphasize conceptual as well as quantitative aspects of the theory. Topics include: Foundations and postulates of quantum mechanics; Schrödinger Equation; one-dimensional problems (potential barriers and tunneling); operators, matrices, states (Dirac notation, representations); uncertainty relations; harmonic oscillator, coherent states; angular momentum and spin; EPR paradox and Bell inequalities; central potential (hydrogen atom, multi-electron atoms); perturbation theory; mixed states, entanglement, measurement; illustrative examples from quantum information theory (quantum computing). The course is part of the core physics education and it is of interest for students of other natural sciences and mathematics. Essential practical experience in analyzing physical phenomena, formulating mathematical models and solving physics problems will be supported by homework exercises in close coordination with the lectures. The aim of the module is an introduction to core topics of physics at a level that prepares for actual research. At the same time, the mathematical repertoire and problem-solving skills are developed. The module also serves as a foundation for physics specialization subjects.

***Intended Learning Outcomes***

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

- describe particle-wave complementarity in quantum mechanics;
- present the theoretical foundations of quantum mechanics;
- solve quantum mechanics problems of practical relevance using advanced mathematical techniques;
- determine the energy levels of quantum systems using algebraic and analytical methods;
- communicate in scientific language using advanced field-specific technical terms.

| |
|---|
| |
| *Indicative Literature*<br><br>L.I. Schiff (1968). Quantum Mechanics 3Rev Ed edition. *New York:* McGraw-Hill.<br><br>and/or<br><br>D.J. Griffiths (2004). Introduction to Quantum Mechanics. Upper Saddle River: Prentice Hall International. |
| *Usability and Relationship to other Modules*<br><br>• Mandatory for a major in Physics<br>• One of three default 2nd year CORE modules for a minor in Physics |
| *Examination Type: Module Examination*<br><br>Assessment Type: Written examination — Duration: 120 min, Weight: 100%<br><br>Scope: All intended learning outcomes of the module. |

## 1.7 Computational Physics

<table>
<tr><td colspan="2">Module Name<br>Computational Physics</td><td colspan="2">Module Code<br>CO-482</td><td>Level (type)<br>Year 2 (CORE)</td><td>CP<br>5.0</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-482-A</td><td colspan="3">Computational Physics I</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>CO-482-B</td><td colspan="3">Computational Physics II</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>Ulrich Kleinekathöfer</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory elective for Physics</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ Applied Mathematics (or: Introduction to Robotics and Intelligent Systems)<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills: • Basics of scientific programming preferably in Python</td><td>Frequency<br><br>Annually<br>(Fall and Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (35 hours)<br>• Private study (35 hours)<br>• Exercises and project (55 hours)</td></tr>
<tr><td>Duration<br><br>2 semesters</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Review the basics of scientific programming preferably in Python.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br>In this Computational Physics module, several practical numerical solutions for typical problems in physics and the natural sciences in general will be discussed. While, for example, the very nature of physics is the expression of relationships between physical quantities in mathematical terms, an analytical solution of the resulting equations is often not available. Instead, numerical solutions based on computer programs are required to obtain useful results for real-life problems. In the module, several numerical techniques are introduced, such as solving ordinary differential equations, partial differential equations, quadrature, random number generation, and Monte Carlo integration. These important tools in numerical simulations will be applied to a selection of problems including the classical dynamics of particles, chaos theory, electrostatics including the Poisson equation, cellular automata including traffic simulations, random walks, the solution of the time-dependent Schrödinger equation, and so forth. The module includes numerous examples and exercises for programming codes.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes<br>By the end of the module, students will be able to<br><br>• explain the basic strategies to simulate physical systems;<br>• apply computer simulations to describe and analyze general problems in physics and related sciences;<br>• design computer programs for specific problems and validate them;<br>• utilize basic numerical schemes such as iterative approaches;<br>• communicate in scientific language using advanced field-specific technical terms.</td></tr>
</table>

*Indicative Literature*

H. Gould, J. Tobochnik, W. Christian (2006). Introduction to Computer Simulation Methods. London: Pearson Education.

And/or:

R. H. Landau, M. J. Paez, C. C. Bordeianu. Computational Physics: Problem Solving with Computers. Weinheim: Wiley-VCH.

*Usability and Relationship to other Modules*

- Computational Physics I focuses on examples relevant for the Analytical Mechanics and Electrodynamics modules, while Computational Physics II focuses on examples relevant for the Statistical Physics and Quantum Mechanics modules.
- Recommended mandatory elective for a major in Physics
- One of three default second year CORE modules for a minor in Physics
- Elective for all other undergraduate study programs.

*Examination Type: Module Examination*

Assessment Type: Project

Duration: 25 hours
Weight: 100%

Scope: All intended learning outcomes of the module

## 1.8 Electrodynamics

<table>
<tr><td colspan="3">Module Name<br>Electrodynamics</td><td>Module Code<br>CO-483</td><td>Level (type)<br>Year 2 (CORE)</td><td>CP<br>5.0</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-483-A</td><td colspan="3">Electrodynamics</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator<br><br>Ulrich Kleinekathöfer, Veit Wagner</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physics</td></tr>
<tr><td rowspan="2">Entry Requirements<br><br>Pre-requisites<br><br>☒ Modern Physics</td><td rowspan="2">Co-requisites<br><br>☒ None</td><td rowspan="2">Knowledge, Abilities, or Skills<br><br>• Mathematical methods at the level of the Applied Mathematics module<br>• Electromagnetism at the level of the first-year physics modules</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (35 hours)<br>• Homework exercises (55 hours)<br>• Private study (35 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparations<br><br>Review the Applied Mathematics module topics and electromagnetism at the level of the first-year courses.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>Electrodynamics is the prototype theory for all fundamental forces of nature. It plays a profound role in modern communication, computing, and control systems, as well as energy production, transport, storage, and use. This module provides an intensive calculus-based introduction to electrodynamics. Topics include electromagnetic fields, Maxwell’s equations, electrostatics, magnetostatics, fields in matter, the covariant formulation of electrodynamics and special relativity, electromagnetic radiation, and optics. The course is part of the core physics education and builds in an essential way on the foundation of the first-year Physics and Applied Mathematics modules. The module is however also accessible and of interest to students without this prerequisite, but with a sufficiently strong background in mathematics. Essential practical experience in analyzing physical phenomena, formulating mathematical models, and solving physics problems will be supported by homework exercises in close coordination with the lectures. The aim of the module is an introduction to the core topics of physics at a level that prepares students for BSc thesis research. At the same time, students' pertinent mathematical repertoires and problem-solving skills are developed. The module also serves as a foundation for physics specialization subjects.</td></tr>
</table>

*Intended Learning Outcomes*

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

- describe Maxwell's equations and present practical applications of electrodynamics;
- apply advanced mathematical techniques to solve electrodynamics problems;
- analyze electrodynamic phenomena and relate them to the underlying fundamental physical laws including special relativity;
- communicate in scientific language using advanced field-specific technical terms.

*Indicative Literature*

D.J. Griffiths (2017). Introduction to Electrodynamics, 4th edition. Cambridge: Cambridge University Press.

and/or

E. M. Purcell & D.J. Morin. Electricity and Magnetism. Cambridge: Cambridge University Press.

*Usability and Relationship to other Modules*

- Mandatory for a major in Physics
- Possible (mandatory) elective for a physics minor

*Examination Type: Module Examination*

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module.

## 1.9 Statistical Physics

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Statistical Physics | CO-484 | Year 2 (CORE) | *5.0* |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CO-484-A | Statistical Physics | Lecture | 5.0 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Stefan Kettemann, Ulrich Kleinekathöfer | • Physics | Mandatory for Physics |

| *Entry Requirements* | | | *Frequency* | *Forms of Learning and Teaching* |
|---|---|---|---|---|
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Annually (Spring) | • Lectures (35 hours)<br>• Homework exercises (55 hours)<br>• Private study (35 hours) |
| ☒ Analytical Mechanics | ☒ None | • First-year mathematics | | |
| | | | *Duration* | *Workload* |
| | | | 1 semester | 125 hours |

*Recommendations for Preparations*

Review thermal physics and calculus at the level of the first-year courses.

*Content and Educational Aims*

Statistical physics describes macroscopic properties of matter by a statistical treatment of their microscopic constituents and finds applications in fields ranging from biophysics to condensed matter and high energy physics. This course deals with an intensive introduction to statistical physics and its applications in condensed matter theory. The course starts with an introduction to the mathematical concepts followed by a brief review of the thermodynamic concepts and quantities. Topics in statistical physics include the statistical basis of thermodynamics, micro-canonical, canonical and grand-canonical ensembles, macroscopic variables, physical applications including an introduction to quantum statistical physics such as Fermi and Bose quantum gases, and related physical phenomena. Based on the multi-particle wave functions of fermions, applications in condensed matter physics are discussed, including Bloch wave functions and the density of states. Essential practical experience in analyzing physical phenomena, formulating mathematical models and solving physics problems will be supported by homework exercises in close coordination with the lectures. The aim of the module is an introduction to the core topics of physics at a level that prepares for BSc thesis research. At the same time, students' pertinent mathematical repertoires and problem-solving skills are developed. The module also serves as a foundation for physics specialization subjects.

*Intended Learning Outcomes*

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

- understand the theoretical foundations and practical applications of statistical physics;
- solve thermodynamics and statistical physics problems of practical relevance using advanced mathematical techniques;
- analyze properties of gases and condensed matter in terms of microscopic and statistical models;
- communicate in scientific language using advanced field-specific technical terms.

*Indicative Literature*

S. Salinas (2001). Introduction to Statistical Physics. New York: Springer.

and/or

H. Gould & J. Tobochnik (2010). Thermal and Statistical Physics. Princeton: Princeton University Press.

*Usability and Relationship to other Modules*

- Mandatory elective CORE module for physics majors
- Possible (mandatory) elective for a physics minor

*Examination Type: Module Examination*

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of the module.

## 1.10 Renewable Energy

| *Module Name*<br>Renewable Energy | | | *Module Code*<br>CO-485 | *Level (type)*<br>Year 2 (CORE) | *CP*<br>*5.0* |
|---|---|---|---|---|---|
| *Module Components* | | | | | |
| *Number* | *Name* | | | *Type* | *CP* |
| CO-485-A | Renewable Energy | | | Lecture | 5.0 |
| *Module Coordinator*<br><br>Stefan Kettemann | *Program Affiliation*<br><br>• Physics | | | *Mandatory Status*<br><br>Mandatory elective for Physics | |
| *Entry Requirements* | | | *Frequency*<br><br>Annually (Spring) | *Forms of Learning and Teaching*<br><br>• Lecture (35 hours)<br>• Private study (35 hours)<br>• Homework exercises and project (55 hours) | |
| *Pre-requisites*<br><br>☒ Classical Physics | *Co-requisites*<br><br>☒ None | *Knowledge, Abilities, or Skills*<br><br>• Physics at advanced high school/first-year university level. | *Duration*<br><br>1 semester | *Workload*<br><br>125 hours | |
| *Recommendations for Preparation*<br><br>None. | | | | | |

*Content and Educational Aims*

Renewable energy resources promise to provide clean, decentralized solutions to the world's energy crisis, as energy resources that directly depend on the power of the sun's radiation. The module provides an overview of the potential and limitations of energy resources. It includes a self-contained introduction to classical thermodynamics. The module includes an overview of energy scenarios based on current energy needs and available energy resources, an introduction to the basic physics of solar energy and the basics of thermodynamics, as well as the physics and engineering aspects of solar cells, solar thermal collectors, wind power, geothermal power, thermophotovoltaics, the potential of biomass energy resources, and hydro, tidal and wave energy. A basic introduction to energy transport and energy storage is also provided. These topics are complemented by an introduction to the basic physics of other energy resources including nuclear energy.

*Intended Learning Outcomes*

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

- present and apply the principles of thermal physics;
- explain advanced concepts of energy generation and storage;
- analyze advantages and disadvantages of different approaches to address the world's energy problem;
- understand the scientific background of energy technologies;
- communicate in scientific language using advanced field-specific technical terms.

*Indicative Literature*

G. Boyle (1996). Renewable Energy. Oxford: Oxford University Press.

and/or

J. Andrews & N. Jelley (2017). Energy Science. Oxford: Oxford University Press.

*Usability and Relationship to other Modules*

- Mandatory elective CORE module for physics majors
- Possible (mandatory) elective for a physics minor

*Examination Type: Module Examination*

Assessment Type: Project,

Duration: 25 hours
Weight:100%

Scope: All intended learning outcomes of the module.

## 1.11 Advanced Physics Lab I

<table>
<tr><td colspan="3">Module Name<br>Advanced Physics Lab I</td><td>Module Code<br>CO-486</td><td>Level (type)<br>Year 2 (CORE)</td><td>CP<br>5.0</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-486-A</td><td colspan="3">Advanced Physics Lab I</td><td>Lab</td><td>5.0</td></tr>
<tr><td>Module Coordinator<br><br>Veit Wagner, Arnulf Materny</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physics major</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ Modern Physics<br>Co-requisites: ☒ AnalMech & Eldyn<br>Knowledge, Abilities, or Skills: • First-year math</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lab (51 hours)<br>• Private study (74 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Students should recap their first-year physics, especially from the lab courses including error analysis.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>Physics is an experimental science. Any hypotheses or theories have to be tested, verified, or falsified by experiments. Therefore, designing and performing experiments, analyzing, and presenting experimental results is a fundamental part of any physics education. In this module, students advance their knowledge in performing experiments as it was introduced in the first-year modules; students work more independently on experiments and write a scientific lab report. They will conduct hands-on experiments on advanced topics in advanced mechanics and electrodynamics requiring an advanced theoretical and mathematical description of phenomena. Scheduled experiments are: Dynamics of rotational motion, Ultrasonic waves, Thermal and electrical conductivity, Hall Effect, Polarization of visible light, Scanning electron microscopy (SEM).<br>By working in teams of two, they will set up experiments, record data, analyze it using the appropriate software and error analysis, and present it in a written report. They will finally describe and explain their work in an oral exam.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes<br><br>By the end of the module, students will be able to<br>1. prepare for the conducting of experiments and use experimental equipment for a specific physical problem;<br>2. set up, perform, and evaluate experiments to investigate typical phenomena in mechanics and electrodynamics;<br>3. use experimental techniques and data acquisition tools to record experimental data;<br>4. analyze the outcomes of experiments by mathematical and computational methods, and use error analysis to assess the accuracy and reproducibility of their results;<br>5. use the appropriate format and language to summarize and describe an experiment, and communicate its outcome in a scientific report;<br>6. organize their work and work responsibly in a team to fulfill the given task;<br>7. orally describe and answer basic questions related to the background, the experimental method, and outcome of the experiment.</td></tr>
</table>

*Indicative Literature*

Lab manual will be provided.

*Usability and Relationship to other Modules*

- Mandatory CORE module for a physics major.
- Possible (mandatory) elective for a physics minor
- Co-requisites are second year CORE modules “Analytical Mechanics” and “Electrodynamics”

*Examination Type: Module Examination*

Assessment Component 1: Lab reports (written reports)
Length: 10-15 pages
Weight: 70%

Scope: Intended learning outcomes (1-6).

Assessment Component 2: Oral examination
Duration: 30 min
Weight: 30%

Scope: Intended learning outcomes (4,7).

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

## 1.12 Advanced Physics Lab II

| *Module Name* | | | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|---|---|
| Advanced Physics Lab II | | | CO-487 | Year 2 (CORE) | *5.0* |
| *Module Components* | | | | | |
| *Number* | *Name* | | | *Type* | *CP* |
| CO-487-A | Advanced Physics Lab II | | | Lab | 5.0 |
| *Module Coordinator*<br><br>Arnulf Materny, Veit Wagner | *Program Affiliation*<br><br>• Physics | | | *Mandatory Status*<br><br>Mandatory for Physics students | |
| *Entry Requirements* | | | *Frequency*<br><br>Annually (Spring) | *Forms of Learning and Teaching*<br><br>• Lab (51 hours)<br>• Private study (74 hours) | |
| *Pre-requisites*<br><br>☒ Modern Physics | *Co-requisites*<br><br>☒ Quantum mechanics & Statistical Physics | *Knowledge, Abilities, or Skills*<br><br>• First-year math | *Duration*<br><br>1 semester | *Workload*<br><br>125 hours | |
| *Recommendations for Preparation*<br><br>Students should recap their first-year physics, especially from the lab courses including error analysis. | | | | | |

*Content and Educational Aims*

Physics is an experimental science. Any hypotheses or theories must be tested, verified, or falsified by experiments. Therefore, designing and performing experiments, analyzing, and presenting experimental results is a fundamental part of any physics education. In this module, students advance their knowledge in performing experiments as introduced in the first-year modules; students work more independently on experiments and write a scientific lab report. They will conduct hands-on experiments on advanced topics in quantum mechanics, atomic physics, and statistical physics requiring an advanced theoretical and mathematical description of phenomena. Scheduled experiments are: Two-Electron Spectra, X-rays and particle-wave duality, Zeeman Effect, Faraday and Kerr Effect, Electron spin and nuclear magnetic resonance, NdYAG laser.
By working in teams of two they will set up experiments, record data, analyze it using appropriate software and error analysis, and present it in a written report. They will finally describe and explain their work in an oral exam.

*Intended Learning Outcomes*

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

1. prepare to conduct experiments and use experimental equipment for a specific physical problem;
2. set up, perform, and evaluate experiments to investigate typical phenomena in quantum mechanics and statistical physics;
3. use experimental techniques and data acquisition tools to record experimental data;
4. analyze the outcomes of experiments by mathematical and computational methods, and use error analysis to assess the accuracy and reproducibility of their results;
5. use the appropriate format and language to summarize and describe an experiment, and communicate its outcome in a scientific report;
6. organize their work and work responsibly in a team to fulfill the given task;
7. orally describe and answer basic questions related to the background, the experimental method and outcome of the experiment.

*Indicative Literature*

Lab manual will be provided.

*Usability and Relationship to other Modules*

- Mandatory CORE module for a physics major.
- Possible (mandatory) elective for a physics minor
- Co-requisites are second year CORE modules"Quantum mechanics" and "Statistical Physics"

*Examination Type: Module Examination*

Assessment Component 1: Lab reports (written reports) — Length: 10-15 pages; Weight: 70%

Scope: Intended learning outcomes (1-6)

Assessment Component 2: Oral examination — Duration: 30 min; Weight: 30%

Scope: Intended learning outcomes (4,7)

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

## 1.13 Advanced Physics Lab III

| | | | | |
|---|---|---|---|---|
| *Module Name*<br>Advanced Physics Lab III | | *Module Code*<br>CO-488 | *Level (type)*<br>Year 2 (CORE) | *CP*<br>*5.0* |
| *Module Components* | | | | |
| *Number* | *Name* | | *Type* | *CP* |
| CO-488-A | Advanced Physics Lab III | | Lab | 5.0 |
| *Module Coordinator*<br>Veit Wagner, Arnulf Materny | *Program Affiliation*<br>• Physics | | *Mandatory Status*<br>Mandatory for Physics | |

| | | | | |
|---|---|---|---|---|
| *Entry Requirements* | | | *Frequency*<br>Annually (Fall) | *Forms of Learning and Teaching*<br>• Lab (51 hours)<br>• Private study (74 hours) |
| *Pre-requisites*<br>☒ Modern Physics | *Co-requisites*<br>☒ AnalMech & ElDyn | *Knowledge, Abilities, or Skills*<br>• First year math | *Duration*<br>1 semester | *Workload*<br>125 hours |

*Recommendations for Preparation*

Students should recap their first-year physics, especially from the lab courses including error analysis.

*Content and Educational Aims*

Physics is an experimental science. Any hypotheses or theories must be tested, verified, or falsified by experiments. Therefore, designing and performing experiments, analyzing, and presenting experimental results is a fundamental part of any physics education. In this module, experimentally interested students advance their knowledge in performing experiments as it was introduced in the first-year modules; students work more independently on experiments and write a scientific lab report. They will conduct hands-on experiments on selected topics in second-year physics requiring an advanced theoretical and mathematical description of phenomena. Scheduled experiments are: Wind tunnel, HeNe-Laser, Solar cell, Peltier and Seebeck effect, Fuel cell and electrolyzer, Stirling Engine.
By working in teams of two, they set up experiments, record data, analyze it using appropriate software and error analysis, and present it in a written report. They finally describe and explain their work in an oral exam.

*Intended Learning Outcomes*

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

1. prepare to conduct experiments and use experimental equipment for a specific physical problem;
2. set up, perform, and evaluate experiments to investigate typical phenomena in mechanics, electromagnetism, quantum mechanics, and statistical physics;
3. use experimental techniques and data acquisition tools to record experimental data;
4. analyze the outcomes of experiments by mathematical and computational methods, and use error analysis to assess the accuracy and reproducibility of their results;
5. use the appropriate format and language to summarize and describe an experiment, and communicate its outcome in a scientific report;
6. organize their work and work responsibly in a team to fulfill the given task;
7. orally describe and answer basic questions related to the background, the experimental method and outcome of the experiment.

*Indicative Literature*

Lab manual will be provided.

*Usability and Relationship to other Modules*

- Mandatory elective CORE module for the physics major.
- Possible (mandatory) elective for a physics minor.
- Co-requisites are second year CORE modules "Analytical Mechanics" and "Electrodynamics"

*Examination Type: Module Examination*

Assessment Component 1: Lab reports (written reports)
Length: 10-15 pages
Weight: 70%

Scope: Intended learning outcomes (1-6)

Assessment Component 2: Oral examination
Duration: 30 min
Weight: 30%

Scope: Intended learning outcomes (4,7)

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

## 1.14 Condensed Matter Physics

<table>
<tr><td colspan="3">Module Name<br>Condensed Matter Physics</td><td>Module Code<br>CA-S-PHY-801</td><td>Level (type)<br>Year 3<br>(CAREER - Specialization)</td><td>CP<br>5.0</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-PHY-801-A</td><td colspan="3">Condensed Matter and Devices</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator<br><br>Veit Wagner</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physics</td></tr>
<tr><td rowspan="2">Entry Requirements<br><br>Pre-requisites<br><br>☒ Statistical Physics</td><td rowspan="2"><br><br>Co-requisites<br><br>☒ None</td><td rowspan="2"><br><br>Knowledge, Abilities, or Skills<br><br>• Quantum Mechanics</td><td>Frequency<br><br>Annually<br>(Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (35 hours)<br>• Homework exercises (45 hours)<br>• Private study (45 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Review statistical mechanics and quantum mechanics at the level of the second-year courses.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>Technological progress and the development of new materials and devices requires a detailed description and understanding of the physics of matter. This course provides a thorough introduction to condensed matter and solid-state physics. Topics include different forms of condensed matter, crystal types, and crystal structures. Based on classical and quantum mechanical Bose/Fermi statistics and the concepts of density-functional theory, the models by Drude and Sommerfeld, Fermi sphere, cohesive energy, classical and quantum harmonic crystals, phonons, and quasiparticles are introduced, as well as the structure and dynamics of solids, band theory and electronic properties, optical properties, magnetism, and superconductivity. The working principles of important semiconductor devices are explained, including transistors, LEDs, solid-state lasers, and solar cells.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes<br><br>By the end of the module, students will be able to<br><br>• determine the basic properties of gases and condensed matter based on microscopic and statistical models;<br>• describe the behavior of electrons and analyze how they influence macroscopic and electronic properties of materials;<br>• select basic experimental techniques and procedures needed to study solid state materials;<br>• communicate in scientific language using advanced field-specific technical terms.</td></tr>
</table>

*Indicative Literature*

C. Kittel (2018). Introduction to Solid State Physics. Hoboken: Wiley.

and/or

S. M. Sze & K. K. Lee (2006). Semiconductor Devices: Physics and Technology. Hoboken: Wiley.

*Usability and Relationship to other Modules*

- Mandatory elective specialization module for physics majors.
- Possible (mandatory) elective for a physics minor
- Useful foundation for many BSc thesis research topics.

*Examination Type: Module Examination*

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

Scope: All intended learning outcomes of the module.

## 1.15 Particles, Fields and Quanta

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Particles, Fields and Quanta | CA-S-PHY-802 | Year 3 (CAREER - Specialization) | *5.0* |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CA-PHY-802-A | Elementary Particles and Fields | Lecture | 2.5 |
| CA-PHY-802-B | Advanced Quantum Physics | Lecture | 2.5 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Peter Schupp | • Physics | Mandatory elective for Physics |

*Entry Requirements*

| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* |
|---|---|---|
| ☒ Quantum Mechanics, Analytical Mechanics | ☒ None | • Mathematics at the level of the Applied Mathematics module |

*Frequency*

Annually (Spring)

*Forms of Learning and Teaching*

- Lectures (35 hours)
- Homework exercises, project/presentation (55 hours)
- Private study (35 hours)

*Duration*

1 semester

*Workload*

125 hours

*Recommendations for Preparation*

Review classical mechanics, quantum mechanics, and electrodynamics at the level of the second-year courses.

*Content and Educational Aims*

This module is devoted to advanced topics in theoretical physics. The first part of the module is devoted to an introductory overview of theoretical and experimental aspects of elementary particle physics, classical and quantum field theory, and (optionally) aspects of nuclear physics and general relativity. The second part of the module provides an introduction to advanced methods and concepts of quantum mechanics with applications. The focus may change from year to year reflecting current trends in physics, for example, quantum computing. The topics of the module will include entanglement, perturbation theory, second quantization, introductory quantum field theory, Feynman diagrams, and gauge theories of the fundamental forces of nature (Standard Model). Examples of possible further topics are path integrals, molecular quantum mechanics, spin dynamics, geometric phase and topology, coherent states, and quantum information theory.

The physics specialization modules aim to prepare students for their further professional, research, or academic careers in physics and related fields with lectures on important advanced topics in physics, an introduction to scientific research methods and tools, and an exposure to original scientific research literature. Lectures are complemented by homework exercises and student projects that culminate in student presentations and/or term papers.

*Intended Learning Outcomes*

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

- describe the building blocks of matter and the fundamental forces of nature;
- calculate quantities of interest in quantum physics like, for example, scattering cross sections or energy levels using perturbation theory and similar advanced methods;
- formulate models of particle physics and quantum systems and derive their properties.

*Indicative Literature*

T. Lancaster (2015). Quantum Field Theory for the Gifted Amateur. Oxford University Press.

Selected topics from: J.J. Sakurai. Modern Quantum Mechanics. Cambridge University Press.

*Usability and Relationship to other Modules*

- Mandatory elective specialization module for physics majors.
- Possible (mandatory) elective for a physics minor

*Examination Type: Module Examination*

Assessment Type: Project with presentation,

Duration of the presentation: 15 min
Weight: 100%

Scope: All intended learning outcomes of the module.

## 1.16 Advanced Applied Physics

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Advanced Applied Physics | CA-S-PHY-803 | Year 3 (CAREER - Specialization) | *5.0* |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CA-PHY-803-A | Biophysics/Nanotechnology | Lecture | 2.5 |
| CA-PHY-803-B | Advanced Optics/Atoms and Molecules | Lecture | 2.5 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Arnulf Materny | • Physics | Mandatory elective for physics |

<table>
<tr><td colspan="3">Entry Requirements</td><td>Frequency</td><td>Forms of Learning and Teaching</td></tr>
<tr><td>Pre-requisites<br>☒ Modern Physics</td><td>Co-requisites<br>☒ None</td><td>Knowledge, Abilities, or Skills<br>• None beyond formal pre-requisites</td><td>Annually (Spring)</td><td>• Lectures (35 hours)<br>• Homework exercises, project and presentation (55 hours)<br>• Private study (35 hours)</td></tr>
<tr><td colspan="3"></td><td>Duration<br>1 semester</td><td>Workload<br>125 hours</td></tr>
</table>

*Recommendations for Preparation*

None.

*Content and Educational Aims*

The Advanced Applied Physics module covers a selection of topics from advanced experimental physics such as biophysics, nanotechnology, advanced optics, or molecular physics. This module provides an introduction and overview to a range of interdisciplinary topics in experimental and computational physics for advanced physics majors. The aim of these partially seminar-style lectures is to enable the students to dive into the research on more complex and molecular systems and their optical characterization. After introductions to the fields, seminal but also recent research is discussed, in parts based on original literature.

The physics specialization modules aim to prepare students for their further professional, research, or academic careers in physics and related fields with lectures on important advanced topics in physics, an introduction to scientific research methods and tools, and an exposure to original scientific research literature. Lectures are complemented by homework exercises and/or student projects that culminate in student presentations and/or term papers.

*Intended Learning Outcomes*

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

- reduce complex systems to their basic physical properties;
- explain phenomena in bio/nanosystems by basic principles from physics;
- qualitatively but mathematically describe bio/nanosystems by their physical properties;
- explain the principles of the electronic properties of atoms and molecules including basic theoretical and experimental techniques to probe these properties;
- understand basic strategies of spectroscopic techniques for molecular systems;

- communicate in scientific language using advance field-specific terms.

*Indicative Literature*

Not specified - current research literature

*Usability and Relationship to other Modules*

- Mandatory elective specialization module for physics majors.
- Possible (mandatory) elective for a physics minor

*Examination Type: Module Examination*

Assessment Type: Project with presentation,

Duration of the presentation: 15 min
Weight: 100%

## 1.17 Foundations of Mathematical Physics

| *Module Name* | | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|---|
| Foundations of Mathematical Physics | | CA-S-MATH-806 | Year 2/3 (Specialization) | *5* |
| ***Module Components*** | | | | |
| *Number* | *Name* | | *Type* | *CP* |
| CA-MATH-806 | Foundations of Mathematical Physics | | Lecture | 5 |
| ***Module Coordinator*** S. Petrat | ***Program Affiliation*** • Mathematics | | ***Mandatory Status*** Mandatory elective for Mathematics and Physics | |
| ***Entry Requirements*** *Pre-requisites* ☒ Applied Mathematics Or ☒Introduction to Robotics and Intelligent Systems (RIS) | *Co-requisites* ☒None | *Knowledge, Abilities, or Skills* • Good command of linear algebra, analysis, and calculus | ***Frequency*** Biennially (Fall) ***Duration*** 1 semester | ***Forms of Learning and Teaching*** • Lectures (35 hours) • Private study (90 hours) ***Workload*** 125 hours |

***Recommendations for Preparation***

Review material from pre-requisite modules, especially Applied Mathematics. Having taken Applied Mathematics is recommended.

***Content and Educational Aims***

This module is about the application of mathematics in physics. Physics and mathematics have a very intimate relationship. On the one hand, big discoveries in physics have often led to interesting new mathematics, and on the other hand, new developments in mathematics have made possible new discoveries in physics. The goal of this module is to look at some examples of that, and to gain an insight what role rigorous mathematics has played and plays today in explaining physical phenomena. This class discusses examples from the major theories of classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics.

A selection of the following topics will be covered:

- Mathematical foundations of classical mechanics
- Hamiltonian dynamics and symplectic geometry
- Integrable systems
- Special functions
- Mathematical foundations of quantum mechanics
- Quantum entanglement
- Fourier analysis
- Variational methods
- Non-linear partial differential equations from physics

- Scattering theory
- Many-body quantum mechanics and second quantization
- Geometric foundations (differential geometry)
- Mathematical problems in statistical mechanics and other fields of physics

*Intended Learning Outcomes*

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

- demonstrate the application of mathematics in the context of physics
- explain the mathematical foundations of classical mechanics, quantum mechanics, statistical physics, and electrodynamics
- discuss the solutions to both linear and non-linear equations in physics
- breakdown the Hamiltonian formalism in the context of classical and quantum mechanics
- apply variational methods and their role in minimization and maximization problems

*Indicative Literature*

S.J. Gustafson, I.M. Sigal (2010). Mathematical Concepts of Quantum Mechanics, 2nd edition. Berlin: Springer.
G. Teschl (2014). Mathematical Methods in Quantum Mechanics, 2nd edition. Rhode Island: AMS.
W. Thirring (1997). Classical Mathematical Physics - Dynamical Systems and Field Theories, 3rd edition, Berlin: Springer.
W. Thirring (2002). Quantum Mathematical Physics - Atoms, Molecules and Large Systems, 2nd edition. Berlin: Springer.

*Usability and Relationship to other Modules*

- This module is a mandatory elective module in Mathematics to be taken in Semester 3 or 5.
- Possible mandatory Elective for a minor in Mathematics
- Mandatory elective for a major in Mathematics
- Mandatory elective Specialization module for a major Physics
- Elective for students of all other undergraduate studies

*Examination Type: Module Examination*

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

## 1.18 Physical Chemistry

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Physical Chemistry | CO-440 | Year 2 (CORE) | *5* |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CO-440-A | Physical Chemistry I | Lecture | 2.5 |
| CO-440-B | Physical Chemistry II | Lecture | 2.5 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Detlef Gabel | • Chemistry and Biotechnology (CBT) | Mandatory for CBT, mandatory elective for Physics and MCCB |

| *Entry Requirements* | | | *Frequency* | *Forms of Learning and Teaching* |
|---|---|---|---|---|
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Annually (Fall) | • Lecture (45 hours)<br>• Private study (45 hours)<br>• Exam preparation (35 hours |
| ☒ General and Inorganic Chemistry<br>or<br>☒Modern Physics | ☒ None | • None beyond formal prerequisites | *Duration*<br>2 semesters | *Workload*<br>125 hours |

*Recommendations for Preparation*

None;

*Content and Educational Aims*

The module provides an introduction to Physical Chemistry and focusses on thermodynamics, kinetics, intermolecular forces, surfaces, and electrochemistry. It also provides an introduction to quantum chemistry. This knowledge is essential to understand when chemical reactions can take place and how fast they can occur, and how molecules interact with each other and the solvent.

*Intended Learning Outcomes*

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

- use the gas laws to predict the behavior of perfect and real gases;
- differentiate between enthalpy, entropy, and Gibbs energy;
- correlate Gibbs energy with equilibrium constants;
- derive the velocities of reactions of zero, first, and the second order;
- derive the velocities of enzyme reactions and coupled reactions;
- explain and apply the concept of activation energy;
- calculate the velocity of reactions as a function of temperature;
- recognize phase transitions from measurable properties;
- explain and apply fundamentals in electrochemistry;
- explain how given molecules and their functional groups can interact with each other and their surroundings;

- recognize the different approaches to quantum chemical calculations;
- use an electronic lab book and share their own results with others through it;
- derive the fundamental equations of importance in physical chemistry;
- demonstrate presentation skills;

*Indicative Literature*

Atkins and de Paula, Elements of Physical Chemistry, 7th edition. Oxford: Oxford University Press, 2017.

*Usability and Relationship to other Modules*

- Pre/corequisite for the Inorganic and Physical Chemistry lab
- Mandatory for a Major and a Minor in CBT
- Mandatory elective specialization module for third year Physics and MCCB major students;

*Examination Type: Module Examination*

Assessment Component 1: Written examination — Duration: 120 min. Weight: 75%

Scope: Intended learning outcomes of the module (1-12)

Assessment Component 1: Presentation — Duration 15 min Weight 25%

Scope: Intended learning outcomes of the module (13-14)

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

## 1.19 **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<br>Mandatory elective for Physics |

| *Entry Requirements* | | | *Frequency* | *Forms of Learning and Teaching* |
|---|---|---|---|---|
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Annually (Fall) | • Lecture (17,5 hours)<br>• Lab (25.5 hours)<br>• Private Study (82.00) |
| ☒ General Electrical Engineering I&II<br><br>Or<br><br>☒Electrodynamics (Physics) | ☒ None | • Linear circuits<br>• Basic Calculus<br>• Basic Linear Algebra | *Duration*<br><br>1 semester | *Workload*<br><br>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*

- Pre-requisite for the 2nd year PCB design lab and 3rd year ECE specialization modules Embedded Systems and Digital Design
- 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.
- Mandatory elective 3rd year Specialization module for Physics major students.
- Mandatory for major in ECE.

*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%.

## 1.20 Internship / Startup and Career Skills

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Internship / Startup and Career Skills | CA-INT-900 | Year 3 (CAREER) | 15 |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CA-INT-900-0 | Internship | Internship | 15 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| Predrag Tapavicki & Christin Klähn (CSC Organization); SPC / Faculty Startup Coordinator (Academic responsibility); | • CAREER module for undergraduate study programs | Mandatory for all undergraduate study programs except IEM |

*Entry Requirements*

| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* |
|---|---|---|
| ☒ at least 15 CP from CORE modules in the major | ☒ None | • Information provided on CSC pages (see below)<br>• Major specific knowledge and skills |

*Frequency*

Annually (Spring/Fall)

*Forms of Learning and Teaching*

- Internship/Start-up
- Internship event
- Seminars, info-sessions, workshops and career events
- Self-study, readings, online tutorials

*Duration*

1 semester

*Workload*

375 Hours consisting of:

- Internship (308 hours)
- Workshops (33 hours)
- Internship Event (2 hours)
- Self-study (32 hours)

*Recommendations for Preparation*

- Reading the information in the menu sections titled "Internship Information," "Career Events," "Create Your Application," and "Seminars & Workshops" at the Career Services Center website: https://jacobs-university.jobteaser.com/en/users/sign_in?back_to_after_login=%2F
- Completing all four online tutorials about job market preparation and the application process, which can be found here: https://jacobs-university.jobteaser.com/en/users/sign_in?back_to_after_login=%2F
- Participating in the internship events of earlier classes

*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 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 Jacobs 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

- describe the scope and the functions of the employment market and personal career development;
- 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.;
- 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.);
- 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;
- justify professional decisions based on theoretical knowledge and academic methods;
- reflect on their professional conduct in the context of the expectations of and consequences for employers and their society;
- reflect on and set their own targets for the further development of their knowledge, skills, interests, and values;
- 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;
- discuss observations and reflections in a professional network.

*Indicative Literature*

Not specified

*Usability and Relationship to other Modules*

- Mandatory for a major in BCCB, CBT, CS, EES, GEM, IBA, IRPH, ISCP, Math, MCCB, Physics, RIS, and SMP.
- 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% |

## 1.21 Thesis and Seminar Physics

<table>
<tr><td colspan="3">Module Name<br>Thesis and Seminar Physics</td><td>Module Code<br>CA-PHY-800</td><td>Level (type)<br>Year 2 (CAREER)</td><td>CP<br>15.0</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-PHY-800-S</td><td colspan="3">Physics Research Seminar</td><td>Seminar</td><td>3.0</td></tr>
<tr><td>CA-PHY-800-T</td><td colspan="3">Physics Thesis</td><td>Project work</td><td>12.0</td></tr>
<tr><td>Module Coordinator<br><br>Jürgen Fritz, Peter Schupp</td><td colspan="3">Program Affiliation<br><br>• Physics</td><td colspan="2">Mandatory Status<br><br>Mandatory for Physics majors</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ Students must be in the third year and have taken at least 30 CP from CORE modules of their major<br><br>Co-requisites: ☒ None<br><br>Knowledge, Abilities, or Skills: • Academic writing skills</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Seminar (40 hours)<br>• Project work (200 hours)<br>• Private study (135 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>375 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>• Students need to recap their physics knowledge in the specific field of their thesis.<br>• Identify an area or a topic of interest and discuss this with your prospective supervisor in good time.<br>• Create a research proposal including a research plan to ensure timely submission.<br>• Ensure you possess all required technical research skills or are able to acquire them on time.<br>• Review the University’s Code of Academic Integrity and Guidelines to Ensure Good Academic Practice.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>Within this module, students use their knowledge in physics, and their mathematical and experimental skills gained during their studies, to become acquainted with an actual research topic. They will demonstrate their mastery of the content and methods of a specific research field in physics as provided by faculty.<br>In the seminar students will read, research, and present seminal papers of physics research. For their thesis they will familiarize themselves with a research topic and conduct physics research under guidance by faculty and research group members. The thesis includes performing experiments or theoretical calculations, the description and documentation of results, and the discussion and interpretation of outcomes. Results will be presented in a Physics Thesis Colloquium and will be written up and documented in a Bachelor Thesis according to the scientific standards in Physics.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes<br><br>By the end of the module, students will be able to<br>1. familiarize themselves with a new field in physics, by finding, reviewing, and digesting the relevant scientific literature;<br>2. prepare for a specific research problem in physics by researching the necessary experimental techniques and/or theoretical and mathematical approaches;<br>3. use and apply the appropriate experimental or theoretical/mathematical techniques to solve a problem in physics;<br>4. analyze the outcome of their research work and evaluate it through discussions with senior scientists;</td></tr>
</table>

5. organize their work and work responsibly and independently in a research team to fulfill a given task or solve a given problem;
6. use the appropriate format and language to summarize and describe their findings in a scientific report (thesis);
7. answer basic questions related to the background, the method used, and the outcomes of their research project;
8. use the appropriate language of the scientific community to communicate, discuss, and defend scientific findings and ideas in physics.

*Usability and Relationship to other Modules*

- Mandatory CAREER modules for the physics major.
- This module builds on all previous modules of the program. Students apply the knowledge, skills and competencies they acquired and practiced during their studies, including research methods and the ability to independently acquire additional skills as and if required.

*Examination Type: Module Component Examinations*

*Module Component 1: Thesis/Projekt*

Assessment Type: Thesis (Thesis) Length: 20-30 pages
Weight: 80%

Scope: All intended learning outcomes.

*Module Component 2: Seminar*

Type: Presentation (Seminar), Duration: 15-30 minutes, Weight: 20%
Scope: Intended learning outcomes 1, 2, 4, 7, 8.

Completion: To pass this module, both module component examinations have to be passed with at least 45%.

## 1.22 **Jacobs Track Modules**

### 1.22.1 Methods and Skills Modules

#### 1.22.1.1 Calculus and Elements of Linear Algebra I

<table>
<tr><td colspan="3">Module Name<br>Calculus and Elements of Linear Algebra I</td><td>Module Code<br>JTMS-MAT-09</td><td>Level (type)<br>Year 1 (Methods)</td><td>CP<br>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>JTMS-09</td><td colspan="3">Calculus and Elements of Linear Algebra I</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator<br><br>Marcel Oliver, Tobias Preußer</td><td colspan="3">Program Affiliation<br><br>• Jacobs Track – Methods and Skills</td><td colspan="2">Mandatory Status<br><br>Mandatory for CS, ECE, RIS, MATH and Physics<br>Mandatory elective for EES</td></tr>
<tr><td rowspan="2">Entry Requirements<br><br>Pre-requisites<br><br>☒ None</td><td rowspan="2">Co-requisites<br><br>☒ None</td><td rowspan="2">Knowledge, Abilities, or Skills<br><br>• Knowledge of Pre-Calculus at High School level (Functions, inverse functions, sets, real numbers, polynomials, rational functions, trigonometric functions, logarithm and exponential function, parametric equations, tangent lines, graphs, elementary methods for solving systems of linear and nonlinear equations)<br>• Knowledge of Analytic Geometry at High School level (vectors, lines, planes, reflection, rotation, translation, dot product, cross product, normal vector, polar coordinates)<br>• Some familiarity with elementary Calculus (limits, derivative) is helpful, but not strictly required.</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (35 hours)<br>• Private study (90 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Review all of higher-level High School Mathematics, in particular the topics explicitly named in “Entry Requirements – Knowledge, Ability, or Skills” above.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>This module is the first in a sequence introducing mathematical methods at the university level in a form relevant for study and research in the quantitative natural sciences, engineering, Computer Science, and Mathematics. The emphasis in these modules is on training operational skills and recognizing mathematical structures in a</td></tr>
</table>

problem context. Mathematical rigor is used where appropriate. However, a full axiomatic treatment of the subject is provided in the first-year modules "Analysis I" and "Linear Algebra".

The lecture comprises the following topics

- Brief review of number systems, elementary functions, and their graphs
- Brief introduction to complex numbers
- Limits for sequences and functions
- Continuity
- Derivatives
- Curve sketching and applications (isoperimetric problems, optimization, error propagation)
- Introduction to Integration and the Fundamental Theorem of Calculus
- Review of elementary analytic geometry
- Vector spaces, linear independence, bases, coordinates
- Matrices and matrix algebra
- Solving linear systems by Gauss elimination, structure of general solution
- Matrix inverse

*Intended Learning Outcomes*

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

- apply 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;
- recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;
- 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*

S.I. Grossman (2014). Calculus of one variable, 2nd edition. Cambridge: Academic Press.
S.A. Leduc (2003). Linear Algebra. Hoboken: Wiley.
K. Riley, M. Hobson, S. Bence (2006). Mathematical Methods for Physics and Engineering, third edition. Cambridge: Cambridge University Press.

*Usability and Relationship to other Modules*

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- The module is followed by "Calculus and Elements of Linear Algebra II". All students taking this module are expected to register for the follow-up module.
- A rigorous treatment of Calculus is provided in the module "Analysis I". All students taking "Analysis I" are expected to either take this module or exceptionally satisfy the conditions for advanced placement as laid out in the Jacobs Academic Policies for Undergraduate Study.
- The second-semester module "Linear Algebra" will provide a complete proof-driven development of the theory of Linear Algebra. Students enrolling in "Linear Algebra" are expected to have taken this module; in particular, the module "Linear Algebra" will assume that students are proficient in the operational aspects of Gauss elimination, matrix inversion, and their elementary applications.
- This module is a prerequisite for the module "Applied Mathematics" which develops more advanced theoretical and practical mathematical tools essential for any physicist or mathematician.
- Mandatory for a major in CS, ECE, RIS, MATH and Physics
- Mandatory elective for a major in EES.
- Pre-requisite for Calculus and Elements of Linear Algebra II
- Elective for all other study programs.

*Examination Type: Module Examination*

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

Scope: All intended learning outcomes of this module

### 1.22.1.2 Calculus and Elements of Linear Algebra II

| *Module Name* | | | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|---|---|
| Calculus and Elements of Linear Algebra II | | | JTMS-MAT-10 | Year 1 (Methods) | *5* |
| ***Module Components*** | | | | | |
| *Number* | *Name* | | | *Type* | *CP* |
| JTMS-10 | Calculus and Elements of Linear Algebra II | | | Lecture | 5 |
| ***Module Coordinator*** | ***Program Affiliation*** | | | ***Mandatory Status*** | |
| Marcel Oliver, Tobias Preußer | • Jacobs Track – Methods and Skills | | | Mandatory for CS, ECE, MATH, Physics, RIS | |
| ***Entry Requirements*** | | | ***Frequency*** | ***Forms of Learning and Teaching*** | |
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Annually (Spring) | • Lectures (35 hours)<br>• Private study (90 hours) | |
| ☒ Calculus and Elements of Linear Algebra I | ☒ None | • None beyond formal pre-requisites | ***Duration***<br>1 semester | ***Workload***<br>125 hours | |

***Recommendations for Preparation***

Review the content of Calculus and Elements of Linear Algebra I

***Content and Educational Aims***

This module is the second in a sequence introducing mathematical methods at the university level in a form relevant for study and research in the quantitative natural sciences, engineering, Computer Science, and Mathematics. The emphasis in these modules is on training operational skills and recognizing mathematical structures in a problem context. Mathematical rigor is used where appropriate. However, a full axiomatic treatment of the subject is provided in the first-year modules "Analysis I" and "Linear Algebra".

The lecture comprises the following topics

- Directional derivatives, partial derivatives
- Linear maps
- The total derivative as a linear map
- Gradient and curl (elementary treatment only, for more advanced topics, in particular the connection to the Gauss and Stokes' integral theorems, see module "Applied Mathematics"
- Optimization in several variables, Lagrange multipliers
- Elementary ordinary differential equations
- Eigenvalues and eigenvectors
- Hermitian and skew-Hermitian matrices
- First important example of eigendecompositions: Linear constant-coefficient ordinary differential equations
- Second important example of eigendecompositions: Fourier series
- Fourier integral transform
- Matrix factorizations: Singular value decomposition with applications, LU decomposition, QR decomposition

***Intended Learning Outcomes***

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

- apply 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;
- recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;

- 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*

S.I. Grossman (2014). Calculus of one variable, 2nd edition. Cambridge: Academic Press.
S.A. Leduc (2003). Linear Algebra. Hoboken: Wiley.
K. Riley, M. Hobson, S. Bence (2006). Mathematical Methods for Physics and Engineering, third edition. Cambridge: Cambridge University Press.

*Usability and Relationship to other Modules*

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- 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.
- Mandatory for CS, ECE, MATH, Physics and RIS.
- Elective for all other study programs.

*Examination Type: Module Examination*

Assessment type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

### 1.22.1.3 Probability and Random Processes

| *Module Name* | | | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|---|---|
| Probability and Random Processes | | | JTMS-MAT-12 | Year 2 (Methods) | *5* |
| ***Module Components*** | | | | | |
| *Number* | *Name* | | | *Type* | *CP* |
| JTMS-12 | Probability and random processes | | | Lecture | 5 |
| ***Module Coordinator*** Marcel Oliver, Tobias Preußer | ***Program Affiliation*** • Jacobs Track – Methods and Skills | | | ***Mandatory Status*** Mandatory for CS, ECE, MATH, Physics, RIS Mandatory elective for EES | |
| ***Entry Requirements*** *Pre-requisites* ☒ Calculus and Elements of Linear Algebra I & 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. | ***Frequency*** Annually (Fall) ***Duration*** 1 semester | ***Forms of Learning and Teaching*** • Lectures (35 hours) • Private study (90 hours) ***Workload*** 125 hours | |
| ***Recommendations for Preparation*** Review all of the first year calculus and linear algebra modules as indicated in "Entry Requirements – Knowledge, Ability, or Skills" above. | | | | | |

***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

- 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;
- recognize the probabilistic structures in an unfamiliar context and translate them into a mathematical problem statement;
- 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*

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students taking this module are expected to be familiar with basic tools from calculus and linear algebra.
- Mandatory for a major in CS, ECE, MATH, Physics and RIS.
- Mandatory elective for a major in EES (if pre-requisites are met).
- Elective for all other study programs.

*Examination Type: Module Examination*

Assessment type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

#### 1.22.1.4 Numerical Methods

<table>
<tr><td colspan="3">Module Name<br>Numerical Methods</td><td>Module Code<br>JTMS-MAT-13</td><td>Level (type)<br>Year 2 (Methods)</td><td>CP<br>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>JTMS-13</td><td colspan="3">Numerical Methods</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator<br><br>Marcel Oliver, Tobias Preußer</td><td colspan="3">Program Affiliation<br><br>• Jacobs Track – Methods and Skills</td><td colspan="2">Mandatory Status<br><br>Mandatory for ECE, MATH, Physics<br>Mandatory elective for CS and RIS</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• 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)<br>• Knowledge of Linear Algebra (vectors, matrices, lines, planes, n-dimensional Euclidean vector space, rotation, translation, dot product (scalar product), cross product, normal vector, eigenvalues,</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (35 hours)<br>• Private study (90 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
</table>

| | | | |
|---|---|---|---|
| | eigenvectors, elementary techniques for solving systems of linear equations) | | |

*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

- describe the basic principles of discretization used in the numerical treatment of continuous problems;
- 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;
- 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;
- implement simple numerical algorithms in a high-level programming language;
- 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*

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions 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.
- Mandatory for a major in ECE, MATH, and Physics.
- Mandatory elective for a major in CS and RIS.
- Elective for all other study programs.

*Examination Type: Module Examination*

Assessment type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module.

### 1.22.1.5 Programming in Python

| *Module Name*<br>Programming in Python | | *Module Code*<br>JTMS-SKI-14 | *Level (type)*<br>Year 1 (Methods) | *CP*<br>*5* |
|---|---|---|---|---|
| ***Module Components*** | | | | |
| *Number* | *Name* | | *Type* | *CP* |
| JTMS-14 | Programming in Python | | Lecture | 5 |
| ***Module Coordinator***<br><br>Kinga Lipskoch | ***Program Affiliation***<br><br>• Jacobs Track – Methods and Skills | | ***Mandatory Status***<br><br>Mandatory for IEM<br>Mandatory elective for EES and Physics | |
| ***Entry Requirements***<br><br>*Pre-requisites*<br><br>☒ None | *Co-requisites*<br><br>☒ None<br><br>*Knowledge, Abilities, or Skills*<br><br>• none | ***Frequency***<br><br>Annually (Fall)<br><br>***Duration***<br><br>1 semester | ***Forms of Learning and Teaching***<br><br>• Class attendance (35 hours)<br>• Private study (85 hours)<br>• Exam preparation (5 hours)<br><br>***Workload***<br><br>125 hours | |

***Recommendations for Preparation***

It is recommended that students install a suitable programming environment (simple editor or Integrated Development Environment) and a new stable version of Python on their notebooks.

***Content and Educational Aims***

This module offers an introduction to programming using the programming language Python. The module presents the basics of Python programming and provides a short overview of the program development cycle. It covers fundamental programming components and constructs in a hands-on manner. The beginning of the module covers the concepts of data types, variables, operators, strings and basic data structures. Next, other programming constructs such as branching, iterations, and data structures such as strings, lists, tuples, and dictionaries are introduced. The module also gives an introduction to functions, as well as simple file handling by introducing reading data from files, processing the data and writing the results to files. Later, object-oriented programming concepts such as constructors, methods, overloaded operators and inheritance are presented. Retrieving data from URLs and processing of larger amounts of data and their queries and storage in files are addressed. Simple interactive graphics and operations are also presented with the help of an object-oriented graphics library.

***Intended Learning Outcomes***

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

- explain basic concepts of imperative programming languages such as variables, assignments, loops, function calls, data structures;
- work with user input from the keyboard, and write interactive Python programs;
- write, test, and debug programs;
- illustrate basic object-oriented programming concepts such as objects, classes, information hiding, and inheritance;
- give original examples of function and operator overloading;
- retrieve data and process and generate data from/to files;
- use some available Python modules and libraries such as those related to data or graphics.

*Indicative Literature*

Kenneth A. Lambert (2014). Fundamentals of Python Data Structures. Boston: Cengage Learning PTR.

Mark Summerfield (2010). Programming in Python: A complete introduction to the Python language, second edition. London: Pearson Education.

John Zelle (2009). Python Programming: An introduction to Computer Science, second edition. Portland: Franklin, Beedle & Associates.

Igor Milovanovic (2013). Python Data Visualization Cookbook. Birmingham: Packt Publishing.

Cay Horsmann, Rance D. Necaise (2014). Python for Everyone. Hoboken: Wiley.

*Usability and Relationship to other Modules*

- The module is a mandatory / mandatory elective module of the Methods and Skills area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Mandatory for a major in IEM.
- Mandatory elective for a major in EES and Physics.
- Elective for all other study programs.

*Examination Type: Module Examination*

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

Scope: All intended learning outcomes of the module
Module achievements: 50% of the assignments passed

### 1.22.1.6 Discrete Mathematics

| ***Module Name*** | ***Module Code*** | ***Level (type)*** | ***CP*** |
|---|---|---|---|
| Discrete Mathematics | CO-501 | Year 2/3 (CORE) | *5.0* |

***Module Components***

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| CO-501-A | Discrete Mathematics | Lecture | 5.0 |

| ***Module Coordinator*** | ***Program Affiliation*** | ***Mandatory Status*** |
|---|---|---|
| K. Mallahi-Karai | • Mathematics | Mandatory elective for Mathematics, CS, Physics and RIS |

| *Entry Requirements* | | | ***Frequency*** | ***Forms of Learning and Teaching*** |
|---|---|---|---|---|
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Annually (Spring) | • Lectures (35 hours)<br>• Private Study (90 hours) |
| ☒ None | ☒ None | • Basic university mathematics: can be acquired via the Methods Modules “Calculus and Elements of Linear Algebra I + II” or “Applied Calculus” and “Finite Mathematics” | ***Duration***<br>1 semester | ***Workload***<br>125 hours |

*Recommendations for Preparation*

- Some basic familiarity with linear algebra is useful, but not technically required.
- It is recommended to have taken the Methods module: Calculus and Elements of Linear Algebra I + II

***Content and Educational Aims***

This module is an introductory lecture in discrete mathematics. The lecture consists of two main components, enumerative combinatorics and graph theory. The lecutre emphasizes connections of discrete mathematics with other areas of mathematics such as linear algebra and basic probability, and outlines applications to areas of computer science, cryptography, etc. where employment of ideas from discrete mathematics has proven to be fruitful. The first part of the lecture—enumerative combinatorics—deals with several classical enumeration problems (Binomial coefficients, Stirling numbers), counting under group actions and generating function. The second half of the lecture—graph theory—includes a discussion of basic notions such as chromatic number, planarity, matchings in graphs, Ramsey theory, and expanders, and their applications.

***Intended Learning Outcomes***
By the end of the module, students will be able to

- demonstrate their mastery of basic tools in discrete mathematics.
- develop the ability to use discrete mathematics concepts (such as graphs) to model problems in computer science.
- analyze the definition of basic combinatorial objects such as graphs, permutations, partitions, etc.
- formulate and design methods sand algorithms for solving applied problems basic on concepts from discrete mathematics.

*Indicative Literature*

J.H. van Lint and R.M. Wilson (2001). A Course in Combinatorics, second edition. Cambridge: Cambridge University Press.

B. Bollobas (1998). Modern Graph Theory, Berlin: Springer.

***Usability and Relationship to other Modules***

- This module is a specialization / CORE module in Mathematics to be taken in Semester 4 or 6.
- This module is recommended for students pursuing a minor in Mathematics
- This module serves as a mandatory elective Methods and Skills module for CS, Physics and RIS
- This module is a good option as an elective module for students in RIS.

*Examination Type: Module Examination*

Assessment Type: Written examination

Duration: 120 min
Weight: 100%

Scope: All intended learning outcomes of this module

### 1.22.2 Big Questions Modules

#### 1.22.2.1 Water: The Most Precious Substance on Earth

<table>
<tr><td colspan="3">Module Name<br>Water: The Most Precious Substance on Earth</td><td>Module Code<br>JTBQ-BQ-002</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>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>JTBQ-002</td><td colspan="3">Water: The Most Precious Substance on Earth</td><td>Lecture/Tutorial</td><td>5</td></tr>
<tr><td>Module Coordinator<br><br>M. Bau and D. Mosbach</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs except IEM</td><td colspan="2">Mandatory Status<br><br>• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td rowspan="2">Entry Requirements<br><br>Pre-requisites<br><br>☒ None</td><td rowspan="2"><br><br>Co-requisites<br><br>☒ None</td><td rowspan="2"><br><br>Knowledge, Abilities, or Skills<br><br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency<br><br>Annually (part I: Fall; part II: Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (17.5 hours)<br>• Project work (90 hours)<br>• Private study (17.5 hours)</td></tr>
<tr><td>Duration<br><br>2 semesters</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Critically following media coverage on the module’s topics in question.</td></tr>
</table>

*Content and Educational Aims*

All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.
Water is the basic prerequisite for life on our planet, but it has become a scarce resource and a valuable commodity. Water is of fundamental importance to the world’s economy and global food supply, in addition to being a driving force behind geopolitical conflict. In this module, the profound impact of water on all aspects of human life will be addressed from very different perspectives: from the natural and environmental sciences and engineering, and from the social and cultural sciences.
Following topical lectures in the Fall semester, students will work on projects on the occasion of the World Water Day (March 22) in small teams comprised of students from various disciplines and with different cultural backgrounds. This teamwork will be accompanied by related tutorials.

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- advance a knowledge-based opinion on the complex module topics: on the physio-chemical properties of water, its origin and history, on the importance of water as a resource, on physical and economic freshwater scarcity, on the risks of water pollution and the challenges faced by waste water treatment, on the concept of virtual water, on the bottled water industry, and on the cultural values and meanings of water;
- formulate coherent written and oral contributions (e.g., to panel discussions) on the topic;
- perform well-organized teamwork;
- present a self-designed project in a university-wide context.

*Indicative Literature*

Finney, John (2015). Water. A Very Short Introduction. Oxford: Oxford University Press.

Zetland, David (2011). The End of Abundance: Economic Solutions to Water Scarcity. California: Aguanomics Press.

United Nation (January 2016): Sustainable Development Goals. Retrieved from https://www.ipcc.ch

*Usability and Relationship to other Modules*

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

Assessment Component 1: Written examination — Duration: 60 min, Weight: 50%

Assessment Component 2: Team project — Weight: 50%

Scope: All intended learning outcomes of the module

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

### 1.22.2.2 Ethics in Science and Technology

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Ethics in Science and Technology | JTBQ-BQ-003 | Year 3 (Jacobs Track) | 5.0 |

*Module Components*

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| JTBQ-003 | Ethics in Science and Technology | Lecture /Projects | 5.0 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| A. Lerchl | • Big Questions Area: All undergraduate study programs, except IEM | • Mandatory for CBT<br>• Mandatory elective for students of all undergraduate study programs, except IEM |

| *Entry Requirements* | | | *Frequency* | *Forms of Learning and Teaching* |
|---|---|---|---|---|
| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | Each semester (Fall & Spring) | • Lectures (35 hours)<br>• Project work (55 hours)<br>• Private study (35 hours) |
| ☒ None | ☒ None | • The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources | *Duration*<br>1 semester | *Workload*<br>125 hours |

*Recommendations for Preparation*

Critically following media coverage of the scientific topics in question.

*Content and Educational Aims*

All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizons with applied problem solving that extends beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.

Ethics is an often neglected, yet essential part of science and technology. Our decisions about right and wrong influence the way in which our inventions and developments change the world. A wide array of examples will be presented and discussed, e.g., the foundation of ethics, individual vs. population ethics, artificial life, stem cells, animal rights, abortion, pre-implantation diagnostics, legal and illegal drugs, the pharmaceutical industry, gene modification, clinical trials and research with test persons, weapons of mass destruction, data fabrication, and scientific fraud.

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- summarize and explain ethical principles;
- critically look at scientific results that seem too good to be true;
- apply the ethical concepts to virtually all areas of science and technology;
- discover the responsibilities of society and of the individual for ethical standards;
- understand and judge the ethical dilemmas in many areas of the daily life;
- discuss the ethics of gene modification at the level of cells and organisms;
- reflect on and evaluate clinical trials in relation to the Helsinki Declaration;
- distinguish and evaluate the ethical guidelines for studies with test persons;
- complete a self-designed project;
- overcome general teamwork problems;
- perform well-organized project work.

*Indicative Literature*

Not specified.

*Usability and Relationship to other Modules*

- Mandatory for CBT
- This module is a mandatory elective module in the Big Questions area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

| | |
|---|---|
| Assessment Component 1: Written examination | Duration: 60 min<br>Weight: 50% |
| Assessment Component 2: Team project | Weight: 50% |

Scope: All intended learning outcomes of the module

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

### 1.22.2.3 Global Health – Historical context and future challenges

<table>
<tr><td colspan="3">Module Name<br>Global Health – Historical context and future challenges</td><td>Module Code<br>JTBQ-BQ-004</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>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>JTBQ-004</td><td colspan="3">Global Health – Historical context and future challenges</td><td>Lecture</td><td>5</td></tr>
<tr><td>Module Coordinator<br><br>A. M. Lisewski</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status<br><br>• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (35 hours)<br>• Private study (90 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Critically following media coverage on the module's topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.<br>This module gives a historical, societal, technical, scientific, and medical overview of the past and future milestones and challenges of global health. Particular focus is put on future global health issues in a world that is interconnected both through mobility and communication networks. This module presents the main milestones along the path to modern health systems, including the development of public hygiene, health monitoring and disease response, and health-related breakthroughs in science, technology, and the economy. Focus is given to pediatric, maternal, and adolescent health, as these are the areas most critical to the well-being of future generations. This module also provides key concepts in global health, epidemiology, and demographics, such as the connection between a society's economic level and its population's health status, measures of health status, demographic and epidemiologic transitions, and modern issues such as the growing fragmentation (at a personal level) of disease conditions and the resulting emergence of personalized medicine. Finally, attention is also given to less publicly prominent global health issues, such as re-emerging diseases, neglected tropical diseases, and complex humanitarian crises.</td></tr>
</table>

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- explain the historical context of current global health surveillance, response systems, and institutions;
- discuss and evaluate the imminent and future challenges to public hygiene and response to disease outbreaks in the context of a global societal network.

*Indicative Literature*

Richard Skolnik (2015). Global Health 101 (Essential Public Health). Burlington: Jones and Bartlett Publishers, Inc.

*Usability and Relationship to other Modules*

- The module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

| | |
|---|---|
| Assessment Type: Written examination | Duration: 60 min. |
| Scope: All intended learning outcomes of the module | Weight: 100% |

### 1.22.2.4 Global Existential Risks

| *Module Name* | | | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|---|---|
| Global Existential Risks | | | JTBQ-BQ-005 | Year 3 (Jacobs Track) | 2.5 |
| ***Module Components*** | | | | | |
| *Number* | *Name* | | | *Type* | *CP* |
| JTBQ-005 | Global Existential Risks | | | Lecture | 2.5 |
| ***Module Coordinator***<br><br>M. A. Lisewski | ***Program Affiliation***<br><br>• Big Questions Area: All undergraduate study programs except IEM | | | ***Mandatory Status***<br><br>• Mandatory elective for students of all undergraduate study programs except IEM | |
| ***Entry Requirements*** | | | ***Frequency***<br><br>Annually (Spring) | ***Forms of Learning and Teaching***<br><br>• Lectures (17.5 hours)<br>• Private study (45 hours) | |
| *Pre-requisites*<br><br>☒ None | *Co-requisites*<br><br>☒ None | *Knowledge, Abilities, or Skills*<br><br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources | ***Duration***<br><br>1 semester | ***Workload***<br><br>62.5 hours | |
| ***Recommendations for Preparation***<br><br>Critically following media coverage on the module's topics in question. | | | | | |

***Content and Educational Aims***

All "Big Questions" (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students' horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.

The more we develop science and technology, the more we also learn about catastrophic and, in the worst case, even existential global dangers that put the entire human civilization at risk of collapse. These doomsday scenarios therefore directly challenge humanity's journey through time as an overall continuous and sustainable process that progressively leads to a more complex but still largely stable human society. The module presents the main known varieties of existential risks, including, for example, astrophysical, planetary, biological, and technological events or critical transitions that have the capacity to severely damage or even eradicate earth-based human civilization as we know it. Furthermore, this module offers a description of the characteristic features of these risks in comparison to more conventional risks, such as natural disasters, and a classification of global existential risks based on parameters such as range, intensity, probability of occurrence, and imminence. Finally, this module reviews several hypothetical monitoring and early warning systems as well as analysis methods that could potentially be used in strategies, if not to eliminate, then at least to better understand and ideally to minimize imminent global existential risks. This interdisciplinary module will allow students to explore this topic across diverse subject fields.

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- explain the varieties of global existential risks;
- discuss approaches to minimize these risks;
- formulate coherent written and oral contributions on this topic.

*Indicative Literature*

Nick Bostrom, Milan M. Cirkovic (eds.) (2011). Global Catastrophic Risk.Oxford: Oxford University Press.

Murray Shanahan (2015). The Technological Singularity. Cambridge:The MIT Press.

Martin Rees (2003) Our Final Hour. New York: Basic Books.

*Usability and Relationship to other Modules*

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

Assessment Type: Written examination — Duration: 60 min.
Scope: All intended learning outcomes of the module — Weight: 100%

### 1.22.2.5 Future: From Predictions and Visions to Preparations and Actions

<table>
<tr><td colspan="3">Module Name<br>Future: From Predictions and Visions to Preparations and Actions</td><td>Module Code<br>JTBQ-BQ-006</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>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>JTBQ-006</td><td colspan="3">Future: From Predictions and Visions to Preparations and Actions</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>Joachim Vogt</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status<br><br>• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (17.5 hours)<br>• Private study (45 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Critically following media coverage of the module’s topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizons with applied problem solving that extend beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.<br>This module addresses selected topics related to the future as a general concept in science, technology, culture, literature, ecology, and economy, and it consists of three parts. The first part (Future Continuous) discusses forecasting methodologies rooted in the idea that key past and present processes are understood and continue to operate such that future developments can be predicted. General concepts covered in this context include determinism, uncertainty, evolution, and risk. Mathematical aspects of forecasting are also discussed. The second part (Future Perfect) deals with human visions of the future as reflected in the arts and literature, ranging from ideas of utopian societies and technological optimism to dystopian visions in science fiction. The third part (Future Now) concentrates on important current developments—such as trends in technology, scientific breakthroughs, the evolution of the Earth system, and climate change—and concludes with opportunities and challenges for present and future generations.</td></tr>
</table>

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- distinguish and qualify important approaches to forecasting and prediction;
- summarize the history of utopias, dystopias, and the ideas presented in classical science fiction;
- characterize current developments in technology, ecology, society, and their implications for the future.

*Indicative Literature*


United Nations (2015, September) Millennium Development Goals. Retrieved from http://www.un.org/millenniumgoals.

United Nation (2016, January): Sustainable Development Goals. Retrieved from http://catalog.jacobs-university.de/search~S0

United Nations University. https://unu.edu

US National Intelligence Council (2017). Global Trends. Retrieved from https://www.dni.gov/index.php/global-trends-home.

International Panel on Climate Change. Retrieved from https://www.ipcc.ch.

World Inequality Lab (2017, December). World Inequality Report 2018. Retrieved from https://wir2018.wid.world.

World Health Organization. Retrieved from http://www.who.int.

World Trade Organization. Retrieved from *https://www.wto.org*

Gapminder. Retrieved from https://www.gapminder.org.

World Bank. Retrieved from http://www.worldbank.org.


*Usability and Relationship to other Modules*

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

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

Scope: All intended learning outcomes of the module

### 1.22.2.6 Climate Change

<table>
<tr><td colspan="3">Module Name<br>Climate Change</td><td>Module Code<br>JTBQ-BQ-007</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>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>JTBQ-007</td><td colspan="3">Climate Change</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br>L. Thomsen/<br>V. Unnithan</td><td colspan="3">Program Affiliation<br>• Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status<br>• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (17.5 hours)<br>• Private study (45 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Critically following media coverage of the module’s topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br>All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.<br>This module will give a brief introduction into the development of the atmosphere throughout Earth's history from the beginning of the geological record up to modern times, and will focus on geological, cosmogenic, and anthropogenic changes. Several major events in the evolution of the Earth that had a major impact on climate will be discussed, such as the evolution of an oxic atmosphere and ocean, the onset of early life, snowball Earth, and modern glaciation cycles. In the second part, the module will focus on the human impact on present climate change and global warming. Causes and consequences, including case studies and methods for studying climate change, will be presented and possibilities for climate mitigation (geo-engineering) and adapting our society to climate change (such as coastal protection and adaption of agricultural practices to more arid and hot conditions) will be discussed.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes</td></tr>
</table>

Students acquire transferable and key skills in this module.

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

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- advance a knowledge-based opinion on the complex module topics, including: impact of climate change on the natural environment over geological timescales and since the industrial revolution, and the policy framework in which environmental decisions are made internationally;
- work effectively in a team environment and undertake data interpretation;
- discuss approaches to minimize habitat destruction.

*Indicative Literature*

The course is based on a self-contained, detailed set of online lecture notes.

Ruddiman, William F. Earth's Climate (2001). Past and future. New York: Macmillan.

*Usability and Relationship to other Modules*

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

| | |
|---|---|
| Assessment Type: Written examination | Duration: 60 min. |
| Scope: All intended learning outcomes of the module | Weight: 100% |

### 1.22.2.7 Extreme Natural Hazards, Disaster Risks, and Societal Impact

<table>
<tr><td colspan="2">Module Name<br>Extreme Natural Hazards, Disaster Risks, and Societal Impact</td><td>Module Code<br>JTBQ-BQ-008</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>2.5</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>JTBQ-008</td><td colspan="2">Extreme Natural Hazards: Disaster Risks, and Societal Impact</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>L. Thomsen</td><td colspan="2">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status<br><br>• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td rowspan="2" colspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br><br>Co-requisites: ☒ None<br><br>Knowledge, Abilities, or Skills<br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (17.5 hours)<br>• Private study (45 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 hours</td></tr>
<tr><td colspan="5">Recommendations for Preparation<br><br>Critically following media coverage of the module’s topics in question.</td></tr>
<tr><td colspan="5">Content and Educational Aims<br><br>All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizons with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.<br>Extreme natural events increasingly dominate global headlines, and understanding their causes, risks, and impacts, as well as the costs of their mitigation, is essential to managing hazard risk and saving lives. This module presents a unique, interdisciplinary approach to disaster risk research, combining natural science and social science methodologies. It presents the risks of global hazards and natural disasters such as volcanoes, earthquakes, landslides, hurricanes, precipitation floods, and space weather, and provides real-world hazard and disaster case studies from Latin America, the Caribbean, Africa, the Middle East, Asia, and the Pacific.</td></tr>
<tr><td colspan="5">Intended Learning Outcomes<br><br>Students acquire transferable and key skills in this module.<br>By the end of this module, student should be able to<br><br>• use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;</td></tr>
</table>

- advance a knowledge-based opinion on the complex module topics, including how natural processes affect and interact with our civilization, especially those that create hazards and disasters;
- distinguish the methods scientists use to predict and assess the risk of natural disasters;
- discuss the social implications and policy framework in which decisions are made to manage natural disasters;
- work effectively in a team environment.

*Indicative Literature*

The course is based on a self-contained, detailed set of online lecture notes.

Ismail-Zadeh, Alik, et al., eds (2014). Extreme natural hazards, disaster risks and societal implications. In *Special Publications of the International Union of Geodesy and Geophysics Vol. 1.* Cambridge: Cambridge University Press.

*Usability and Relationship to other Modules*

- The module is a mandatory elective module of the Big Questions area, that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules)
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute such knowledge and competences to class discussions and activities.

*Examination Type: Module Examination*

Assessment Type: Written examination — Duration: 60 min.
Scope: All intended learning outcomes of the module — Weight: 100%

### 1.22.2.8 International Development Policy

<table>
<tr><td colspan="3">Module Name<br>International Development Policy</td><td>Module Code<br>JTBQ-BQ-009</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>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>JTBQ-009</td><td colspan="3">International Development Policy</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>C. Knoop</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs, except IEM</td><td colspan="2">Mandatory Status<br><br>• Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking, and a proficient handling of data sources</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lecture (17.5 hours)<br>• Presentations<br>• Private study (45 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Critically following media coverage of the module’s topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>All “Big Questions” (BQ) modules deal with the economic, technological, societal, and environmental contexts of the global issues and challenges of the coming decades. BQ modules intend to raise awareness of those challenges and broaden students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become informed and responsible citizens in a global society.<br>We live in a world where still a large number of people still live in absolute poverty without access to basic needs and services, such as food, sanitation, health care, security, and proper education. This module provides an introduction to the basic elements of international development policy, with a focus on the relevant EU policies in this field and on the Sustainable Development Goals/SDGs of the United Nations. The students will not only learn about the tools applied in modern development policies, but also about the critical aspects of monitoring and evaluating the results of development policy. Module-related oral presentations and debates will enhance the students’ learning experience.</td></tr>
</table>

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- breakdown the complexity of modern development policy;
- identify, explain, and evaluate the tools applied in development policy;
- formulate well-justified criticism of development policy;
- summarize and present a module-related topic in an appropriate verbal and visual form.

*Indicative Literature*

Francis Fukuyama (2006). The end of history and the last man. New York: Free Press.

Kingsbury, McKay, Hunt (2008). International Development.Issues and challenges. London: Palgrave.

A.Sumner, M.Tiwari (2009) After 2015: International Development Policy at a crossroad. New York: Palgrave Macmillan.

Graduate Institute of International Development, G. Carbonnier eds. (2001). International Development Policy: Energy and Development. New York:Palgrave Macmillan.

John Donald McNeil. International Development: Challenges and Controversy. Sentia Publishing,e-book.

*Usability and Relationship to other Modules*

- This module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

Assessment Type: Presentation — Duration: 10 minutes per student

Scope: All intended learning outcomes of the module — Weight: 100%

### 1.22.2.9 Sustainable Value Creation with Biotechnology. From Science to Business

<table>
<tr><td colspan="3">Module Name<br>Sustainable Value Creation with Biotechnology. From Science to Business.</td><td>Module Code<br>JTBQ-BQ-011</td><td>Level (type)<br>Year 3<br>(Jacobs Track)</td><td>CP<br>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>JTBQ-011</td><td colspan="3">Sustainable Value Creation with Biotechnology. From Science to Business</td><td>Lecture - Tutorial</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br>Marcelo Fernandez Lahore</td><td colspan="3">Program Affiliation<br><ul><li>Jacobs Track - Big Questions</li></ul></td><td colspan="2">Mandatory Status<br><ul><li>Mandatory elective for students of all undergraduate study except IEM</li></ul></td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br><table><tr><td>Pre-requisites<br><br>☒ None</td><td>Co-requisites<br><br>☒ None</td><td>Knowledge, Abilities, or Skills<br><ul><li>The ability and openness to engage in interdisciplinary issues on bio-based value creation</li><li>media literacy, critical thinking and a proficient handling of data sources</li></ul></td></tr></table></td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><ul><li>Lecture and Tutorial (17.5 hours)</li><li>Private study (45 hours)</li></ul></td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br>https://www.ctsi.ucla.edu/researcher-resources/files/view/docs/EGBS4_Kolchinsky.pdf<br>https://link.springer.com/article/10.1057/jcb.2008.27<br>https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf</td></tr>
</table>

*Content and Educational Aims*

All "Big Questions" (BQ) modules deal with the economic, technological, societal and environmental contexts of the global issues and challenges of the coming decades. The BQ modules intend to raise awareness of those challenges and broaden the students' horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules support students in their development to become an informed and responsible citizen in a global society.
This module has a particular focus on the role that Biotechnology and Biorefining is expected to play in social, economic and environmental contexts.

To deliver such a vision the module will prepare students to extract value form Biotechnology and associated activities. This will be done in the form of business cases that will be systematically developed by students alongside the development of the module. In this way, students will develop entrepreneurial skills while understanding basic business-related activities that are not always present in a technical curriculum. Case development will also provide students with the possibility of understanding the social, economic, environmental impact that Biotechnology and Biorefining can deliver in a Bio-Based Economy. The knowledge and skills gained through this module are in direct and indirect support of the UN 2030 Agenda for Sustainable Development: "Transforming our World".

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- design and develop a Business Case based on the tools provided by modern Biotechnology;
- explain the interplay between Science, Technology and Economics / Finance;
- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- work effectively in a team environment and undertake data interpretation and analysis;
- discuss approaches to value creation in the context of Biotechnology and Sustainable Development;
- explain the ethical implications of technological advance and implementation;
- demonstrate presentation skills.

*Indicative Literature*

Springham, D., V. Moses & R.E. Cape (1999). Biotechnology – The Science and the Business. 2nd. Ed. Boca Raton: CRC Press.

Kornberg, Arthur (2002). The Golden Helix: Inside Biotech Ventures. Sausalito, CA: University Science Books.

UNESCO, Director-General. (2017). UNESCO moving forward the 2030 Agenda for Sustainable Development. Retrieved from https://unesdoc.unesco.org/ark:/48223/pf0000247785

*Usability and Relationship to other Modules*

- The module is a mandatory elective module in the Big Questions area, which is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute their knowledge and competencies to class discussions and activities.

*Examination Type: Module Examination*

Assessment Component 1: Term Paper — Length:1.500 – 3.000 words; Weight: 75%

Scope: Intended learning outcomes of the module (1-6)

Assessment Component 2: Presentation — Duration: 10-15 min.

| |
|---|
| Weight: 25%<br>Scope: Intended learning outcomes of the module (2-7) |

### 1.22.2.10 Gender and Multiculturalism. Debates and Trends in Contemporary Societies

<table>
<tr><td colspan="3">Module Name<br>Gender and Multiculturalism. Debates and Trends in Contemporary Societies</td><td>Module Code<br>JTBQ-BQ-013</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>5.0</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>JTBQ-013</td><td colspan="3">Gender and Multiculturalism: Debates and Trends in Contemporary Societies</td><td>Lecture</td><td>5.0</td></tr>
<tr><td>Module Coordinator<br><br>J. Price</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs</td><td colspan="2">Mandatory Status<br><br>Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites<br>☒ None<br><br>Co-requisites<br>☒ None<br><br>Knowledge, Abilities, or Skills<br>• The ability and openness to engage in interdisciplinary issues of global relevance<br>• Media literacy, critical thinking and a proficient handling of data sources</td><td>Frequency<br><br>Annually (Fall)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures (17.5 hours)<br>• Project work (90 hours)<br>• Private study (17.5 hours)</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>125 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Critical following of the media coverage on the module's topics in question.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br>All "Big Questions" (BQ) modules deal with the economic, technological, societal and environmental contexts of the global issues and challenges of the coming decades. The BQ modules intend to raise awareness of those challenges and broaden the students' horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules are relevant for every university graduate in order to become an informed and responsible citizen in a global society.<br>The objective of this module is to introduce and familiarize students with the current debates, trends and analytical frameworks pertaining how gender is socially constructed in different cultural zones. Through lectures, group discussions and reflecting upon cultural cases, students will familiarize themselves with the current trends and the different sides of ongoing cultural and political debates that shape cultural practices, policies and discourses. The module will zoom-in on topics such as: cultural identity; the social construction of gender; gender fluidity and its backlash; gender and human rights; multiculturalism as a perceived threat in plural societies, among others. Students will be provided with opportunities for reflection and to ultimately develop informed opinions concerning topics that are continue to define some of the most contested cultural debates of contemporary societies. Furthermore, participants will engage their ideas in "hands on" projects aimed at moving</td></tr>
</table>

the needle from mere reflection by conducting “action-research” that will inform the outcomes of their course projects.

*Intended Learning Outcomes*

Students acquire transferable and key skills in this module.

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

- use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines;
- summarize and evaluate the current cultural, political and legal debates concerning the social construction of gender in contemporary societies;
- reflect and develop informed opinions concerning the current debates and trends that are shaping ideas of whether multiculturalism ideals are realistic in pluralist western societies, or whether multiculturalism is a failed project;
- identify, explain and evaluate the role that societal forces, such as religion, socio-economic, political and migratory factors play in the construction of gendered structures in contemporary societies;
- develop a well-informed perspective concerning the interplay of science and culture in the debates around gender fluidity;
- deconstruct and reflect on the intersectionality between populist/nationalist discourses and gender discrimination;
- reflect and propose societal strategies and initiatives that attempt to answer the big questions presented in this module regarding gendered and cross-culturally-based inequalities;
- complete a self-designed project, collect and distill information from an “action-research” perspective;summarizing the process in a suitable reporting format;
- consider the application of an algorithm for group formation (not mandatory);
- overcome general teamwork problems in order to perform well-organized project work.

*Indicative Literature*

Biological Limits of Gender Construction Author(s): J. Richard Udry

Source: American Sociological Review , Jun., 2000, Vol. 65, No. 3 (Jun., 2000), pp. 443- 457. Published by: American Sociological Association Stable URL: https://www.jstor.org/stable/2657466

The Development of Gendered Interests and Personality Qualities From Middle Childhood Through Adolescence: A Biosocial Analysis. Susan M. McHale, Aryn M. Dotterer, Ji-Yeon Kim, Ann C. Crouter and Alan Booth. Child Development, March/April 2009, Volume 80, Number 2, Pages 482–495

Factors influencing attitudes to violence against women. Michael Flood and Bob Pease. Trauma, Violence, & ABuse, Vol. 10, No. 2, April 2009 125-142 dOi: 10.1177/1524838009334131. 2009 sAge Publications

Gender and Anti-immigrant Attitudes in Europe. Aaron Ponce (2017) Socius: Sociological Research for a Dynamic World. Volume 3: 1–17. Reprints and permissions: sagepub.com/journalsPermissions.nav

*Usability and Relationship to other Modules*

- The module is a mandatory elective module of the Big Questions area, that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules)
- Students are encouraged to relate the content of their previous modules to the topics of this module and contribute such knowledge and competences to class discussions and activities.

*Examination Type: Module Examination*

Assessment Type: Team Project

Weight: 100%

Scope: All intended learning outcomes of the module

### 1.22.2.11 The Challenge of Sustainable Energy

<table>
<tr><td colspan="3">Module Name<br>The Challenge of Sustainable Energy</td><td>Module Code<br>JTBQ-BQ-014</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>2.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3"></td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-014</td><td colspan="3">The Challenge of Sustainable Energy</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>K. Smith Stegen</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs</td><td colspan="2">Mandatory Status<br><br>Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td rowspan="2" colspan="3">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• Ability to read texts from a variety of disciplines</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures and Group Exercises</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Reflect on their own behavior and habits with regard to sustainability.</td></tr>
<tr><td colspan="6">Content and Educational Aims<br>All “Big Questions” (BQ) modules deal with the economic, technological, societal and environmental contexts of the global issues and challenges of the coming decades. The BQ modules intend to raise awareness of those challenges and broaden the students’ horizon with applied problem solving beyond the borders of their own disciplines. Knowledge and skills offered in the interdisciplinary BQ modules are relevant for every university graduate in order to become an informed and responsible citizen in a global society.<br>How can wide-scale social, economic and political change be achieved? This module examines this question in the context of encouraging “sustainability”. To address global warming and environmental degradation, humans must adopt more sustainable lifestyles. Arguably, the most important change is the transition from conventional fuels to renewable sources of energy, particularly at the local, country and regional levels. The main challenge to achieving an “energy transition” stems from human behavior and not from a lack of technology or scientific expertise. This module thus examines energy transitions from the perspective of the social sciences, including political science, sociology, psychology, economics and management. To understand the drivers of and obstacles to technology transitions, students will learn the “Multi-Level Perspective”. Some of the key questions explored in this module include: What is meant by sustainability? Are renewable energies “sustainable”? How can a transition to renewable energies be encouraged? What are the main social, economic, and political challenges? How can these (potentially) be overcome? The aim of the course is to provide students with the tools for reflecting on energy transitions from multiple perspectives.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes<br>Students acquire transferable and key skills in this module.<br>By the end of this module, students will be able to<br>• articulate the history of the sustainability movement and the major debates;</td></tr>
</table>

- identify different types of renewable energies;
- explain the multi-level perspective (MLP), which models technology innovations and transitions;
- summarize the obstacles to energy transitions;
- compare a variety of policy mechanisms for encouraging renewable energies.

*Usability and Relationship to other Modules*

- The module is a mandatory elective module of the Big Questions area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).
- For students interested in sustainability issues, this module complements a variety of modules from different programs, such as “International Resource Politics” (IRPH/SMP), “Environmental Science” (EES), “General Earth and Environmental Sciences” (EES), and “Renewable Energies” (Physics).

*Examination Type: Module Examination*

Assessment Type: Written Examination

Duration: 60 min
Weight: 100%

Scope: All intended learning outcomes of the module

### 1.22.2.12 State, Religion and Secularism

<table>
<tr><td colspan="3">Module Name<br>State, Religion and Secularism</td><td>Module Code<br>JTBQ-BQ-015</td><td>Level (type)<br>Year 3 (Jacobs Track)</td><td>CP<br>2.5</td></tr>
<tr><td colspan="6">Module Components</td></tr>
<tr><td>Number</td><td colspan="3"></td><td>Type</td><td>CP</td></tr>
<tr><td>JTBQ-015</td><td colspan="3">State, religion and secularism</td><td>Lecture</td><td>2.5</td></tr>
<tr><td>Module Coordinator<br><br>Manfred O. Hinz</td><td colspan="3">Program Affiliation<br><br>• Big Questions Area: All undergraduate study programs</td><td colspan="2">Mandatory Status<br><br>Mandatory elective for students of all undergraduate study programs, except IEM</td></tr>
<tr><td colspan="3" rowspan="2">Entry Requirements<br><br>Pre-requisites: ☒ None<br>Co-requisites: ☒ None<br>Knowledge, Abilities, or Skills:<br>• Ability to read texts from a variety of disciplines</td><td>Frequency<br><br>Annually (Spring)</td><td colspan="2">Forms of Learning and Teaching<br><br>• Lectures and Group Exercises</td></tr>
<tr><td>Duration<br><br>1 semester</td><td colspan="2">Workload<br><br>62.5 Hours</td></tr>
<tr><td colspan="6">Recommendations for Preparation<br><br>Reflect on the situation and role in respective home-country</td></tr>
<tr><td colspan="6">Content and Educational Aims<br><br>The relationship between state and religion has been a matter of concern in most if not all societies. Is religion above the state, or is it to the state to determine the place of religion? What does secularity mean? To what extent will religion accept secularity? Where does the idea of secularity come from? The course State, religion, secularism will search for answers to questions of this nature. After introducing to the topic and looking at some legal attempts to regulate the relationship between state and religion, the focus will be, on the one hand, on Christianity and secularity and, on Islam and secularity, on the other. Depending on the interest of participants, other religions and their relationships to states of relevance can be added.</td></tr>
<tr><td colspan="6">Intended Learning Outcomes<br><br>By the end of this course, students should be able<br>• To understand the basic problems that have led to different models to regulate the relationship between the state and religion;<br>• To reflect critically the situation of state and religion in selected countries;<br>• To assess the values behind the concept of democracy and human rights;<br>• To use the acquired knowledge to strengthen the capacity towards respect for others and tolerance.</td></tr>
<tr><td colspan="6">Usability and Relationship to other Modules<br><br>• The module is a mandatory elective module of the Big Questions area that is part of the Jacobs Track (Methods and Skills modules; Community Impact Project module; Language modules; Big Questions modules).</td></tr>
</table>

- For students interested in State, Religion and secularism, this module complements modules from other programmes, such as IRPH and SMP

*Examination Type: Module Examination*

| | |
|---|---|
| Assessment Type: Term paper | Length:1.500 – 3.000 words<br>Weight: 100% |
| Scope: All intended learning outcomes of the module. | |

## 1.22.3 Community Impact Project

| *Module Name* | *Module Code* | *Level (type)* | *CP* |
|---|---|---|---|
| Community Impact Project | JTCI-CI-950 | Year 3 (Jacobs Track) | *5* |

***Module Components***

| *Number* | *Name* | *Type* | *CP* |
|---|---|---|---|
| JTCI-950 | Community Impact Project | Project | 5 |

| *Module Coordinator* | *Program Affiliation* | *Mandatory Status* |
|---|---|---|
| CIP Faculty Coordinator | • All undergraduate study programs except IEM | Mandatory for all undergraduate study programs except IEM |

***Entry Requirements***

| *Pre-requisites* | *Co-requisites* | *Knowledge, Abilities, or Skills* | *Frequency* | *Forms of Learning and Teaching* |
|---|---|---|---|---|
| ☒ at least 15 CP from CORE modules in the major | ☒ None | • Basic knowledge of the main concepts and methodological instruments of the respective disciplines | Annually (Fall) | • Introductory, accompanying, and final events: 10 hours<br>• 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 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 Jacobs as socially conscious and responsible graduates (part of the Jacobs 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 should 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

### 1.22.4 Language Modules

The descriptions of the language modules are provided in a separate document, the "Language Module Handbook" that can be accessed from here: https://www.jacobs-university.de/study/learning-languages

# 2 Appendix

## 2.1 Intended Learning Outcomes Assessment-Matrix

| Physics | | | | | CHOICE Modules 1-3 | Classical Physics | Modern Physics | Applied Mathematics | Intro to Robotics & Intell. Sys | Analytical Mechanics | Electrodynamics | Computational Physics | Advanced Physics Lab 1 | Quantum Mechanics | Statistical Physics | Renewable Energy | Advanced Physics Lab 2 | Advanced Physics Lab 3 | Condensed Matter Physics | Particles, Fields, Quanta | Advanced Applied Physics | Advanced Applied Physics | Bachelor Thesis | JT Methods/Skills 1-4 Math | Internship | JT Big Questions | Community Impact Project | JT Language 1-4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Semester | | | | | 1/2 | 1 | 2 | 2 | 2 | 3 | 3 | 3+4 | 3 | 4 | 4 | 4 | 4 | 3/5 | 5 | 6 | 6 | 6 | 6 | 1-4 | 5 | 5/6 | 5 | 1-4 |
| Mandatory/mandatory elective | | | | | me | m | m | me | me | m | m | e | m | m | m | e | m | e | me | me | me | me | m | me | m | me | m | m |
| Credits | | | | | 22.5 | 7.5 | 7.5 | 7.5 | 7.5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 15 | 20 | 15 | 10 | 5 | 10 |
| | Competencies* | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Program Learning Outcomes** | **A** | **E** | **P** | **S** | | | | | | | | | | | | | | | | | | | | | | | | |
| Recall and understand the basic facts, principles and formulas, and experimental evidence from the major fields of physics, that is classical physics, modern physics, and statistical physics. | x | | | | | x | x | | | x | x | | x | x | x | x | x | x | x | x | x | x | | | | | | |
| Describe and understand natural and technical phenomena by reducing them to basic physical principles from the different fields of physics. | x | x | | | | x | x | | x | x | x | x | | x | x | x | | | x | x | x | x | | | | | | |
| Apply a variety of mathematical methods and tools especially from analysis and linear algebra to describe physical systems. | x | x | | | | | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | x | | | | |
| Use numerical and computational methods to describe and analyze physical systems. | x | x | | | | | | x | x | | | x | | | | | | | | | | | | x | | | | |
| Examine physical problems, apply mathematical skills and knowledge from various fields of physics to find possible solutions and assess them critically. | x | x | | | | x | x | x | | x | x | x | x | x | x | x | x | x | x | x | x | x | x | | | | | |
| Conceive and apply analogies, approximations, estimates or extreme cases to test the plausibility of ideas or solution to physical problems. | x | x | | | | | | | | x | x | | | x | x | | | | x | x | x | x | x | | | | | |
| Setup and perform experiments, analyze their outcomes with the pertinent precision and present them properly. | x | x | | | | x | x | | | | | | x | | | | x | x | | | | | (x) | | | | | |
| Working responsibly in a team on a common task, with the necessary preparation, planning, communication and work organization. | x | x | x | x | | x | x | | | | | | x | | | | x | x | | | | | (x) | | | | | |
| Use the appropriate language of the scientific community to communicate, discuss, and defend scientific findings and ideas in physics. | x | x | x | | | | | | | | | | x | | | | x | x | | x | x | x | x | | x | | | |
| Get aquainted with a new field in physics, by finding, reviewing and digesting the relevant scientific information to work independently or as a team member on a physics related problem or on a scientific research project. | | | x | | | | | | | | | | x | | | | x | x | | x | x | x | x | | x | | | |
| Apply knowledge and understanding from the BSc Physics education to advance their personal career either by professional employment or by further academic or professional education. | | | x | | | | | | | | | | | | | | | | | | | | x | | x | | | |
| Take on responsibility for their own personal and professional role in society by critical self-evaluation and self-analysis. | | | | x | | | | | | | | | | | | | | | | | | | x | | x | x | x | |
| Adhere to and defend ethical, scientific, and professional standards, but also reflect and respect different views. | | | | x | | | | | | | | | | | | | | | | | | | | | | x | x | x |
| Act as scientifically literate citizen to provide sound evidence-based solutions and arguments especially when communicating with specialists or laymen, or when dealing with technology or science issues. | | | | x | | | | | | | | | | | | x | | | | | | | | | | x | x | |
| Appreciate the importance of education, community, and diversity for personal development and a peaceful and sustainable world. | | | x | x | | | | | | | | | | | | | | | | | | | | | x | x | x | x |
| **Assessment Type** | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Oral examination | | | | | | | | | | | | | x | | | | x | x | | | | | | | | | | |
| Final written exam | | | | | | x | x | x | x | x | x | | | x | x | | | | x | | | | | x | | | | |
| Project | | | | | | | | | | | | x | | | | x | | | | | | | x | | | | x | |
| Essay | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| (Lab) report | | | | | | x | x | x | x | | | | x | | | | x | x | | | | | (x) | | | | | |
| Poster presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Presentation | | | | | | | | | | | | | | | | | | | | x | x | x | x | | | | | |
| Various | | | | | | | | | | | | | | | | | | | | | | | | | | x | | x |
| Module achievements/bonus achievements | | | | | | | | | | | | | | | | | | | | | | | | | | | | x |

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

*Figure 4: Intended Learning Outcomes Assessment-Matrix*