



JACOBS  
UNIVERSITY



## 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).

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# 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 for the democratic, peaceful, and sustainable development of the societies in which they live. This is achieved through a high-quality teaching as well as manageable study loads and supportive study conditions. Study programs and related study abroad programs convey academic knowledge as well as the ability to interact positively with other individuals and groups in culturally diverse environments. The ability to succeed in the working world is a core objective for all study programs at Jacobs University, both in terms of actual disciplinary subject matter and also to the social skills and intercultural competence. Study-program-specific modules and additional specializations provide the necessary depth, interdisciplinary offerings and 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 supplements 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 in 2018. 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 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 studies 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 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 4th and 5th 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 at the same time 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 also to 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 world-wide leading universities.

The scientific knowledge, the international network of physics alumni, the problem solving and social skills acquired during the 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 by an internship and by working in research groups of professors for their BSc thesis work or even before. The level of courses is en par with physics programs at internationally leading 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 worldwide leading universities.

Our physics graduates are very successful in either getting admitted to top postgraduate programs (MSc/PhD) in physics and related fields, directly entering employment, or starting their own businesses. We use the 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 to pursue 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 trained hands-on 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 like biophysics, computational physics, particles and fields, 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 and formulas, and experimental evidence from the major fields of physics, that is classical physics (mechanics, thermodynamics, optics, 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, 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;
- setup and perform experiments, analyze their outcomes with the pertinent precision and present them properly;

- working 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 and respect different views;
- 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;
- 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 among 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 comes also from the sector of medical technology. 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 at the same time 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 the 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 world-wide leading 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 qualification - as management consultants, patent attorneys, market analysts, or risk managers. Many BSc degree recipients go on to graduate school in physics and other fields, as careers in research and development usually require a postgraduate degree.

Here, Jacobs University Physics BSc graduates have an excellent placement record in the top graduate programs. Very helpful for career development is also the opportunity for international network building with Jacobs University students coming from more than a hundred different nations. Good communication skills are essential, since many physicists work as part of a team, have contact to clients with non-physics background, 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 rewarding careers after their time at Jacobs University. Furthermore, the Alumni Office helps students establish a long-lasting and worldwide network which comes in handy 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, instead 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 she/he has acquired the higher education entrance qualification, Jacobs University accepts the common international university entrance tests as a replacement of the entrance examination. Applicants who have a subject-related entrance qualification (fachgebundene Hochschulreife) may be admitted only to respective studies programs.

For more detailed information about the admission 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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<https://www.jacobs-university.de/directory/jfritz>

or visit our program website: <http://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 the opportunity to gain insight into the professional world, apply their intercultural competences and reflect on their roles and ambitions for employment and in a globalized society.

All undergraduate programs at 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 undergraduate 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:

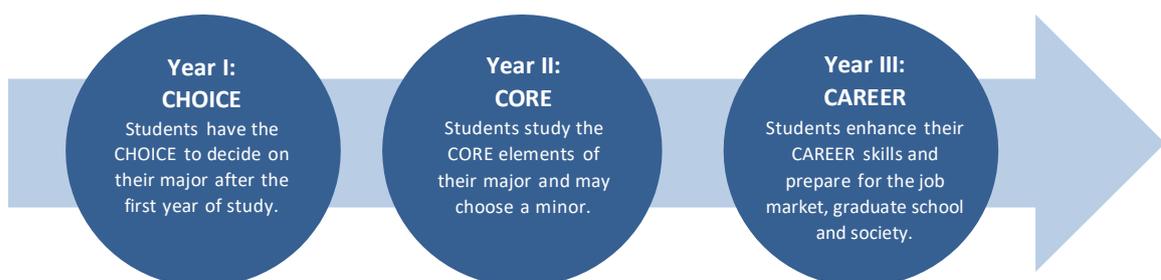


Figure 1: The Jacobs University 3C-Model

#### 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 be from their intended major. A unique feature of our curriculum 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 support students in their decision-making regarding their major study program as contact persons from the faculty.

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)

Physics can choose between the following mandatory elective modules (see explanation below):

- 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 give physics students an overview of the major field 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 the 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 by the Introduction to RIS (with a MATLAB lab) to accommodate students that plan to pursue a major in IMS or CS. Students who do not take the Applied Mathematics Module may have to independently catch up on missing mathematics topics relevant for Electrodynamics and other CORE physics courses.

The remaining CHOICE modules (22.5 CP) can be selected in the first year of studies according to interest and with the aim to allow a change of major until the beginning of the second year, when the major becomes fixed.

#### 2.2.1.1 Major Change Option

Students can still change to another major at their beginning of the second year of studies if 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 in the first year of studies prior to changing their major.

Physics students that 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:

- Mathematics (Math)  
CHOICE Module: Analysis I (7.5 CP)  
CHOICE Module: Advanced Linear Algebra (7.5 CP)  
CHOICE Module: Applied Mathematics
- Earth and Environmental Science (EES)  
CHOICE Module: General Earth & Environmental Sciences (7.5 CP)  
CHOICE Module: General Geosciences (7.5 CP)

- Electrical and Computer Engineering (ECE)  
CHOICE Module: General Electrical Engineering I (7.5 CP)  
CHOICE Module: General Electrical Engineering II (7.5 CP)  
CHOICE Module: Programming in C and C++ (7.5 CP)
- Intelligent Mobile Systems (IMS)  
CHOICE Module: Programming in C and C++ (7.5CP)  
CHOICE Module: Algorithms and Data Structures (7.5CP)  
*CHOICE Module: Introduction to Robotics and Intelligent Systems (7.5 CP)<sup>1</sup>*
- Computer Science (CS)  
CHOICE Module: Programming in C and C++ (7.5CP)  
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)<sup>1</sup>*
- Integrated Social Sciences (ISS)  
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)
- Psychology  
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 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 taken:

- 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),

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

- 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 studies according to interest and with the aim to pursue a minor.

The Physics CORE modules contain an advanced discussion of the major field of physics, as given in their title. They focus on the theory and mathematical description of the respective field but also include discussion of additional experimental findings and methods. In Advanced Physics Lab I, students will perform advanced experiments from mechanics and electrodynamics, whereas in the 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 the students' knowledge and skills, support the critical reflection of 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 their minor selection; 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 the respective Study and Examination Plans. 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 and make decisions about their career path after graduation. To explore available choices and to gain professional experience, students undertake a mandatory summer internship. The third year of studies allows Physics students to take Specialization modules within their discipline, but also focuses on the responsibility of students beyond their discipline (see Jacobs Track).

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

### 2.2.3.1 Internship / Start-up and Career Skills Module

As a core element of 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 role in employment and society, and find a professional orientation. The internship can also establish valuable contacts for the students' Bachelor's thesis project, for the selection of a Master program graduate school or further employment after graduation. This module is complemented by career advising and several career skills workshops throughout all six semesters that prepare students for the transition from student life to professional life. As an alternative to the full-time internship, students interested in setting up their own company can apply for a start-up option to focus on developing of their business plans.

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

### 2.2.3.2 Specialization Modules

In the third year of their studies, students take 15 CP from major-specific or major-related, advanced Specialization modules to consolidate their knowledge and to be exposed to state-of-the-art research in the areas of their interest. This curricular component is offered as a portfolio of modules, from which students can make free selections during their 5th and 6th 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 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, an integral part of all undergraduate study programs, 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 the Methods and Skills area in their curriculum. The modules that are specifically assigned to each study programs equip students with transferable academic skills. They convey and practice specific methods that are indispensable for each students' chosen study program. Students are required to take 20 CP in the Methods and Skills area. The size of all Methods and Skills modules is 5 CP.

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

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

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

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

and

- Methods Module: Programming in Python (5 CP)
- Methods Module: Finite 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 5th and 6th 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 5th 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 it is also a fundamental part of modern technology. A physics minor is especially interesting for students who want to get 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 on 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 field 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 be trained hands-on 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, that is classical physics (mechanics, thermodynamics, optics, 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, apply appropriate mathematical methods and physical knowledge to find possible solutions within a specific field of physics;
- setup 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 2019. 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>)

Jacobs University Bremen reserves the right to substitute modules by replacements and/or reduce the number of mandatory/mandatory-elective modules offered.

### 4.2 Degree

Upon successful completion of the study program, students are awarded a Bachelor of Science degree in Physics.

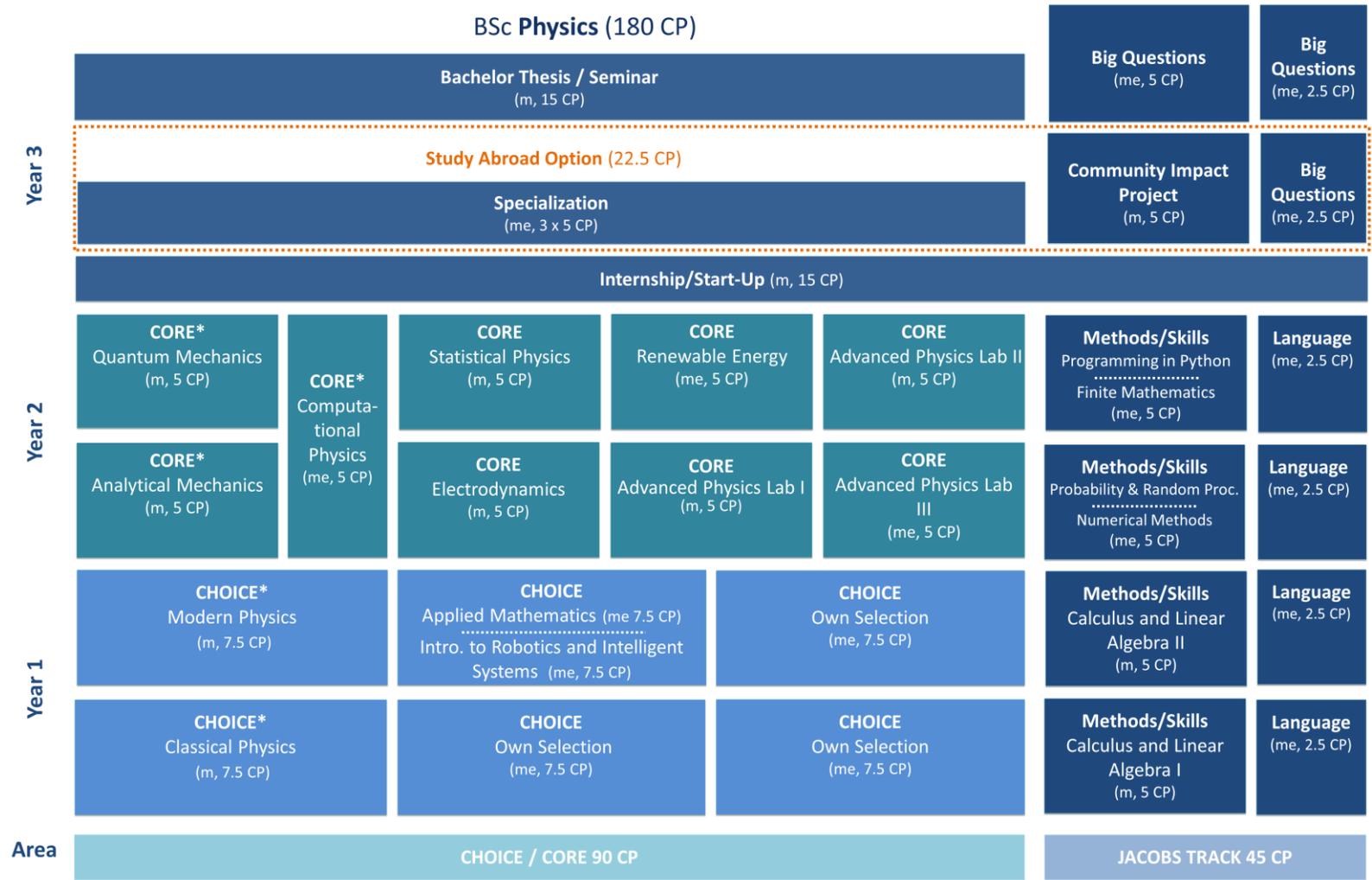
### **4.3 Graduation Requirements**

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



\* default minor modules (default minor)  
m = mandatory  
me = mandatory elective

Figure 2: Schematic Study Plan for Physics

# 6 Study and Examination Plan

Physics BSc								Jacobs Track Modules (General Education)							
Matriculation Fall 2019															
Program-Specific Modules								Type							
Program-Specific Modules	Type	Assessment	Period	Status <sup>1</sup>	Sem.	CP		Jacobs Track Modules (General Education)	Type	Assessment	Period	Status <sup>1</sup>	Sem.	CP	
<b>Year 1 - CHOICE</b>								<b>15</b>							
Take the mandatory CHOICE modules listed below, these are a requirement for the physics program.															
<b>Unit: Classical and Modern Physics (default minor)</b>								<b>Unit: Skills / Methods</b>							
<b>CH-140 Module: Classical Physics (default minor)</b>								<b>JTMS-MAT-09 Module: Calculus and Linear Algebra I</b>							
CH-140-A	Classical Physics	Lecture	Written exam	Final exam period		1	5	JTMS-09	Calculus and Linear Algebra I	Lecture	Written exam	Final exam period			
CH-140-B	Classical Physics Lab	Lab	Lab report			1	2.5								
<b>CH-141 Module: Modern Physics (default minor)</b>								<b>JTMS-MAT-10 Module: Calculus and Linear Algebra II</b>							
CH-141-A	Modern Physics	Lecture	Written exam			2	5	JTMS-10	Calculus and Linear Algebra II	Lecture	Written exam	Final exam period			
CH-141-B	Modern Physics Lab	Lab	Lab report			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).								<b>Unit: Language</b>							
<b>CH-202 Module: Applied Mathematics</b>								German is default language. Native German speakers take modules in another offered language.							
CH-202-A	Advanced Calculus and Methods of Mathematical Physics	Lecture	Written exam	Final exam period		2	5	JTLA	<b>Module: Language 1</b>						
CH-202-B	Numerical Software Lab	Lab	Lab report			2	2.5	JTLA-xxx	Language 1	Seminar	Various			me 1 2.5	
<b>CH-220 Module: Introduction to Robotics and Intelligent Systems</b>								JTLA							
CH-220-A	Introduction to Robotics and Intelligent Systems	Lecture	Written examination	Final exam period		2	5	JTLA-xxx	Language 2	Seminar	Various			me 2 2.5	
CH-220-B	Intro to RIS - lab	Lab				2	2.5								
<b>Unit: CHOICE (own selection)</b>															
Take three further CHOICE modules from those offered for other study programs: Two modules in 1st, one in 2nd semester.															
<b>Year 2 - CORE</b>								<b>15</b>							
Take all modules listed below or replace 1.5 CP of mandatory elective ("me") modules by suitable CORE modules from other study programs <sup>2</sup>															
<b>Unit: Advanced Physics I</b>								<b>Unit: Skills / Methods (take a total of 10 CP of skills/methods modules, see list below)</b>							
<b>CO-480 Module: Analytical Mechanics (default minor)<sup>2</sup></b>								<b>JTMS-MAT-12 Module: Probability and Random Processes</b>							
CO-480-A	Analytical Mechanics	Lecture	Written exam	Final exam period		3	5	JTMS-12	Probability and Random Processes	Lecture	Written exam	Final exam period		me 3 5	
<b>CO-481 Module: Quantum Mechanics (default minor)<sup>2</sup></b>								<b>JTMS-MAT-13 Module: Numerical Methods</b>							
CO-481-A	Quantum Mechanics	Lecture	Written exam	Final exam period		4	5	JTMS-13	Numerical Methods	Lecture	Written exam	Final exam period		me 4 5	
<b>CO-482 Module: Computational Physics (default minor)<sup>2</sup></b>								Alternatives:							
CO-482-A	Computational Physics I	Lecture				3	2.5	<b>JTMS-SKI-14 Module: Programming in Python</b>						me 3 5	
CO-482-B	Computational Physics II	Lecture	Project			4	2.5	JTMS-14	Programming in Python	Lecture	Written exam	Final exam period		me 5	
<b>Unit: Advanced Physics II</b>								<b>JTMS-MAT-11 Module: Finite Mathematics</b>							
CO-483	<b>Module: Electrodynamics</b>						5	JTMS-11	Finite Mathematics	Lecture	Written exam	Final exam period		me 4 5	
CO-483-A	Electrodynamics	Lecture	Written exam	Final exam period		3									
<b>CO-484 Module: Statistical Physics</b>															
CO-484-A	Statistical Physics	Lecture	Written exam	Final exam period		4									
<b>CO-485 Module: Renewable Energy</b>															
CO-485-A	Renewable Energy	Lecture	Project			4									
<b>Unit: Advanced Physics Labs</b>								<b>Unit: Language</b>							
<b>CO-486 Module: Advanced Physics Lab I</b>								German is default language. Native German speakers take modules in another offered language.							
CO-486-A	Advanced Physics Lab I	Lab	Lab report	Final exam period		3	5	JTLA	<b>Module: Language 3</b>					me 3 2.5	
<b>CO-487 Module: Advanced Physics Lab II</b>								JTLA-xxx							
CO-487-A	Advanced Physics Lab II	Lab	Lab report	Final exam period		4	5	JTLA-xxx	Language 3	Seminar	Various			me	
<b>CO-488 Module: Advanced Physics Lab III</b>								JTLA							
CO-488-A	Advanced Physics Lab III	Lab	Lab report	Final exam period		5/3	5	JTLA-xxx	Language 4	Seminar	Various			me 4 2.5	
<b>Year 3 - CAREER</b>								<b>15</b>							
<b>CA-INT-900 Module: Internship / Startup and Career Skills</b>								<b>Unit: Big Questions</b>							
CA-INT-900-0	Internship / Startup and Career Skills	Internship	Report/Business Plan				4/5	15	JTBQ	<b>Module: Big Questions</b>				me 5/6	
<b>CA-PHY-800 Module: Thesis / Seminar Physics</b>								Take a total of 10 CP of Big Questions modules with each 2.5 or 5 CP							
CA-PHY-800-S	Thesis Physics	Project	Thesis and Presentation				6	15						me	
CA-PHY-800-T	Seminar Physics	Seminar					3								
<b>Unit: Specialization Physics (Take a total of 15 CP of specialization modules)</b>								<b>Unit: Community Impact Project</b>							
<b>CA-S-PHY-801 Module: Condensed Matter Physics</b>								<b>JTCL-CL-950 Module: Community Impact Project</b>							
CA-S-PHY-801-A	Condensed Matter and Electronic Devices	Lecture	Written exam	Final exam period		5	5	JTCL-950	Community Impact Project	Project	Project			me 5 5	
<b>CA-PHY-802 Module: Particles, Fields and Quanta</b>															
CA-PHY-802-A	Elementary Particles and Fields	Lecture				6	2.5								
CA-PHY-802-B	Advanced Quantum Physics	Lecture	Presentation			6	2.5								
<b>CA-PHY-803 Module: Advanced Applied Physics</b>															
CA-PHY-803-A	Biophysics / Nanotechnology	Lecture				6	2.5								
CA-PHY-803-B	Advanced Optics / Atoms and Molecules	Lecture	Presentation			6	2.5								
Specialization electives from other study programs (see physics study program handbook)								various							
<b>Total CP</b>								<b>180</b>							

<sup>1</sup>Status: (m = mandatory, me = mandatory elective). <sup>2</sup>Alternative module choices for a minor in physics are possible (see physics study program handbook).

<sup>3</sup>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

## 7 Module Descriptions

### 7.1 Classical Physics

<b>Module Name</b> Classical Physics			<b>Module Code</b> CH-140	<b>Level (type)</b> Year 1 (CHOICE)	<b>CP</b> 7.5
<b>Module Components</b>					
<i>Number</i>	<i>Name</i>			<i>Type</i>	<i>CP</i>
CH-140-A	Classical Physics Lecture			Lecture	5.0
CH-140-B	Classical Physics Lab			Lab	2.5
<b>Module Coordinator</b> Jürgen Fritz	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>			<b>Mandatory Status</b> Mandatory for Physics	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>		annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Lab (25.5 hours)</li> <li>Homework (42 hours)</li> <li>Private study (85 hours)</li> </ul>
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>high school physics</li> <li>high school math</li> </ul>		<b>Duration</b> 1 semester	
<b>Recommendations for Preparation</b>					
<p>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. Level and content follow standard textbooks for calculus-based first year university physics such as Young &amp; Freedman: University Physics, Halliday &amp; Resnick &amp; Walker: Fundamentals of Physics, and Tipler &amp; Mosca: Physics.</p>					
<b>Content and Educational Aims</b>					
<p>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 high school level.</p> <p>Emphasis is laid 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.</p> <p>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, gravitation and oscillations; 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 into classical optics including refraction and reflection, lenses and optical instruments, waves, interference and diffraction.</p>					

### ***Intended Learning Outcomes***

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

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

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

- Mandatory for a major in Physics.
- Mandatory for a minor in Physics.
- Prerequisite for 1<sup>st</sup> year Physics CHOICE module “Modern Physics”.
- Prerequisite for 2<sup>nd</sup> year Physics CORE modules “Analytical Mechanics” and “Renewable Energy”.
- Elective for all other undergraduate study programs.

### ***Assessment***

**In all module descriptions the category “Assessment” describes the requirements for the award of ECTS credit points (CP) for the respective module.**

Type: Written examination (Lecture),

Duration: 120 min

Weight: 75%

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

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

Type: Lab Reports (Lab),

Length: 8-12 pages

Weight: 25%

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

## 7.2 Modern Physics

<b>Module Name</b> Modern Physics		<b>Module Code</b> CH-141	<b>Level (type)</b> Year 1 (CHOICE)	<b>CP</b> 7.5
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CH-141-A	Modern Physics Lecture		Lecture	5.0
CH-141-B	Modern Physics Lab		Lab	2.5
<b>Module Coordinator</b> Jürgen Fritz	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Lab (25.5 hours)</li> <li>Homework Problem (42 hours)</li> <li>Private study (85 hours)</li> </ul>
<input checked="" type="checkbox"/> Classical Physics	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>high school physics</li> <li>high school math</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 187.5 hours
<b>Recommendations for Preparation</b>				
<p>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. Level and content follow standard textbooks for calculus-based first year university physics such as Young &amp; Freedman: University Physics, Halliday &amp; Resnick &amp; Walker: Fundamentals of Physics, and Tipler &amp; Mosca: Physics.</p>				
<b>Content and Educational Aims</b>				
<p>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 high school level. Emphasis is laid 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.</p> <p>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 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, energy levels of atoms, spin, and 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 for the in-depth treatment in the second year courses.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to:				
<ol style="list-style-type: none"> <li>recall the basic facts and experimental evidence in electromagnetism and modern physics;</li> <li>understand the basic concepts of fields, potential, and current, elementary particles and their interactions, the duality of particles and waves, and apply them to physical phenomena;</li> </ol>				

3. describe and understand natural and technical phenomena in electromagnetism and modern physics by reducing them to their basic physical principles;
4. apply calculus and vector analysis to describe physical systems;
5. examine basic physical problems, find possible solutions and assess them critically;
6. setup experiments, analyze their outcomes by using error analysis and present them properly;
7. record experimental data using basic experimental techniques and data acquisition tools;
8. use the appropriate format and language to describe and communicate outcome of experiments and solution of theoretical problems.

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

- Mandatory for a major in Physics.
- Mandatory for a minor in Physics.
- Prerequisite for 2nd year Physics CORE modules “Advanced Physics Lab 1-3” and “Quantum Mechanics”.
- Prerequisite for 3<sup>rd</sup> year Physics Specialization module “Advanced Applied Physics”
- Elective for all other undergraduate study programs.

***Assessment***

Type: Written examination (Lecture),

Duration: 120 min

Weight: 75%

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

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

Type: Lab Reports (Lab),

Length: 8-12 pages

Weight: 25%

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

### 7.3 Applied Mathematics

<b>Module Name</b> Applied Mathematics		<b>Module Code</b> CH-202	<b>Level (type)</b> Year 1 (CHOICE)	<b>CP</b> 7.5
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>	<i>CP</i>	
CH-202-A	Advanced Calculus and Methods of Mathematical Physics	Lecture	5	
Ch-202-B	Numerical Software Lab	Lab	2.5	
<b>Module Coordinator</b>  Marcel Oliver Ulrich Kleinekathöfer	<b>Program Affiliation</b>  • Mathematics	<b>Mandatory Status</b>  Mandatory for Mathematics Mandatory elective for ECE and Physics		
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Lab (17.5 hours)</li> <li>Private Study (135 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None			
		<b>Duration</b>	<b>Workload</b>	
		1 semester	187.5 hours	
<b>Recommendations for Preparation</b>				
Recapitulate single variable Calculus at a level of at least "Calculus and Elements of Linear Algebra I"				
<b>Content and Educational Aims</b>				
<p>This module covers advanced topics from calculus which are part of the core mathematics education of every Physicist and also form 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.</p> <p>Topics covered include:</p> <ul style="list-style-type: none"> <li>Taylor series, power series, uniform convergence</li> <li>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</li> <li>Riemann integration in several variables, line integrals</li> <li>The Gauss and Stokes integral theorems</li> <li>Change of variables, integration in polar coordinates</li> <li>Fourier integrals + distributions</li> <li>Applications to partial differential equations important in physics (Laplace, Poisson, diffusion, wave equations)</li> <li>Very brief introduction to complex analysis (Cauchy formula + residue theorem)</li> </ul>				

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, fast Fourier transform)
- Visualization using Matplotlib, including a general introduction to 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

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

#### ***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 Linear Algebra I and II”
- It is also valuable for students in Computer Science, IMS, 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

#### ***Assessment***

Type: Written examination,

Duration: 120 min,

Weight: 70%

Scope: Intended learning outcomes of the lecture (5, 7).

Type: Lab report,

Length: approx. 30 pages,

Weight: 30%

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

Additional bonus homework as a voluntary task can improve the grade by 0.33 points (German grading system) but is not required to reach the best grade in the module (1.0).

## 7.4 Introduction to Robotics and Intelligent Systems

<b>Module Name</b> Introduction to Robotics and Intelligent Systems		<b>Module Code</b> CH-220	<b>Level (type)</b> Year 1 (CHOICE)	<b>CP</b> 7.5
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>	<i>CP</i>	
CH-220-A	Introduction to Robotics and Intelligent Systems - Lecture	Lecture	5	
CH-220-B	Introduction to Robotics and Intelligent Systems - Seminar	Lab	2.5	
<b>Module Coordinator</b>  Francesco Maurelli	<b>Program Affiliation</b>  • Intelligent Mobile Systems (IMS)		<b>Mandatory Status</b>  Mandatory for IMS Mandatory for CS Mandatory elective for ECE and Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Lab (17.5 hours)</li> <li>Private study (115 hours)</li> <li>Exam preparation (20 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None			
		<b>Duration</b>	<b>Workload</b>	
		1 semester	187.5 hours	
<b>Recommendations for Preparation</b>				
Review basic linear algebra concepts, vector and matrix operations.				
<b>Content and Educational Aims</b>				
<p>This module represents an initial introduction to the 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 about particle kinematics, rigid bodies and basics of trajectory planning. The second part of the module offers an introduction to 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. 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 into practical hands-on work with various components of intelligent systems. It will focus on the interface of a microcontroller with commonly used sensors and actuators.</p>				
<b>Intended Learning Outcomes</b>				
By the end of this module, successful students will be able to				
<ul style="list-style-type: none"> <li>compute 3D transformations;</li> <li>understand and apply kinematics laws;</li> <li>apply trajectory planning techniques;</li> <li>model common mechanical and electrical systems;</li> <li>understand and apply the uni-lateral Laplace transform and its inverse;</li> <li>explore linear systems and tune their behavior;</li> <li>program the open-source electronic prototyping platform Arduino;</li> <li>interface Arduino to several different sensors and actuators.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory for a major in IMS and CS.</li> </ul>				

- Mandatory for a minor in IMS.
- Mandatory elective for a major in ECE and Physics.
- This module is the foundation of the CORE modules in the following years.

**Assessment**

Type: Written examination

Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of the module.

Module achievements: Lab report

## 7.5 Analytical Mechanics

<b>Module Name</b> Analytical Mechanics		<b>Module Code</b> CO-480	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-480-A	Analytical Mechanics		Lecture	5.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Homework exercises (55 hours)</li> <li>Private study (35 hours)</li> </ul>
<input checked="" type="checkbox"/> Classical <input type="checkbox"/> Physics	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>mathematics at the level of the Applied Mathematics module</li> </ul>	<b>Duration</b> 1 semester	
<b>Recommendations for Preparation</b>				
Review classical mechanics and calculus at the level of the first-year courses.				
<b>Content and Educational Aims</b>				
<p>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, 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 core topics of physics at a level that prepares for BSc thesis 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.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to				
<ul style="list-style-type: none"> <li>understand the classical foundations of physics;</li> <li>solve mechanics problems of practical relevance using advanced mathematical techniques;</li> <li>analyze mechanical systems using Newton's laws and re-formulate them in terms of Lagrangian and Hamiltonian mechanics;</li> <li>formulate physical laws using variational methods and derive the equations of motion of physical systems;</li> <li>derive the equivalence of energy and matter in the framework of the special theory of relativity;</li> <li>understand Lorentz transformations and apply them;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory for a major in Physics.</li> <li>One of three default 2<sup>nd</sup> year CORE modules for a minor in Physics</li> </ul>				

- Prerequisite for 2<sup>nd</sup> year Physics CORE module “Statistical Physics”
- Co-requisite for 2<sup>nd</sup> year Physics CORE module “Advanced Physics Lab 1 and 3”

**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).

## 7.6 Quantum Mechanics

<b>Module Name</b> Quantum Mechanics		<b>Module Code</b> CO-481	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-481-A	Quantum Mechanics		Lecture	5.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> mandatory for Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Homework exercises (55 hours)</li> <li>Private study (35 hours)</li> </ul>
<input checked="" type="checkbox"/> Modern <input type="checkbox"/> Physics	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>Mathematics at the level of the Applied Mathematics Module</li> </ul>	<b>Duration</b> 1 semester	
<b>Recommendations for Preparations</b>				
<b>Content and Educational Aims</b>				
<p>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.</p>				
<b>Intended Learning Outcomes</b>				
<p>By the end of this module, students will be able to</p> <ul style="list-style-type: none"> <li>describe particle-wave complementarity in quantum mechanics;</li> <li>present the theoretical foundations of quantum mechanics;</li> <li>solve quantum mechanics problems of practical relevance using advanced mathematical techniques;</li> <li>determine the energy levels of quantum systems using algebraic and analytical methods;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				

- Mandatory for a major in Physics
- One of three default 2<sup>nd</sup> year CORE modules for a minor in Physics

***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).

## 7.7 Computational Physics

<b>Module Name</b> Computational Physics		<b>Module Code</b> CO-482	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-482-A	Computational Physics I		Lecture	2.5
CO-482-B	Computational Physics II		Lecture	2.5
<b>Module Coordinator</b>  Ulrich Kleinekathöfer	<b>Program Affiliation</b>  • Physics		<b>Mandatory Status</b>  Mandatory elective for physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Private study (35 hours)</li> <li>Exercises and project (55 hours)</li> </ul>	
<input checked="" type="checkbox"/> Applied Mathematics (or: Introduction to Robotics and Intelligent Systems)	<input checked="" type="checkbox"/> None			
		2 semesters	125 hours	
<b>Recommendations for Preparation</b>				
Review the basics of scientific programming preferably in Python.				
<b>Content and Educational Aims</b>				
<p>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 analytic 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 as well as 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 incl. traffic simulations, random walks, solution of the time-dependent Schrödinger equation etc. The module includes numerous examples and exercises for programming codes.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to				
<ul style="list-style-type: none"> <li>explain the basic strategies to simulate physical systems;</li> <li>apply computer simulations to describe and analyze general problems in physics and related sciences;</li> <li>design computer programs for specific problems and validate them;</li> <li>utilize basic numerical schemes such as iterative approaches;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>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.</li> </ul>				

- Recommended mandatory elective for a major in Physics
- One of three default 2<sup>nd</sup> year CORE modules for a minor in Physics
- Elective for all other undergraduate study programs.

**Assessment**

Type: Project

Duration: 25 hours

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).

## 7.8 Electrodynamics

<b>Module Name</b> Electrodynamics		<b>Module Code</b> CO-483	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-483-A	Electrodynamics		Lecture	5.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Homework exercises (55 hours)</li> <li>Private study (35 hours)</li> </ul>
<input checked="" type="checkbox"/> Modern <input type="checkbox"/> Physics	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>Mathematical methods at the level of the Applied Mathematics Module</li> <li>Electromagnetism at the level of the first-year physics modules</li> </ul>	<b>Duration</b> 1 semester	
<b>Recommendations for Preparations</b>				
Review the Applied Mathematics Module topics and electromagnetism at the level of the first-year courses.				
<b>Content and Educational Aims</b>				
<p>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, 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 core topics of physics at a level that prepares for BSc thesis research. At the same time, the pertinent mathematical repertoire and problem-solving skills are developed. The module also serves as a foundation for physics specialization subjects.</p>				
<b>Intended Learning Outcomes</b>				
By the end of this module, students will be able to				
<ul style="list-style-type: none"> <li>describe Maxwell's equations and present practical applications of electrodynamics;</li> <li>apply advanced mathematical techniques to solve electrodynamics problems;</li> <li>analyze electrodynamic phenomena and relate them to the underlying fundamental physical laws including special relativity;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory for a major in Physics</li> <li>Possible (mandatory) elective for a physics minor</li> </ul>				

***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).

## 7.9 Statistical Physics

<b>Module Name</b> Statistical Physics		<b>Module Code</b> CO-484	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>		<i>CP</i>
CO-484-A	Statistical Physics	Lecture		5.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Homework exercises (55 hours)</li> <li>Private study (35 hours)</li> </ul>	
<input checked="" type="checkbox"/> Analytical <input type="checkbox"/> Mechanics	<input checked="" type="checkbox"/> None			
	<i>Knowledge, Abilities, or Skills</i> <ul style="list-style-type: none"> <li>First year mathematics</li> </ul>	1 semester	125 hours	
<b>Recommendations for Preparations</b>				
Review thermal physics and calculus at the level of the first year courses.				
<b>Content and Educational Aims</b>				
<p>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 like 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 core topics of physics at a level that prepares for BSc thesis research. At the same time, the pertinent mathematical repertoire and problem-solving skills are developed. The module also serves as a foundation for physics specialization subjects.</p>				
<b>Intended Learning Outcomes</b>				
By the end of this module, students will be able to				
<ul style="list-style-type: none"> <li>understand the theoretical foundations and practical applications of statistical physics;</li> <li>solve thermodynamics and statistical physics problems of practical relevance using advanced mathematical techniques;</li> <li>analyze properties of gases and condensed matter in terms of microscopic and statistical models;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				

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

**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).

## 7.10 Renewable Energy

<b>Module Name</b> Renewable Energy		<b>Module Code</b> CO-485	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-485-A	Renewable Energy		Lecture	5.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory    elective    for physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Private study (35 hours)</li> <li>Homework exercises and project (55 hours)</li> </ul>
<input checked="" type="checkbox"/> Classical Physics	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>Physics at advanced high school/first year university level.</li> </ul>	<b>Duration</b> 1 semester	
<b>Recommendations for Preparation</b>				
<b>Content and Educational Aims</b>				
<p>Renewable energy resources promise to provide clean, decentralized solutions to the world energy crisis, as energy resources which directly depend on the power of the sun's radiation. The module gives 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 physics and engineering aspects of solar cells, solar thermal collectors, wind power, geothermal power, thermophotovoltaics, the potential of biomass energy resources, hydro, tidal and wave energy. A basic introduction to energy transport and energy storage is given. These topics are complemented by an introduction to the basic physics of other energy resources including nuclear energy.</p>				
<b>Intended Learning Outcomes</b>				
<p>By the end of the module, students will be able to</p> <ul style="list-style-type: none"> <li>present and apply the principles of thermal physics;</li> <li>explain advanced concepts of energy generation and storage;</li> <li>analyze advantages and disadvantages of different approaches to address the world's energy problem;</li> <li>understand the scientific background of energy technologies;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory elective CORE module for physics majors</li> <li>Possible (mandatory) elective for a physics minor</li> </ul>				
<b>Assessment</b>				

Type: Project,

Duration: 25 hours

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).

## 7.11 Advanced Physics Lab 1

<b>Module Name</b> Advanced Physics Lab 1		<b>Module Code</b> CO-486	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-486-A	Advanced Physics Lab 1		Lab	5.0
<b>Module Coordinator</b> Jürgen Fritz	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics major	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	<ul style="list-style-type: none"> <li>Lab (51 hours)</li> <li>Private study (74 hours)</li> </ul>	
<input checked="" type="checkbox"/> Modern Physics	<input checked="" type="checkbox"/> AnalMech & Eldyn	<ul style="list-style-type: none"> <li>First year math</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>				
Students should recap their first-year physics, especially from the lab courses including error analysis.				
<b>Content and Educational Aims</b>				
<p>Physics is an experimental science. Any hypotheses or theory has 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 first year modules: Students work more independently on experiments and write a scientific lab report. They will do hands-on experiments on advanced topics in advanced mechanics and electrodynamics requiring also an advanced theoretical and mathematical description of phenomena. By working in teams of two students they setup 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.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to				
<ol style="list-style-type: none"> <li>prepare for doing experiments and using experimental equipment for a specific physical problem;</li> <li>setup, perform, and evaluate experiments to investigate typical phenomena in mechanics and electrodynamics;</li> <li>using experimental techniques and data acquisition tools to record experimental data;</li> <li>analyze outcomes of experiments by mathematical and computational methods, and use error analysis to assess the accuracy and reproducibility of their results;</li> <li>use the appropriate format and language to summarize and describe an experiment, and communicate its outcome in a scientific report;</li> <li>organize their work and work responsibly in a team to fulfill the given task;</li> <li>orally describe and answer basic questions related to the background, the experimental method and outcome of the experiment.</li> </ol>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory for a major in Physics.</li> <li>Possible (mandatory) elective for a physics minor</li> <li>Co-requisites are 2<sup>nd</sup> year CORE modules “Analytical Mechanics” and “Electrodynamics”</li> </ul>				
<b>Assessment</b>				

Type: Lab reports (written reports),

Scope: Intended learning outcomes (1-6).

Length: 10-15 pages

Weight: 70%

Type: Oral examination,

Scope: Intended learning outcomes (4,7).

Duration: 30 min

Weight: 30%

Scope: All intended learning outcomes of the module.

## 7.12 Advanced Physics Lab 2

<b>Module Name</b> Advanced Physics Lab 2		<b>Module Code</b> CO-487	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>	<i>CP</i>	
CO-487-A	Advanced Physics Lab 2	Lab	5.0	
<b>Module Coordinator</b> Jürgen Fritz	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics students	
<b>Entry Requirements</b>		<b>Frequency</b> annually	<b>Forms of Learning and Teaching</b> <ul style="list-style-type: none"> <li>Lab (51 hours)</li> <li>Private study (74 hours)</li> </ul>	
<i>Pre-requisites</i> <input checked="" type="checkbox"/> Modern Physics	<i>Co-requisites</i> <input checked="" type="checkbox"/> Quantum mechanics & Statistical Physics	<i>Knowledge, Abilities, or Skills</i> <ul style="list-style-type: none"> <li>First year math</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b> Students should recap their first-year physics, especially from the lab courses including error analysis.				
<b>Content and Educational Aims</b> Physics is an experimental science. Any hypotheses or theory 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 it was introduced in first year modules: Students work more independently on experiments and write a scientific lab report. They will do hands-on experiments on advanced topics in quantum mechanics and atomic physics and statistical physics requiring also an advanced theoretical and mathematical description of phenomena. By working in teams of two students they setup 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.				
<b>Intended Learning Outcomes</b> By the end of the module, students will be able to <ol style="list-style-type: none"> <li>prepare for doing experiments and using experimental equipment for a specific physical problem;</li> <li>set up, perform, and evaluate experiments to investigate typical phenomena in quantum mechanics and statistical physics;</li> <li>using experimental techniques and data acquisition tools to record experimental data;</li> <li>analyze outcomes of experiments by mathematical and computational methods, and use error analysis to assess the accuracy and reproducibility of their results;</li> <li>use the appropriate format and language to summarize and describe an experiment, and communicate its outcome in a scientific report;</li> <li>organize their work and work responsibly in a team to fulfill the given task;</li> <li>orally describe and answer basic questions related to the background, the experimental method and outcome of the experiment.</li> </ol>				
<b>Usability and Relationship to other Modules</b> <ul style="list-style-type: none"> <li>Mandatory CORE module for the Physics major.</li> <li>Possible (mandatory) elective for a physics minor</li> <li>Has other Physics CORE modules as corequisites.</li> </ul>				

**Assessment**

Type: Lab reports (written reports)

Length: 10-15 pages  
Weight: 70%

Scope: Intended learning outcomes (1-6)

Type: Oral examination

Duration: 30 min  
Weight: 30%

Scope: Intended learning outcomes (4,7)

### 7.13 Advanced Physics Lab 3

<b>Module Name</b> Advanced Physics Lab 3		<b>Module Code</b> CO-488	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-488-A	Advanced Physics Lab 3		Lab	5.0
<b>Module Coordinator</b> Jürgen Fritz	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	<ul style="list-style-type: none"> <li>Lab (51 hours)</li> <li>Private study (74 hours)</li> </ul>	
<input checked="" type="checkbox"/> Modern Physics	<input checked="" type="checkbox"/> AnalMech & EIDyn	<ul style="list-style-type: none"> <li>First year math</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>				
Students should recap their first-year physics, especially from the lab courses including error analysis.				
<b>Content and Educational Aims</b>				
<p>Physics is an experimental science. Any hypotheses or theory 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 first year modules: Students work more independently on experiments and write a scientific lab report. They will do hands-on experiments on advanced topics in second year physics requiring also an advanced theoretical and mathematical description of phenomena. By working in teams of two students they setup 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.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to				
<ol style="list-style-type: none"> <li>prepare for doing experiments and using experimental equipment for a specific physical problem;</li> <li>setup, perform, and evaluate experiments to investigate typical phenomena in mechanics, electromagnetism, quantum mechanics and statistical physics;</li> <li>using experimental techniques and data acquisition tools to record experimental data;</li> <li>analyze outcomes of experiments by mathematical and computational methods, and use error analysis to assess the accuracy and reproducibility of their results;</li> <li>use the appropriate format and language to summarize and describe an experiment, and communicate its outcome in a scientific report;</li> <li>organize their work and work responsibly in a team to fulfill the given task;</li> <li>orally describe and answer basic questions related to the background, the experimental method and outcome of the experiment.</li> </ol>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory Elective CORE module for the Physics major.</li> <li>Possible (mandatory) elective for a physics minor</li> <li>Has other Physics CORE modules as corequisites.</li> </ul>				
<b>Assessment</b>				

Type: Lab reports (written reports)

Length: 10-15 pages

Weight: 70%

Scope: Intended learning outcomes (1-6)

Type: Oral examination

Duration: 30 min

Weight: 30%

Scope: Intended learning outcomes (4,7)

## 7.14 Condensed Matter Physics

<b>Module Name</b> Condensed Matter Physics		<b>Module Code</b> CA-S-PHY-801	<b>Level (type)</b> Year 3 (Specialization)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>		<i>CP</i>
CA-PHY-801-A	Condensed Matter and Devices	Lecture		5.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> mandatory for physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lecture (35 hours)</li> <li>Homework exercises (45 hours)</li> <li>Private study (45 hours)</li> </ul>	
<input checked="" type="checkbox"/> Statistical Physics	<input checked="" type="checkbox"/> None			
<i>Knowledge, Abilities, or Skills</i>		<b>Duration</b>	<b>Workload</b>	
<ul style="list-style-type: none"> <li>Quantum Mechanics</li> </ul>		1 semester	125 hours	
<b>Recommendations for Preparation</b>				
Review statistical mechanics and quantum mechanics at the level of the second year courses.				
<b>Content and Educational Aims</b>				
<p>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 the concepts of density-functional theory, the models by Drude and Sommerfeld, Fermi sphere, cohesive energy, classical and quantum harmonic crystal, phonons and quasiparticles are introduced; as well as the structure and dynamics of solids, band theory and electronic properties, optical properties, magnetism, and superconductivity. Working principles of important semiconductor devices are explained, including transistors, LED's, solid-state lasers and solar cells.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to				
<ul style="list-style-type: none"> <li>determine the basic properties of gases and condensed matter based on microscopic and statistical models;</li> <li>describe the behavior of electrons and analyze how they influence macroscopic and electronic properties of materials;</li> <li>select basic experimental techniques and procedures needed to study solid state materials;</li> <li>communicate in scientific language using advanced field-specific technical terms.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				
<ul style="list-style-type: none"> <li>Mandatory elective specialization module for physics majors.</li> <li>Possible (mandatory) elective for a physics minor</li> <li>Useful foundation for many BSc thesis research topics.</li> </ul>				
<b>Assessment</b>				
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 by 0.33 points (German grading system) but is not required to reach the best grade in the module (1.0).

## 7.15 Particles, Fields and Quanta

<b>Module Name</b> Particles, Fields and Quanta		<b>Module Code</b> CA-S-PHY-802	<b>Level (type)</b> Year 3 (Specialization)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CA-PHY-802-A	Elementary Particles and Fields		Lecture	2.5
CA-PHY-802-B	Advanced Quantum Physics		Lecture	2.5
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> mandatory elective for physics	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Homework exercises, project/presentation (55 hours)</li> <li>Private study (35 hours)</li> </ul>
<input checked="" type="checkbox"/> Quantum Mechanics, Analytical Mechanics	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>Mathematics at the level of the Applied Mathematics Module</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>				
Review classical mechanics, quantum mechanics and electrodynamics at the level of the second year courses.				
<b>Content and Educational Aims</b>				
<p>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 into advanced methods and concepts of quantum mechanics with applications. The focus may change from year to year reflecting current trends in physics, like e.g. quantum computing. Topics of the module will include entanglement, perturbation theory, second quantization, introductory quantum field theory, Feynman diagrams, 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, quantum information theory.</p> <p>The physics specialization modules aim to prepare students for their further professional, research or academic career 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.</p>				
<b>Intended Learning Outcomes</b>				
By the end of the module, students will be able to:				
<ul style="list-style-type: none"> <li>describe the building blocks of matter and the fundamental forces of nature;</li> <li>calculate quantities of interest in quantum physics like e.g. scattering cross sections or energy levels using perturbation theory and similar advanced methods;</li> <li>formulate models of particle physics and quantum systems and derive their properties.</li> </ul>				
<b>Usability and Relationship to other Modules</b>				

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

**Assessment**

Type: Project with presentation,

Duration of the presentation: 15 min

Weight: 100%

Scope: All intended learning outcomes of the module.

Bonus achievement: Additional bonus homework as a voluntary task can improve the grade by 0.33 points (German grading system) but is not required to reach the best grade in the module (1.0).

## 7.16 Advanced Applied Physics

<b>Module Name</b> Advanced Applied Physics		<b>Module Code</b> CA-S-PHY-803	<b>Level (type)</b> Year 3 (Specialization)	<b>CP</b> 5.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CA-PHY-803-A	Biophysics / Nanotechnology		Lecture	2.5
CA-PHY-803-B	Advanced Optics / Atoms and Molecules		Lecture	2.5
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> mandatory    elective    for physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Homework exercises, project and presentation (55 hours)</li> <li>Private study (35 hours)</li> </ul>	
<input checked="" type="checkbox"/> Modern Physics	<input checked="" type="checkbox"/> None			
		<b>Duration</b>	<b>Workload</b>	
		1 semester	125 hours	
<b>Recommendations for Preparation</b>				
<b>Content and Educational Aims</b>				
<p>The Advanced Applied Physics module covers a selection of topics from advanced experimental physics such as biophysics, nanotechnology, advanced optics or molecular physics. This modules gives an introduction and overview to a range of interdisciplinary topics in experimental and computational physics for advanced physics majors. Aim of these partially seminar-style lectures is to enable the students to dive into the research on complex systems and their optical characterization. After introductions to the fields, seminal but also recent research is discussed, in part based on original literature.</p> <p>The physics specialization modules aim to prepare students for their further professional, research or academic career 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.</p>				

**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 principles of 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.

**Usability and Relationship to other Modules**

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

**Assessment**

Type: Project with presentation,

Duration of the presentation: 15 min

Weight: 100%

Bonus achievement: Additional bonus homework as a voluntary task can improve the grade by 0.33 points (German grading system) but is not required to reach the best grade in the module (1.0).

## 7.17 Foundations of Mathematical Physics

<b>Module Name</b> Foundations of Mathematical Physics		<b>Module Code</b>	<b>Level (type)</b> Year 2/3 (Specialization)	<b>CP</b> 5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>		<b>CP</b>
	Foundations of Mathematical Physics	Lecture		5
<b>Module Coordinator</b> S. Petrat	<b>Program Affiliation</b> • Mathematics		<b>Mandatory Status</b> Mandatory elective for Mathematics and Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<b>Pre-requisites</b> <input checked="" type="checkbox"/> Applied Mathematics Or <input checked="" type="checkbox"/> Introduction to Robotics and Intelligent Systems (IMS)		biennially	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Private Study (90 hours)</li> </ul>	
<b>Co-requisites</b> <input checked="" type="checkbox"/> None		<b>Knowledge, Abilities, or Skills</b>	<b>Duration</b>	<b>Workload</b>
		<ul style="list-style-type: none"> <li>Good command of linear algebra, analysis, and calculus</li> </ul>	1 semester	125 hours
<b>Recommendations for Preparation</b>				
Review material from pre-requisite modules, especially Applied Mathematics. Having taken Applied Mathematics is recommended.				
<b>Content and Educational Aims</b>				
<p>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 new discoveries in physics possible. The goal of this module is to look at some examples of that, and to get an insight into which role rigorous mathematics has played and plays nowadays in explaining physical phenomena. This class discusses examples from the major theories of classical mechanics, quantum mechanics, electrodynamics, and statistical mechanics.</p> <p>A selection of the following topics will be covered:</p> <ul style="list-style-type: none"> <li>Mathematical foundations of classical mechanics</li> <li>Hamiltonian dynamics and symplectic geometry</li> <li>Integrable systems</li> <li>Special Functions</li> <li>Mathematical Foundations of quantum mechanics</li> <li>Quantum entanglement</li> <li>Fourier analysis</li> <li>Variational methods</li> <li>Non-linear partial differential equations from physics</li> <li>Scattering theory</li> <li>Many-body quantum mechanics and second quantization</li> <li>Geometric foundations (differential geometry)</li> </ul>				

- 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

***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
- 3<sup>rd</sup> year Mandatory elective Specialization module for major Physics students
- Elective for students of all other undergraduate studies

***Assessment***

Type: Written Exam

Duration: 120 min

Scope: All intended learning outcomes of this module

Bonus achievement: Additional bonus homework as a voluntary task can improve the grade by 0.33 points (German grading system) but is not required to reach the best grade in the module (1.0).

## 7.18 Physical Chemistry

<b>Module Name</b> Physical Chemistry		<b>Module Code</b> CO-440	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CO-440-A	Physical Chemistry I		Lecture	2.5
CO-440-B	Physical Chemistry II		Lecture	2.5
<b>Module Coordinator</b> Detlef Gabel	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Chemistry</li> </ul>		<b>Mandatory Status</b> Mandatory for Chemistry, mandatory elective for Physics and MCCB	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lecture (45 hours)</li> <li>Private study (45 hours)</li> <li>Exam preparation (35 hours)</li> </ul>	
<input checked="" type="checkbox"/> General and Inorganic Chemistry Or <input checked="" type="checkbox"/> Modern Physics	<input checked="" type="checkbox"/> None			
		2 semesters	125 hours	
<b>Recommendations for Preparation</b>				
None				
<b>Content and Educational Aims</b>				
<p>The module gives an introduction into Physical Chemistry and focusses on thermodynamics, kinetics, intermolecular forces, surfaces, and electrochemistry. It also gives an introduction into 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.</p>				

**Intended Learning Outcomes**

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

1. use the gas laws to predict the behavior of perfect and real gases;
2. differentiate between enthalpy, entropy, and Gibbs energy;
3. correlate Gibbs energy with equilibrium constants;
4. derive the velocities of reactions of zero, first, and second order;
5. derive the velocities of enzyme reactions and coupled reactions;
6. explain and apply the concept of activation energy;
7. calculate the velocity of reactions as a function of temperature;
8. recognize phase transitions from measurable properties;
9. explain and apply fundamentals in electrochemistry;
10. explain how given molecules and their functional groups can interact with each other and their surrounding;
11. recognize the different approaches to quantum chemical calculations;
12. use an electronic lab book and share their own results with others through it
13. derive the fundamental equations of importance in physical chemistry
14. demonstrate presentation skills

**Usability and Relationship to other Modules**

- Pre/corequisite for the Inorganic and Physical Chemistry lab
- Mandatory for a Major and a Minor in Chemistry
- Mandatory elective specialization module for 3rd year Physics and MCCB major students.

**Assessment**

Type: Written examination

Duration: 120 min.

Weight: 75%

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

Type: Presentation

Duration 15 min

Weight 25%

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

## 7.19 Electronics

<b>Module Name</b> Electronics		<b>Module Code</b> CO-526	<b>Level (type)</b> Year 2 (CORE)	<b>CP</b> 5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>		<b>CP</b>
CO-526-A	Electronics	Lecture		2.5
CO-526-B	Electronics Lab	Lab		2.5
<b>Module Coordinator</b> Dr. Mathias Bode	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Electrical and Computer Engineering (ECE)</li> </ul>		<b>Mandatory Status</b> Mandatory for ECE Mandatory elective for Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<b>Pre-requisites</b> Co-requisites <input checked="" type="checkbox"/> None <input checked="" type="checkbox"/> General Electrical Engineering I&II Or <input checked="" type="checkbox"/> Electrodynamics (Physics)		annually  <b>Duration</b> 1 semester	<ul style="list-style-type: none"> <li>Lecture (17,5 hours)</li> <li>Lab (25.5 hours)</li> <li>Private Study (82.00)</li> </ul> <b>Workload</b> 125 hours	
<b>Knowledge, Abilities, or Skills</b> <ul style="list-style-type: none"> <li>Linear circuits</li> <li>Basic Calculus</li> <li>Basic Linear Algebra</li> </ul>				
<b>Recommendations for Preparation</b> Revise linear circuits from your 1 <sup>st</sup> year, and get textbook & lab material. See dedicated module Web pages for details (links on CampusNet).				
<b>Content and Educational Aims</b> Electronics and circuits are at the core of modern technology. This module comprises a lecture and a lab component. It builds on the 1 <sup>st</sup> 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

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

**Usability and Relationship to other Modules**

- Pre-requisite for the 2<sup>nd</sup> year PCB design lab and 3<sup>rd</sup> 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 3<sup>rd</sup> year.
- Mandatory elective 3<sup>rd</sup> year Specialization module for Physics major students.
- Mandatory for major in ECE.

**Assessment**

Type: Written examination

Duration: 120 min

Weight: 50%

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

Type: Lab reports

Length: 5-10 pages per experiment session

Weight: 50%

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

## 7.20 Internship / Startup and Career Skills

<b>Module Name</b> Internship / Startup and Career Skills		<b>Module Code</b> CA-INT-900	<b>Level (type)</b> Year 3 (CAREER)	<b>CP</b> 15
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>		<b>CP</b>
CA-INT-900-0	Internship	Internship		15
<b>Module Coordinator</b>  Predrag Tapavicki & Christin Klähn (CSC Organization); SPC / Faculty Startup Coordinator (Academic responsibility);	<b>Program Affiliation</b>  • CAREER module for undergraduate study programs		<b>Mandatory Status</b>  Mandatory for all undergraduate study programs except IEM	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<b>Pre-requisites</b>  <input checked="" type="checkbox"/> at least 15 CP from CORE modules in the major	<b>Co-requisites</b>  <input checked="" type="checkbox"/> None	<b>Knowledge, Abilities, or Skills</b>  • Information provided on CSC pages (see below) • Major specific knowledge and skills	annually	<ul style="list-style-type: none"> <li>• Internship/Start-up</li> <li>• Internship Event</li> <li>• Seminars, Info-sessions, Workshops and Career Events</li> <li>• Self-Study, Readings, Online Tutorials</li> </ul>
		<b>Duration</b> 1 semester	<b>Workload</b>  375 Hours consisting of: <ul style="list-style-type: none"> <li>• Internship (308 hours)</li> <li>• Workshops (33 hours)</li> <li>• Internship Event (2 hours)</li> <li>• Self-study (32 hours)</li> </ul>	
<b>Recommendations for Preparation</b>				
<ul style="list-style-type: none"> <li>• Reading the information in the menu sections “Internship Information”, “Career Events”, “Create Your Application” and “Seminars &amp; Workshops” at the Career Services Center website <a href="http://csc-microsite.user.jacobs-university.de/">http://csc-microsite.user.jacobs-university.de/</a></li> <li>• Completing all four online tutorials about the job market preparation and the application process ( <a href="http://csc-microsite.user.jacobs-university.de/create-your-application/tutorials/">http://csc-microsite.user.jacobs-university.de/create-your-application/tutorials/</a>)</li> <li>• Participation at Internship Events of earlier classes</li> </ul>				
<b>Content and Educational Aims</b>				
<p>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 in society, to apply these skills and this knowledge in real life whilst getting practical experience, to find professional orientation, and develop their personality and in their career. The module supports the programs’ aims of preparing students for gainful, qualified employment and the development of their personality.</p>				

The full-time internship must be related to major area of study and extends over a minimum period of two consecutive months, normally scheduled just before the 5<sup>th</sup> semester, with the internship event and submission of the internship report in the 5<sup>th</sup> semester. Upon approval by the SPC and CSC, the internship may take place at other times, such as before teaching starts in the 3<sup>rd</sup> or after teaching finishes in the 6<sup>th</sup> 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.

The internship will be gradually prepared in semesters 1 to 4 by 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 job interviews and/or assessment centers. In addition to this mandatory part, students can customize their set of skills regarding the application challenges and 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 the acquired job market skills in an actual internship/job search situation and to gain a 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 initial StartUp-idea. This presentation will be held at the beginning of the 4<sup>th</sup> semester. A jury of faculty members will judge the potential to realize the 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 set out in the Policies for Bachelor Studies apply.

The concluding Internship Event will be conducted in each study program (or a cluster of related study programs) and will formally conclude the module by providing students the opportunity to present their internships and reflect on the lessons learned within their major area of study. The purpose is not only to self-reflect the whole process but also to create the professional network within the academic community, especially with the aspect of entering the Alumni Network after graduation. It is recommended that all three classes of the same major are present at this event to enable the creation of networks between older and younger students and to create a learning environment for younger students in the sense of "lessons learned" effect from 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: identify personal interests, select appropriate internship destinations or start-up opportunities, conduct interviews, pitches or assessment centers, negotiate related employment, 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 expectations by and consequences for employers and the society;
- reflect on and set own targets for further development of their knowledge, skills, interests and values;
- establish and expand contacts with potential employers or business partner and possibly other students and alumni to build their own professional network to create employment opportunities in the future;
- discuss observations and reflection in a professional network.

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

- Mandatory for a major in BCCB, Chemistry, CS, EES, GEM, IBA, IRPH, Psychology, Math, MCCB, Physics, IMS and ISS.

- 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.

***Assessment***

Type: Internship Report or Business Plan and Reflection  
Scope: All intended learning outcomes

Length: approx. 3.500 words  
Weight: 100%

## 7.21 Thesis and Seminar Physics

<b>Module Name</b> Thesis and Seminar Physics		<b>Module Code</b> CA-PHY-800	<b>Level (type)</b> Year 2 (CAREER)	<b>CP</b> 15.0
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>		<i>Type</i>	<i>CP</i>
CA-PHY-800-S	Physics Research Seminar		Seminar	3.0
CA-PHY-800-T	Physics Thesis		Project work	12.0
<b>Module Coordinator</b> Peter Schupp	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Physics</li> </ul>		<b>Mandatory Status</b> Mandatory for Physics majors	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Seminar (40 hours)</li> <li>Project work (200 hours)</li> <li>Private study (135 hours)</li> </ul>	
<input checked="" type="checkbox"/> Students must be in the third year and have taken at least 30 CP from CORE modules of their major.	<input checked="" type="checkbox"/> None			
		1 semester	375 hours	
<b>Recommendations for Preparation</b>				
<ul style="list-style-type: none"> <li>Students need to recap their physics knowledge in the specific field of their thesis.</li> <li>Identify an area or a topic of interest and discuss this with your prospective supervisor in good time.</li> <li>Create a research proposal including a research plan to ensure timely submission.</li> <li>Ensure you possess all required technical research skills or are able to acquire them on time.</li> <li>Review the University's Code of Academic Integrity and Guidelines to Ensure Good Academic Practice</li> </ul>				
<b>Content and Educational Aims</b>				
<p>Within this module, students use their knowledge in physics, their mathematical and experimental skills gained during their studies, to become acquainted with an actual research topic. They will demonstrate their mastery of content and methods of a specific research field in physics as provided by faculty.</p> <p>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 do physics research under guidance by faculty and research group members. The thesis includes performing experiments or theoretical calculations, description and documentation of results, and 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.</p>				
<b>Intended Learning Outcomes</b>				
<p>By the end of the module, students will be able to</p> <ul style="list-style-type: none"> <li>familiarize themselves with a new field in physics, by finding, reviewing and digesting the relevant scientific literature;</li> <li>prepare for a specific research problem in physics by researching the necessary experimental techniques and / or theoretical and mathematical approaches;</li> </ul>				

- use and apply the appropriate experimental or theoretical / mathematical techniques to solve a problem in physics;
- analyze the outcome of their research work and evaluate it by discussions with senior scientists;
- organize their work and work responsibly and independently in a research team to fulfill a given task or solve a given problem;
- use the appropriate format and language to summarize and describe their findings in a scientific report (thesis);
- answer basic questions related to the background, the method used and the outcome of their research project;
- 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 acquire additional skills independently as and if required.

***Assessment***

Type: Thesis (Thesis)

Length: 20-30 pages

Weight: 80%

Scope: All intended learning outcomes.

Type: Presentation (Seminar), Duration: 15-30 minutes, Weight: 20%

Scope: Intended learning outcomes 1, 2, 4, 7, 8.

## 7.22 Jacobs Track Modules

### 7.22.1 Methods and Skills Modules

#### 7.22.1.1 Calculus and Linear Algebra I

<b>Module Name</b> Calculus and Linear Algebra I			<b>Module Code</b> JTMS-MAT-09	<b>Level (type)</b> Year 1 (Methods)	<b>CP</b> 5
<b>Module Components</b>					
<i>Number</i>	<i>Name</i>			<i>Type</i>	<i>CP</i>
JTMS-09	Calculus and Linear Algebra I			Lecture	5
<b>Module Coordinator</b>  Marcel Oliver, Tobias Preußner		<b>Program Affiliation</b>  • Jacobs Track – Methods and Skills		<b>Mandatory Status</b>  Mandatory for CS, ECE, IMS, MATH and Physics Mandatory elective for EES	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>  <input checked="" type="checkbox"/> None	<i>Co-requisites</i>  <input checked="" type="checkbox"/> None	<i>Knowledge, Abilities, or Skills</i>  <ul style="list-style-type: none"> <li>• 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)</li> <li>• Knowledge of Analytic Geometry at High School level (vectors, lines, planes, reflection, rotation, translation, dot product, cross product, normal</li> </ul>		annually	<ul style="list-style-type: none"> <li>• Lectures (35 hours)</li> <li>• Private Study (90 hours)</li> </ul>
			<b>Duration</b> 1 semester	<b>Workload</b> 125 hours	

<ul style="list-style-type: none"> <li>vector, polar coordinates)</li> <li>• Some familiarity in elementary Calculus (limits, derivative) is helpful, but not strictly required.</li> </ul>		
<p><b>Recommendations for Preparation</b></p> <p>Review all of higher-level High School Mathematics, in particular the topics explicitly named in “Entry Requirements – Knowledge, Ability, or Skills” above.</p>		
<p><b>Content and Educational Aims</b></p> <p>This module is the first in a sequence introducing mathematical methods at 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 lies in 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 done in the first-year modules “Analysis I” and “Linear Algebra”.</p> <p>The lecture comprises the following topics</p> <ul style="list-style-type: none"> <li>• Brief review of number systems, elementary functions, and their graphs</li> <li>• Brief introduction to complex numbers</li> <li>• Limits for sequences and functions</li> <li>• Continuity</li> <li>• Derivative</li> <li>• Curve sketching and applications (isoperimetric problems, optimization, error propagation)</li> <li>• Introduction to Integration and the Fundamental Theorem of Calculus</li> <li>• Review of elementary analytic geometry</li> <li>• Vector spaces, linear independence, bases, coordinates</li> <li>• Matrices and matrix algebra</li> <li>• Solving linear systems by Gauss elimination, structure of general solution</li> <li>• Matrix inverse</li> </ul>		
<p><b>Intended Learning Outcomes</b></p> <p>By the end of the module, students will be able to</p> <ul style="list-style-type: none"> <li>• 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;</li> <li>• recognize the mathematical structures in an unfamiliar context and translate them into a mathematical problem statement;</li> <li>• 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.</li> </ul>		
<p><b>Usability and Relationship to other Modules</b></p> <ul style="list-style-type: none"> <li>• 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).</li> <li>• 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.</li> <li>• 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.</li> <li>• 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.</li> <li>• This module is a prerequisite for the module “Applied Mathematics” which develops more advanced theoretical and practical mathematical tools essential for any physicist and mathematician.</li> <li>• Mandatory for a major in CS, ECE, IMS, MATH and Physics</li> <li>• Mandatory elective for a major in EES.</li> </ul>		

- Pre-requisite for Calculus and Linear Algebra II
- Elective for all other study programs.

**Assessment**

Type: Written examination

Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of this module

### 7.22.1.2 Calculus and Linear Algebra II

<b>Module Name</b> Calculus and Linear Algebra II		<b>Module Code</b>	<b>Level (type)</b> Year 1 (Methods)	<b>CP</b> 5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>		<b>CP</b>
JTMS-10	Calculus and Elements of Linear Algebra II	Lecture		5
<b>Module Coordinator</b>	<b>Program Affiliation</b>		<b>Mandatory Status</b>	
Marcel Oliver, Tobias Preußner	• Jacobs Track – Methods and Skills		Mandatory for CS, ECE, MATH, Physics, IMS	
<b>Entry Requirements</b>		<b>JTMS-MAT-10</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>		<i>Frequency</i>	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Private Study (90 hours)</li> </ul>	
<input checked="" type="checkbox"/> Calculus and Linear Algebra I	<i>Co-requisites</i> <input checked="" type="checkbox"/> None	<i>Knowledge, Abilities, or Skills</i> <ul style="list-style-type: none"> <li>None beyond formal pre-requisites</li> </ul>		
			<b>Workload</b> 125 hours	
<b>Recommendations for Preparation</b>				
Review the content of Calculus and Elements of Linear Algebra I				
<b>Content and Educational Aims</b>				
<p>This module is the second in a sequence introducing mathematical methods at 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 lies in 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 done in the first-year modules "Analysis I" and "Linear Algebra".</p> <p>The lecture comprises the following topics</p> <ul style="list-style-type: none"> <li>Directional derivatives, partial derivatives</li> <li>Linear maps</li> <li>The total derivative as a linear map</li> <li>Gradient and curl (elementary treatment only, for more advanced topics, in particular the connection to the Gauss and Stokes' integral theorem, see module "Applied Mathematics")</li> <li>Optimization in several variables, Lagrange multipliers</li> <li>Elementary ordinary differential equations</li> <li>Eigenvalues and eigenvectors</li> <li>Hermitian and skew-Hermitian matrices</li> <li>First important example of eigendecompositions: Linear constant-coefficient ordinary differential equations</li> <li>Second important example of eigendecompositions: Fourier series</li> <li>Fourier integral transform</li> <li>Matrix factorizations: singular value decomposition with applications, LU decomposition, QR decomposition</li> </ul>				

**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.

**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 done 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 IMS
- Elective for all other study programs.

**Assessment**

Type: Written examination

Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of this module

### 7.22.1.3 Probability and Random Processes

<b>Module Name</b> Probability and Random Processes		<b>Module Code</b> JTMS-MAT-12	<b>Level (type)</b> Year 2 (Methods)	<b>CP</b> 5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>		<b>CP</b>
JTMS-12	Probability and random processes	Lecture		5
<b>Module Coordinator</b> Marcel Oliver, Tobias Preußner	<b>Program Affiliation</b> • Jacobs Track – Methods and Skills		<b>Mandatory Status</b> Mandatory for CS, ECE, MATH, Physics, IMS Mandatory elective for EES	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Private Study (90 hours)</li> </ul>
<input checked="" type="checkbox"/> Calculus and Linear Algebra I & II	None	<ul style="list-style-type: none"> <li>Knowledge of calculus at the level of a first year calculus module (Differentiation, integration one and several variables, trigonometric functions, logarithm and exponential function).</li> <li>Knowledge of linear algebra at the level of a first year university module (Eigenvalues and eigenvectors, diagonalization of matrices).</li> <li>Some familiarity with elementary probability theory at the high school level.</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>				
Review all of the first year calculus and linear algebra modules as indicated in “Entry Requirements – Knowledge, Ability, or Skills” above.				
<b>Content and Educational Aims</b>				
<p>This module aims at providing 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 <i>Stochastic Processes</i>.</p> <p>The lecture comprises the following topics</p> <ul style="list-style-type: none"> <li>Brief review of number systems, elementary functions, and their graphs</li> <li>Outcomes, Events &amp; Sample Space. Combinatorial probability.</li> <li>Conditional probability and Bayes’ formula.</li> <li>Binomials &amp; Poisson-Approximation</li> </ul>				

- 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 & Moments, Covariance.
- High dimensional probability: Chebyshev and Chernoff bounds.
- Moment Generating Functions & Characteristic Functions,
- The Central limit theorem.
- Random Vectors & 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.

***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, IMS.
- Mandatory elective for a major in EES (if pre-requisites are met)
- Elective for all other study programs.

***Assessment***

Type: Written examination

Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of this module

### 7.22.1.4 Numerical Methods

<b>Module Name</b> Numerical Methods		<b>Module Code</b> JTMS-MAT-13	<b>Level (type)</b> Year 2 (Methods)	<b>CP</b> 5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>		<b>CP</b>
JTMS-13	Numerical Methods	Lecture		5
<b>Module Coordinator</b>	<b>Program Affiliation</b>		<b>Mandatory Status</b>	
Marcel Oliver, Tobias Preußner	<ul style="list-style-type: none"> <li>Jacobs Track – Methods and Skills</li> </ul>		Mandatory for ECE, MATH, Physics Mandatory elective for CS and IMS	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>
<b>Pre-requisites</b>	<b>Co-requisites</b>	<b>Knowledge, Abilities, or Skills</b>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Private Study (90 hours)</li> </ul>
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>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)</li> <li>Knowledge of Linear Algebra (vectors, matrices, lines, planes, n-dimensional Euclidean vector space, rotation, translation, dot product (scalar product), cross product, normal vector, eigenvalues, eigenvectors, elementary techniques for solving systems of linear equations)</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>				

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 Casteljaeu’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 which are 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 potential limitations and caveats of such algorithms.

### ***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.
- 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 ECE, MATH, and Physics.
- Mandatory elective for a major in CS and IMS
- Elective for all other study programs.

**Assessment**

Type: Written examination

Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of this module

### 7.22.1.5 Programming in Python

<b>Module Name</b> Programming in Python		<b>Module Code</b> JTMS-SKI-14	<b>Level (type)</b> Year 1 (Methods)	<b>CP</b> 5
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>		<i>CP</i>
JTMS-14	Programming in Python	Lecture		5
<b>Module Coordinator</b> Kinga Lipskoch	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track – Methods and Skills</li> </ul>		<b>Mandatory Status</b> Mandatory for IEM Mandatory elective for BCCB, EES and Physics	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Class attendance (35 hours)</li> <li>Independent study (85 hours)</li> <li>Exam preparation (5 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None			
		<b>Duration</b>	<b>Workload</b>	
		1 semester	125 hours	
<b>Recommendations for Preparation</b>				
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.				
<b>Content and Educational Aims</b>				
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 learning the concepts of data types, variables, operators, strings and basic data structures. Then other programming constructs such as branching, iterations, and data structures like strings, lists, tuples, and dictionaries are taught. The module also gives an introduction into functions, as well as simple file handling by introducing reading data from files, processing the data and writing the results into files. Later object-oriented programming concepts like constructors, methods, overloaded operators and inheritance are presented. Retrieving data from urls and processing of larger amounts of data and their query and storage in files are addressed. Simple interactive graphics and operations are also presented with the help of an object-oriented graphics library.				
<b>Intended Learning Outcomes</b>				
By the end of this module, students should be able to:				
<ul style="list-style-type: none"> <li>explain basic concepts of imperative programming languages such as variables, assignments, loops, function calls, data structures, etc.;</li> <li>work with user input from the keyboard, write interactive Python programs;</li> <li>write, test, and debug programs;</li> <li>illustrate basic object-oriented programming concepts such as objects, classes, information hiding and inheritance;</li> <li>give original examples of function and operator overloading;</li> <li>retrieve data and process and generate data from/to files;</li> <li>use some available python modules and libraries like data or graphics related ones.</li> </ul>				

***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 BCCB, EES and Physics.
- Elective for all other study programs.

***Assessment***

Type: Written examination

Duration 120 minutes

Weight: 100%

Scope: All intended learning outcomes of the module

Module achievements: 50% of the assignments passed

### 7.22.1.6 Finite Mathematics

<b>Module Name</b> Finite Mathematics			<b>Module Code</b> JTMS-MAT-11	<b>Level (type)</b> Year 1 (Methods)	<b>CP</b> 5
<b>Module Components</b>					
<b>Number</b>	<b>Name</b>			<b>Type</b>	<b>CP</b>
JTMS-11	Finite Mathematics			Lecture	5
<b>Module Coordinator</b> Marcel Oliver, Tobias Preußner		<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track – Methods and Skills</li> </ul>		<b>Mandatory Status</b> Mandatory for IEM Mandatory elective and Physics	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Private Study (90 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	The topics in this module are elementary, yet some command of mathematical language is required at a level that corresponds to an upper-level high-school education in mathematics and/or the Jacobs University first-semester modules <i>Mathematical Concepts in the Sciences, Applied Calculus, or Calculus and Elements of Linear Algebra I.</i>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours	
<b>Recommendations for Preparation</b>					
Review -the following topics at high school or elementary university level:					
<ul style="list-style-type: none"> <li>Elementary solution strategies for systems of linear equations,</li> <li>Solution of quadratic equations</li> <li>Factorization of polynomials</li> <li>Equations of lines</li> <li>Elementary notions of probability</li> </ul>					

### **Content and Educational Aims**

This module is the second semester in a sequence of mathematical methods modules for students in the sciences, industrial engineering, and management majors. It aims at rounding off the mathematical education for students in these majors with topics from matrix algebra, probability, and related subjects in a way that is directly useful for the applications in experimental sciences, economics, management, and applied engineering.

The lecture comprises the following topics

- Graphs of lines and planes
- Linear regression and applications
- Systems of linear equations and applications
- Matrix formulation of linear equations, matrix algebra
- Gauss elimination, inverse matrix
- Linear inequalities
- Markov chain
- Sets, counting principles, permutations, combinations
- Sample space, event, probability
- conditional probability, independence, Bayes' rule with applications
- expected value, variance, standard deviation
- Binomial distribution and normal distribution
- Elementary descriptive statistics

### **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 science; economics, business, and applied engineering to the extent that they are covered by the content of this module.

### **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 serves as a preparation for the 2nd year IEM CORE module Operations Research.
- This module is accessible to all Jacobs students with a minimum of mathematical pre-knowledge and covers a broad range of non-Calculus applications of mathematics across a broad spectrum of fields of study
- It most naturally complements the module *Applied Calculus* which covers elementary Calculus-based applications of mathematics in a similar spectrum of fields
- There is no strict dependence between *Applied Calculus* and *Finite Mathematics*, but the default recommendation is to take *Applied Calculus* in the first semester and *Finite Mathematics* in the second semester
- Students in majors that require a more advanced mathematics and methods education should consult their program handbooks
- The first year modules *Calculus and Elements of Linear Algebra I+II* can be used in place of the modules *Applied Calculus* and *Finite Mathematics*, respectively, to satisfy the graduation requirements in majors in which they are mandatory.
- Mandatory for major in IEM
- Mandatory elective for a major in Physics.
- Elective for all other study programs.

### **Assessment**

Type: Written examination

Duration: 120 min

Weight: 100%

Scope: All intended learning outcomes of this module

## 7.22.2 Big Questions Modules

### 7.22.2.1 Digitalization: Challenges and Opportunities for Business and Society

<b>Module Name</b> Big Questions: Digitalization: Challenges and Opportunities for Business and Society			<b>Module Code</b> JTBO-BQ-001	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 5
<b>Module Components</b>					
<b>Number</b>		<b>Type</b>		<b>CP</b>	
JTBO-001	Digitalization: challenges and opportunities for business and society		Lecture/Projects	5	
<b>Module Coordinator</b> A. Wilhelm	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track - Big Questions</li> </ul>			<b>Mandatory Status</b> <ul style="list-style-type: none"> <li>Mandatory elective for students of all undergraduate study programs except IEM</li> </ul>	
<b>Entry Requirements</b>			<b>Frequency</b> annually	<b>Forms of Learning and Teaching</b>	
<b>Pre-requisites</b> <input checked="" type="checkbox"/> None	<b>Co-requisites</b> <input checked="" type="checkbox"/> None	<b>Knowledge, Abilities, or Skills</b> <ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<ul style="list-style-type: none"> <li>17.5 h Lectures</li> <li>90 h Project work</li> <li>17.5 h Private Study</li> </ul>	
<b>Workload</b> 125 hours					
<b>Recommendations for Preparation</b> Critical following of media coverage on the module's topics in question.					
<b>Content and Educational Aims</b> <p>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.</p> <p>Digitalization is currently one of the major change drivers in our globalized world affecting all aspects of our lives: from private aspects, such as the way we find and select friends and partners, to economic principles such as the replacement of human labor by robots and artificial intelligence. Big data is a further buzz word of the digitalization process: the massive storage and analysis of comprehensive information of customers and citizens instill both hopes and fears to the public. From a business perspective, digitalization is often portrayed as a sea of big opportunities while at the same time many companies are under pressure to comply and adapt to rapidly changing processes and business approaches. The public debate on digitalization, particularly on big data, is torn between the two poles portrayed by the writers George Orwell and Aldous Huxley: complete surveillance and oppression on the one end, irrelevance and narcissism on the other. The technological research quite naturally is mostly concerned with the technical feasibility of the approaches, the continuously increasing challenges with respect to the digitalization process, and the creative solutions needed to tackle them. In this module, you will get an overview on digitalization by looking at it from various aspects, primarily the business</p>					

and societal point of view. There will be a fundamental exposition to the technological side of digitalization as far as it is needed for assessing the societal and business implications.

***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 debate about big data, the pros and cons, from both a business perspective as well as a societal perspective
- prioritize the major threats and opportunities of digitalization
- advance a knowledge-based opinion on how technological possibilities and innovations can drive business practices and initiate public discourse and debate
- complete a self-designed project, collect information, distill information and summarize in a suitable reporting format
- overcome general teamwork problems in order to perform well-organized project work

***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.

***Assessment***

Type: Team project

Weight: 100%

Scope: All intended learning outcomes of the module

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

<b>Module Name</b> Big Questions: Water: The Most Precious Substance on Earth			<b>Module Code</b> JTbQ-BQ-002	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 5
<b>Module Components</b>					
<i>Number</i>	<i>Name</i>			<i>Type</i>	<i>CP</i>
JTbQ-002	Water - The most precious substance on earth			Lecture/Tutorial	5
<b>Module Coordinator</b>  M. Bau and D. Mosbach	<b>Program Affiliation</b>  • Jacobs Track - Big Questions			<b>Mandatory Status</b>  • Mandatory elective for students of all undergraduate study programs except IEM	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>• 17.5 h Lectures</li> <li>• 90h Project work</li> <li>• 17.5 Private Study</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>• the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>• media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 2 semesters	<b>Workload</b> 125 hours	
<b>Recommendations for Preparation</b>					
Critical following of media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>Water is the basic prerequisite for life on our planet, but has become a scarce resource and a valuable commodity; it is of fundamental importance for the world economy and for global food supply and 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, as well as from social and cultural sciences.</p> <p>Following topical lectures in the Fall semester, students will work on projects on the occasion of World Water Day (March 22) in small teams comprised of students from various disciplines and with different cultural backgrounds. The teamwork will be accompanied by related tutorials.</p>					
<b>Intended Learning Outcomes</b>					
Students acquire transferable and key skills in this module.					
By the end of this module, students will be able to					

1. use their disciplinary factual and methodological knowledge to reflect on interdisciplinary questions by comparing approaches from various disciplines
2. advance a knowledge-based opinion on the complex module topics: on the physico-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 the cultural values and meanings of water.
3. formulate coherent written and oral contributions (e.g., to (panel) discussions) on the topic
4. perform well-operating teamwork
5. present a self-designed project in a university-wide context

***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.

***Assessment***

Type: Written examination

Duration: 60 min

Weight: 50%

Scope: Intended learning outcomes (1-3)

Type: Team project

Weight: 50%

Scope: Intended learning outcomes (1-5)

### 7.22.2.3 Ethics in Science and Technology

<b>Module Name</b> Big Questions: Ethics in Science and Technology			<b>Module Code</b> JTBQ-BQ-003	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 5.0
<b>Module Components</b>					
<b>Number</b>	<b>Name</b>			<b>Type</b>	<b>CP</b>
JTBQ-003	Ethics in Science and Technology			Lecture /Projects	5.0
<b>Module Coordinator</b>  A. Lerchl	<b>Program Affiliation</b>  • Jacobs Track - Big Questions			<b>Mandatory Status</b>  • Mandatory for Chemistry • Mandatory elective for all other undergraduate study programs except IEM	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>		annually	<ul style="list-style-type: none"> <li>• 35 h Lectures (hours)</li> <li>• 55 h Project work</li> <li>• 35 h Private Study</li> </ul>
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>• the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>• media literacy, critical thinking and a proficient handling of data sources</li> </ul>		<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>					
Critical following of media coverage of the scientific topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>Ethics is an often neglected, but essential part of science and technology. Our decisions about right and wrong influenced the way, how our inventions and developments change the world. A wide array of examples will be presented and discussed, e.g., foundation of ethics, individual vs. population ethics, artificial life, stem cells, animal rights, abortion, pre-implantation diagnostics, legal and illegal drugs, pharmaceutical industry, gene modification, clinical trials and research with test persons, weapons of mass destruction, data fabrication, and scientific fraud.</p>					

**Intended Learning Outcomes**

Students acquire transferable and key skills in this module.

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

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

**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.
- Mandatory for a major in Chemistry

**Assessment**

Type: Written examination

Duration: 60 min  
Weight: 50%

Scope: Intended learning outcomes (1-9)

Type: team project

Weight: 50%

Scope: Intended learning outcomes (1, 3-12)

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

<b>Module Name</b> Big Questions: Global Health – Historical context and future challenges			<b>Module Code</b> JTbQ-BQ-004	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 5
<b>Module Components</b>					
<i>Number</i>		<i>Name</i>		<i>Type</i>	<i>CP</i>
JTbQ-004		Global Health – Historical context and future challenges		Lecture	5
<b>Module Coordinator</b> A. M. Lisewski		<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track - Big Questions</li> </ul>		<b>Mandatory Status</b> <ul style="list-style-type: none"> <li>Mandatory elective for students of all undergraduate study programs except IEM</li> </ul>	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (35 hours)</li> <li>Private Study (90 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 125 hours	
<b>Recommendations for Preparation</b>					
Critical following of the media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>This module gives a historical, societal, technical, scientific and medical overview over the past and future milestones and challenges of global health. Particular focus is on future global health issues in a world that is interconnected both through mobility and through communication networks. Presented are 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 economy. Focus is given to children, maternal and adolescent health, as these are most critical to the well-being of next generations. The module also provides key concepts in global health, epidemiology and demographics such as the connection between a society's economical level and its population's health status, measures of health status, demographic and epidemiologic transitions, as well as modern issues such as the growing fragmentation (to a personal level) of disease conditions and the resulting emergence of personalized medicine. Finally, attention is also given to publicly less prominent global health issues, such as re-emergent diseases, neglected tropical diseases, and complex humanitarian crises.</p>					

***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 today's global health surveillance and response systems and institutions.
- discuss and evaluate the imminent and future challenges of public hygiene and response to disease outbreaks in a global society network context.

***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.

***Assessment***

Type: Written examination

Duration: 60 min.

Weight: 100%

Scope: All intended learning outcomes of the module

### 7.22.2.5 Global Existential Risks

<b>Module Name</b> Big Questions: Global Existential Risks			<b>Module Code</b> JTbQ-BQ-005	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 2.5
<b>Module Components</b>					
<i>Number</i>	<i>Name</i>			<i>Type</i>	<i>CP</i>
JTbQ-005	Global Existential Risks			Lecture	2.5
<b>Module Coordinator</b>  M. A. Lisewski	<b>Program Affiliation</b>  • Jacobs Track - Big Questions			<b>Mandatory Status</b>  • Mandatory elective for students of all undergraduate study programs except IEM	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lectures (17.5 hours)</li> <li>Private Study (45 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 62.5 hours	
<b>Recommendations for Preparation</b>					
Critical following of media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>The more we develop science and technology, the more we also learn about global catastrophic and, in the worst case, even absolutely existential dangers that put the entire human civilization at risk to total collapse and thus to an abrupt and irrevocable end. These doomsday risks 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 lecture presents the main known varieties of existential risks including, for example, astrophysical, planetary, biological, and technological events and critical transitions that have a capacity to severely damage or even to eradicate Earth-based human civilization as we know it. It further offers a description of their characteristic features, 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, it reviews some hypothetical monitoring and early warning systems as well as analysis methods that could potentially be used in strategies, if not to eliminate, but at least to better understand and ideally to minimize imminent global existential risks. This interdisciplinary lecture will allow students to look across diverse subject fields.</p>					

**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 varieties of global existential risks;
- discuss approaches to minimize the risks;
- formulate coherent written and oral contributions on the topic.

**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.

**Assessment**

Type: Written examination

Duration: 60 min.

Weight: 100%

Scope: All intended learning outcomes of the module

### 7.22.2.6 Future - From Predictions and Visions to Preparations and Actions

<b>Module Name</b> Big Questions: Future: From Predictions and Visions to Preparations and Actions			<b>Module Code</b> JTbQ-BQ-006	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 2.5
<b>Module Components</b>					
<b>Number</b>	<b>Name</b>			<b>Type</b>	<b>CP</b>
JTbQ-006	Future: From Predictions and Visions to Preparations and Actions			Lecture	2.5
<b>Module Coordinator</b> Joachim Vogt	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track - Big Questions</li> </ul>			<b>Mandatory Status</b> <ul style="list-style-type: none"> <li>Mandatory elective for students of all undergraduate study programs except IEM</li> </ul>	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<b>Pre-requisites</b>	<b>Co-requisites</b>	<b>Knowledge, Abilities, or Skills</b>	annually	<ul style="list-style-type: none"> <li>Lecture (17.5 hours)</li> <li>Private Study (45 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 62.5 hours	
<b>Recommendations for Preparation</b>					
Critical following of the media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>This module addresses selected topics related to Future as a general concept in science, technology, culture, literature, ecology, economy, and consists of three parts. The first part (Future Continuous) discusses forecasting methodologies rooted in the idea that the 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 chances and challenges for present and future generations.</p>					

**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
- distinguish and qualify important approaches to forecasting and prediction
- summarize the history of utopias and dystopias, and ideas presented in classical science fiction
- characterize current developments in technology, ecology, society, and their implications for the future

**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.

**Assessment**

Type: Written examination

Duration: 60 min

Weight: 100%

Scope: All intended learning outcomes of the module

### 7.22.2.7 Climate Change

<b>Module Name</b> Big Questions: Climate Change			<b>Module Code</b> JTbQ-BQ-007	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 2.5
<b>Module Components</b>					
<i>Number</i>	<i>Name</i>			<i>Type</i>	<i>CP</i>
JTBQ-007	Climate Change			Lecture	2.5
<b>Module Coordinator</b> L. Thomsen/ V. Unnithan	<b>Program Affiliation</b> <ul style="list-style-type: none"><li>Jacobs Track - Big Questions</li></ul>			<b>Mandatory Status</b> <ul style="list-style-type: none"><li>Mandatory elective for students of all undergraduate study programs except IEM</li></ul>	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>Lecture (17.5 hours)</li> <li>Private Study (45 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 62.5 hours	
<b>Recommendations for Preparation</b>					
Critical following of the media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>This module will give a brief introduction into the development of the atmosphere throughout Earth's history from the beginning of the geological record 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, onset of early life, snowball Earth, and modern glaciation cycles. In the second part, the course will focus on 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 of climate mitigation (geo-engineering) and adaptation of our society to climate change (such as coastal protection and adaption of agricultural practices to more arid and hot conditions) will be discussed.</p>					
<b>Intended Learning Outcomes</b>					
<p>Students acquire transferable and key skills in this module.</p> <p>By the end of this module, the students should be able to</p>					

- 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: impacts of climate change on the natural environment over geological timescales and since the industrial revolution, 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.

***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.

***Assessment***

Type: Written examination

Duration: 60 min.;

Weight: 100%

Scope: All intended learning outcomes of the module

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

<b>Module Name</b> Big Questions: Extreme Natural Hazards, Disaster Risks and Societal Impact		<b>Module Code</b> JTbQ-BQ-008	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 2.5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>		<b>Type</b>	<b>CP</b>
JTbQ-008	Extreme Natural Hazards: Disaster Risks and Societal Impact		Lecture	2.5
<b>Module Coordinator</b> L. Thomsen	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track - Big Questions</li> </ul>		<b>Mandatory Status</b> <ul style="list-style-type: none"> <li>Mandatory elective for students of all undergraduate study programs except IEM</li> </ul>	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>
<b>Pre-requisites</b>	<b>Co-requisites</b>	<b>Knowledge, Abilities, or Skills</b>	annually	<ul style="list-style-type: none"> <li>Lecture (17.5 hours)</li> <li>Private Study (45 hours)</li> </ul>
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 62.5 hours
<b>Recommendations for Preparation</b>				
Critical following of the media coverage on the module's topics in question.				
<b>Content and Educational Aims</b>				
<p>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.</p> <p>Extreme natural events, increasingly dominate our global headlines, and understanding their causes, risks, and impacts, as well as the costs of 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 such as volcanoes, earthquakes, landslides, hurricanes, precipitation floods and space weather, and provides real-world hazard case studies from Latin America, the Caribbean, Africa, the Middle East, Asia and the Pacific region.</p>				
<b>Intended Learning Outcomes</b>				
<p>Students acquire transferable and key skills in this module.</p> <p>By the end of this module, the student should be able to</p>				

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

***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.

***Assessment***

Type: Written examination

Duration: 60 min.

Weight: 100%

Scope: All intended learning outcomes of the module

## 7.22.2.9 International Development Policy

<b>Module Name</b> Big Questions: International Development Policy			<b>Module Code</b> JTbQ-BQ-009	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 2.5
<b>Module Components</b>					
<i>Number</i>		<i>Name</i>		<i>Type</i>	<i>CP</i>
JTbQ-009		International Development Policy		Lecture	2.5
<b>Module Coordinator</b>  C. Knoop		<b>Program Affiliation</b>  • Jacobs Track - Big Questions		<b>Mandatory Status</b>  • Mandatory elective for students of all undergraduate study programs except IEM	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>	annually	<ul style="list-style-type: none"> <li>• Lecture (17.5 hours)</li> <li>• Oral Presentations</li> <li>• Private Study (45 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>• the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>• media literacy, critical thinking and a proficient handling of data sources</li> </ul>	<b>Duration</b> 1 semester	<b>Workload</b> 62.5 hours	
<b>Recommendations for Preparation</b>					
Critical following of the media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>We live in a world where still a large number of people live in absolute poverty and without access to basic needs and services, such as food, sanitation, health care, security and proper education. This module provides an introduction to 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 learn about the tools applied in modern development policies but also about critical aspects of monitoring and evaluating the results of development policy. Module related oral presentations and debates will enhance the students' learning experience.</p>					

**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.

**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.

**Assessment**

Type: Presentation

Duration: 10 minutes per student

Weight: 100%

Scope: All intended learning outcomes of the module

7.22.2.10 Global Challenges to International Peace and Security

<b>Module Name</b> Big Questions: Global Challenges to International Peace and Security			<b>Module Code</b> JTbQ-BQ-010	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 5
<b>Module Components</b>					
<i>Number</i>		<i>Name</i>		<i>Type</i>	<i>CP</i>
JTbQ-010		Global Challenges to International Peace and Security		Lecture	5
<b>Module Coordinator</b> C. Knoop		<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track - Big Questions</li> </ul>		<b>Mandatory Status</b> <ul style="list-style-type: none"> <li>Mandatory elective for students of all undergraduate study programs except IEM</li> </ul>	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	<i>Knowledge, Abilities, or Skills</i>		annually	<ul style="list-style-type: none"> <li>Lecture (35h)</li> <li>Private Study (90h)</li> </ul>
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None	<ul style="list-style-type: none"> <li>the ability and openness to engage in interdisciplinary issues of global relevance</li> <li>media literacy, critical thinking and a proficient handling of data sources</li> </ul>		<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>					
Critical following of the media coverage on the module's topics in question.					
<b>Content and Educational Aims</b>					
<p>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.</p> <p>We live in a multi-polar world where multiple crisis situations have rather become the rule than the exception. World peace and security are challenged by various developments and factors, such as the risk of proliferation of weapons of mass destruction, the spread of international terrorism, organized and cybercrime but also by the man-made and natural effects of climate changes and the growing gap between the few very rich and the many utterly poor people living on our planet. This module provides an introduction to some of the most important threat scenarios for global peace and security. The students will learn about the tools available to deal with these challenges with a focus on the European Union, the African Union and the United Nations. In this context, the concepts of multilateralism and bilateral efforts to achieve world peace and security will also be examined.</p>					

**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 global threats to peace and security;
- identify, explain and evaluate important tools available to international actors in the interest of world peace and security;
- formulate well-justified criticism of these tools and explain their limits;
- summarize and present a module related topic in an appropriate verbal and visual form ;

**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.

**Assessment**

Type: Presentation

Duration: 10 minutes

Weight: 100%

Scope: All intended learning outcomes of the module

7.22.2.11 Sustainable Value Creation with Biotechnology. From Science to Business

<b>Module Name</b> Sustainable Value Creation with Biotechnology. From Science to Business.		<b>Module Code</b> JTBQ-BQ-011	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 2.5
<b>Module Components</b>				
<i>Number</i>	<i>Name</i>	<i>Type</i>		<i>CP</i>
JTBQ-011	Sustainable Value Creation with Biotechnology. From Science to Business	Lecture - Tutorial		2.5
<b>Module Coordinator</b> Marcelo Fernandez Lahore	<b>Program Affiliation</b> <ul style="list-style-type: none"> <li>Jacobs Track - Big Questions</li> </ul>		<b>Mandatory Status</b> <ul style="list-style-type: none"> <li>Mandatory for Chemistry</li> <li>Mandatory elective for students of all undergraduate study except IEM</li> </ul>	
<b>Entry Requirements</b>		<b>Frequency</b>	<b>Forms of Learning and Teaching</b>	
<i>Pre-requisites</i>	<i>Co-requisites</i>	annually	<ul style="list-style-type: none"> <li>Lecture and Tutorial (17.5 hours)</li> <li>Private Study (45 hours)</li> </ul>	
<input checked="" type="checkbox"/> None	<input checked="" type="checkbox"/> None			
<i>Knowledge, Abilities, or Skills</i>		<b>Duration</b>	<b>Workload</b>	
<ul style="list-style-type: none"> <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>		1 semester	62.5 hours	
<b>Recommendations for Preparation</b>				
<a href="https://www.ctsi.ucla.edu/researcher-resources/files/view/docs/EGBS4_Kolchinsky.pdf">https://www.ctsi.ucla.edu/researcher-resources/files/view/docs/EGBS4_Kolchinsky.pdf</a> <a href="https://link.springer.com/article/10.1057/icb.2008.27">https://link.springer.com/article/10.1057/icb.2008.27</a> <a href="https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf">https://sustainabledevelopment.un.org/content/documents/21252030%20Agenda%20for%20Sustainable%20Development%20web.pdf</a>				

### **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 course. 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 course 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

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

### **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.

### **Assessment**

Type: Term Paper

Length:1.500 – 3.000 words

Weight: 75%

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

Type: Presentation

Duration: 10-15 min.

Weight: 25%

Scope: Intended learning outcomes of the module (2-7)

### 7.22.3 Community Impact Project

<b>Module Name</b> Community Impact Project		<b>Module Code</b> JTCl-CI-950	<b>Level (type)</b> Year 3 (Jacobs Track)	<b>CP</b> 5
<b>Module Components</b>				
<b>Number</b>	<b>Name</b>	<b>Type</b>	<b>CP</b>	
JTCl-950	Community Impact Project	Project	5	
<b>Module Coordinator</b> CIP Faculty Coordinator		<b>Program Affiliation</b> • Jacobs Track - Community Impact Project	<b>Mandatory Status</b> Mandatory for all undergraduate study programs except IEM	
<b>Entry Requirements</b>			<b>Frequency</b>	<b>Forms of Learning and Teaching</b>
<b>Pre-requisites</b>  <input checked="" type="checkbox"/> see below	<b>Co-requisites</b>  <input checked="" type="checkbox"/> None	<b>Knowledge, Abilities, or Skills</b>  • Basic knowledge of the main concepts and methodological instruments of the respective disciplines  • xxxxx	annually	<ul style="list-style-type: none"> <li>• Introductory, accompanying and final events: 10 hours</li> <li>• Self-organized teamwork and/or practical work in the community: 115 hours</li> </ul>
			<b>Duration</b> 1 semester	<b>Workload</b> 125 hours
<b>Recommendations for Preparation</b>				
Develop or join a community impact project before the 5 <sup>th</sup> semester based on the introductory events during the 4 <sup>th</sup> semester, using the database of projects, communicating with fellow students and faculty and finding potential companies, organizations or communities to target.				
<b>Content and Educational Aims</b>				
<p>CIPs are self-organized, major related and problem centered applications of the students' acquired knowledge and skills. The 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. They ideally connect the campus community to other communities, companies, organizations in a mutually beneficial way.</p> <p>Students are encouraged to create their own projects and find partners (e.g. companies, schools, NGOs), but will get help by the CIP faculty coordinator team and faculty mentors in doing so. They can join and collaborate in interdisciplinary groups that attack a given issue from different disciplinary perspectives.</p> <p>Student activities are self-organized but can draw on support and guidance by faculty and the CIP faculty coordinator team.</p>				
<b>Intended Learning Outcomes</b>				
<p>The Community Impact Project is designed to convey the required personal and social competencies to enable students to finish their studies at Jacobs as socially conscious and responsible graduates (Jacobs mission) and to convey social and personal competencies to the students, including a practical awareness for the societal context and relevance of their academic discipline:</p> <ul style="list-style-type: none"> <li>• understand real life issues of communities, organizations and industries and relate them to concepts of the own discipline;</li> <li>• enhance problem-solving skills and develop critical faculty, create solutions to problems and communicate them appropriately to their audience;</li> <li>• apply media and communication skills in diverse and non-peer social contexts;</li> <li>• develop awareness for the societal relevance of own scientific action and a sense of social;</li> <li>• responsibility for the social surrounding;</li> <li>• reflect own behaviour critically in relation to social expectations and consequences;</li> </ul>				

- ability to work in a team and deal with diversity, develop cooperation and conflict skills, strengthen empathy and ambiguity tolerance.

***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 generations' projects (4th semester).
- Mandatory for all undergraduate study programs except IEM.
- Study abroad students are allowed to substitute the module with 5 CP of Big Questions modules.

***Assessment***

Type: Project, not numerically graded (pass/fail)

Scope: All intended learning outcomes of the module

#### 7.22.4 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>

## 8 Appendix

### 8.1 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		
					1/2	1	2	2	2	3	3	3+4	3	4	4	4	4	4	3/5	5	6	6	6	6	6	6	1-4	5	5/6	5
Semester					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		
Program Learning Outcomes					Competencies*																									
					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							
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							
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			
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						
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						
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)					
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			
Get acquainted 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			
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
Adhere to and defend ethical, scientific, and professional standards, but also reflect and respect different views.																												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
Appreciate the importance of education, community, and diversity for personal development and a peaceful and sustainable world.									x	x																		x	x	x
<b>Assessment Type</b>																														
oral examination														x				x	x											
final written exam						x	x	x	x	x	x			x	x						x					x				
project essay												x												x				x		
(lab) report						x	x	x	x				x						x	x					(x)					
poster presentation																														
presentation																						x	x	x						
variable																											x		x	
module achievements/bonus achievements																														
*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