JACOBS
UNIVERSITY

School of Engineering and Science

Physics (BSc)

Bachelor's Degree Program

Contents

1 Physics at Jacobs University

1.1 Concept

Physics, the foundation of the natural sciences and many engineering disciplines, forms the basis of our understanding of objects as diverse as elementary particles, molecules, living cells, electronic devices, stars and galaxies. Their behavior and properties are governed by the same universal physical principles. The core physics curriculum, comprising a broad range of fundamental topics, focuses on these general principles. From the very beginning, lectures covering both theory and experiment are accompanied by lab courses. More detailed knowledge relevant for a guided research project in the third year is acquired in specialization courses. Throughout their education, students have close contact to faculty. The scientific understanding, problem solving strategies, and technical skills gained during the physics program open up many career opportunities in academia, research, management, and society.

The accredited physics program at Jacobs University is a three year Bachelor of Science degree (B.Sc.) program following the official guidelines established, e.g., by the Eurobachelor (180 ECTS credits total). The first year offers a broad natural science eduction with lectures accompanied by lab courses. The three *General Physics* courses and the corresponding lab courses provide an introduction to physics. These courses are neither the traditional experimental physics courses nor pure theoretical physics course. Both aspects are combined. In the first year, special emphasis is laid on general principles, not on mathematical derivations. Nevertheless, it is realized that physics requires a solid mathematical foundation. In cooperation with Mathematics at Jacobs University a series of Engineering and Science Mathematics courses has been developed that provides the necessary mathematical background in close coordination with the physics lectures. The introductory physics course is taken together with introductory courses in at least one other subject. Before the second year, students should then decide which will be their major or, in exceptional cases, their majors. The second year and third year are devoted to the professional education in the chosen major. While still multidisciplinary, the second year deepens the knowledge in various fields of physics through advanced lectures and labs. The third year allows students a certain degree of specialization and fosters independent work and research skills. A main focus of the third year is *guided research* on experimental and/or theoretical problems culminating in the B.Sc. thesis. With two semesters of guided research and the equivalent of three regular courses, students spend considerably more time on research than in most physics BSc programs at other universities. With its special focus on research and its ideal student to faculty ratio, Jacobs University gives especially skilled undergraduate students the unique opportunity to participate in real research work already during their undergraduate education.

The physics curriculum follows a *shell model*, which is unique to Jacobs University: As indicated by the name, the subject material in the major is presented in integrated shells of increasing depth. The main contrast to other approaches is the sequence in which the teaching material is presented. The first year focuses on multidisciplinarity within the School of Engineering and Science. The students have the opportunity to study at least two subjects in courses that provide an comprehensive treatment of the whole subject at an introductory level. Specialized lectures are postponed to the second and third year. This eases the transition from high school to university and helps to accommodate the different levels of preparation of our diverse student body, with students come from over one hundred different nations with just as diverse academic backgrounds. The physics curriculum like the curricula of the other majors in the School of Engineering and Science guarantees a broad education, going far beyond a sequence of courses in a single subject. In addition all students attend courses in the School of Humanities and Social Sciences and University Study Courses (USC), which are unique to Jacobs University. USCs' are taught by two professors, one from each School, and students from both Schools apply their respective specialist knowledge to issues of common interest.

The key characteristics of the physics program at Jacobs University as compared to programs at other universities both within and outside Germany are the internationality of the student body and the faculty, the fact that all courses are taught in English, multidisciplinarity – there are no formal boundaries between departments, close contact of students to faculty facilitated by the excellent faculty-student ratio, and the integrated internship program after the second year. Jacobs University is the first private university in Germany to offer a physics program. The quality of the program is continuously evaluated by students and an international Advisory Board. Faculty members are pursuing active research programs, the high fraction of third party funded research assures that the scientific focus remains up-to-date. A further characteristic of the programs offered at Jacobs University is the pervasive use of information technology for educational purposes, which includes the use of computers for teaching, the exchange of course material via course homepages and internet access throughout the campus. Funding is available for students to participate in research, field trips, to visit conferences and to take part in international events and competitions. In the past, teams of physics students from Jacobs University have participated very successfully in international physics and mathematics competitions.

1.2 Career Options

The three year B.Sc. program in physics at Jacobs University gives a solid but flexible foundation that supports careers in diverse fields, from basic research over engineering, life sciences, to finance and management. In addition it forms the basis for graduate studies. We have an excellent track record in placing our students into top graduate programs at renowned universities worldwide and also offer several suitable graduate programs on campus. The multidisciplinary eduction offered at Jacobs University further extends the career opportunities. The problem solving and technical skills gained during the physics program are in demand in various fields of industry, academia and society. The scientific understanding gained in physics prepares our students to become leaders in an increasingly technology driven world.

Physicists are the all-rounders among the natural scientists. More than two thirds of physicists work on advancing our scientific knowledge or develop new technologies, products, and processes. Most positions are offered from research centers, scientific institutes, and universities. In industry, physicists work in the fields like IT & software development, electronics, laser & optics, and semiconductors. An increasing demand for physicists comes also from medical technology[1,2,3]. Another large fraction of physicists holds faculty positions at universities and colleges or works as teachers in secondary schools or high schools. The broad training of ana-

[1]German Physical Society (DPG): http://www.dpg-physik.de/service/studium.html

[2]US Department of Labor: http://bls.gov/oco/ocos052.htm

[3]American Physical Society: http://www.aps.org/careers/

lytical skills, technical thinking and appreciation of complexity and subtlety allows physicists to work, especially with additional qualification, as management consultants, patent attorneys, market analysts, or risk managers. About 30% of physics BSc degree recipients go on to graduate school in physics and about 20% go to graduate schools in other fields. Most of the rest usually enters engineering related areas[4]. For careers in research and development a doctoral degree is usually required[2]. Very helpful for career development is the opportunity for international network building with Jacobs University students coming from more than one hundred nations. Good communication skills are also important, since many physicists work as part of a team, have for example contact to clients with non-physics background, and write research papers and proposals. These skills are particularly well developed in the broad and multidisciplinary undergraduate program at Jacobs University.

The physics curriculum at Jacobs University is designed to ensure that students are well prepared for graduate programs in physics, other natural sciences and engineering at leading universities in Europe and North America. Our physics program especially follows the recommendations of the German Physical Society (DPG) for a BSc curriculum and includes all topics required for the GRE Physics test. Students that wish to continue their studies at Jacobs University can also do so: Graduate students will find interesting research opportunities at Jacobs University in a truly multidisciplinary environment and can continue their studies leading to Master and PhD degrees. Since this year, Jacobs University offers a graduate program in physics within our Physical Sciences Graduate Program. Interested physics students who experienced Jacobs physics research in their undergraduate education and who like to continue in a specific field offered by our faculty, can make use of several "fast track" options leading to an MSc or a PhD in Physics.[5] Additional graduate programs that involve physics faculty and are also of interest for physics students are offered at Jacobs University in Mathematical Sciences, Molecular Life Science, and Computer Science.

For more details see `http://ses.jacobs-university.de/ses/physics`.

[4] American Physical Society: www.aps.org/educ; see also: Institute of Physics (UK): careers.iop.org

[5] For more information see: `http://ses.jacobs-university.de/ses/physical-sciences`.

2 Modules: Physics

All BSc programs at Jacobs University are structured in terms of modules. A module is a combination of courses (lectures, lab units or other types of courses) that are related by common learning goals. Here we describe the content of the modules and characterize the skills and abilities that the student is expected to acquire. Irrespective of the modular structure, the learning progress is documented with credit points and grades attributed to individual courses and lab units. This facilitates the control of the study progress on a semester basis, while the modules may extend over a year or, in exceptional cases, even over longer periods.

Credits are defined in terms of the European Credit Transfer System (ECTS). A regular course with two times 75 minutes of class time per week for 14 weeks plus homework assignments, projects, tutorials and exams is assigned 5 ECTS credit points.

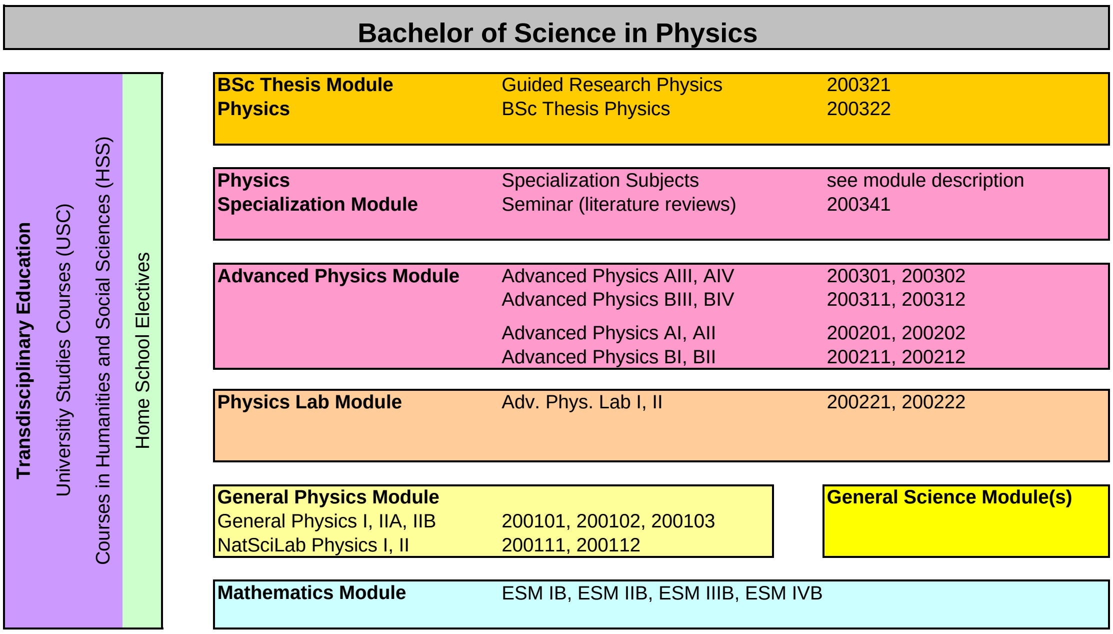

Figure 1: Physics Module Structure

In the following the individual modules are being defined with respect to learning goals and competencies that are to be acquired. The course numbers refer to the individual courses and the descriptions of their content in section 5 of the handbook.

2.1 General Science

Home School Electives and transdisciplinary courses are not listed in this overview.

120150 – Engineering and Science Mathematics

Short Name: ESM B-series (physics)
Semester: 1 – 4
Credit Points: 20 ECTS

General Information Students of physics are required to take two first year and two second year Engineering and Science Mathematics course. The recommended sequence is *ESM 1B – Multivariable Calculus and Ordinary Differential Equations*, *ESM 2B – Linear Algebra, Probability, Fourier Analysis*, *ESM 3B – Complex Variables, Partial Differential Equations*, and *ESM 4B– Orthogonal Functions, Transforms, Groups*. While the ESM A-series is a possible alternative, taking *ESM 1B – Multivariable Calculus and Ordinary Differential Equations* in the first year is strongly recommended; second year courses in Physics will assume a working knowledge in this area.

Learning goals
- Working skills in all areas of Mathematics that are needed in Physics
- Problem solving skills
- Training in abstract reasoning and symbolic manipulation
- Ability to turn real-world (physics) problems into concise mathematical questions
- Ability to interpret mathematical statements when applied to real-world problems

Courses
120111 ESM 1B – Multivariable Calculus, ODEs
120112 ESM 2B – Linear Algebra, Probability, Fourier Analysis
120211 ESM 3B – Complex Variable Calculus and PDEs
120212 ESM 4B – Orthogonal Functions, Transforms, Groups

XX0100 – General Science Module

Short Name: ModGenSES
Semester: 1 – 2
Credit Points: 15 ECTS

General Information The first year general science modules consist of general lectures and associated lab units in at least one other subject of the many possible choices offered at Jacobs University including, e.g., BCCB, Chemistry, Earth and Space Sciences, Mathematics, ...

Learning goals
- An introduction to other sciences offered within the School of Engineering and Science (SES)
- Broadened education, transdisciplinary skills

Courses

One or more general engineering and science lectures (5 ECTS credits)

One or more Natural Science Lab Units associated with the above lectures (2.5 ECTS credits)

2.2 Physics Major

This section describes the duration, number of credits, and learning goals of the modules and lists the courses. Course descriptions can be found in section 5.

Semester	Physics Major Core Courses		
1 - Fall 01	**General Physics I** *Mechanics, Thermodynamics*		**NatSciLab Physics I** (1/3 semester)
2 - Spring 01	**General Physics IIA** *Electromagnetism, Optics*	**General Physics IIB** *Modern Physics*	**NatSciLab Physics II** (1/3 semester)
Summer break			
3 - Fall 02	**Adv Physics A I** *Analytical Mechanics*	**Adv Physcis B I** *Electrodynamics, Relativity*	**AdvPhysLab I**
4 - Spring 02	**Adv Physics A II** *Quantum Mechanics*	**Adv Physics B II** *Thermodynamics, Statistical Physics*	**AdvPhysLab II**
Summer break	***Internship***		
5 - Fall 03	**Adv Physics A III** *Applied Quantum and Statistical Physics*	**Adv Physics B III** *Condensed Matter and Solid State Physics*	**Guided Research Physics** *in research group*
6 - Spring 03	**Adv Physics A IV** *Elementary Particles and Fields*	**Adv Physics B IV** *Semiconductor Devices, Advanced Optics*	**Guided Research and BSc Thesis** *in research group*

Figure 2: Mandatory physics courses

200100 – General Physics Module

Short Name: ModPhysGen
Semester: 1 – 2
Credit Points: 20 ECTS

General Information This module comprises the three courses of the General Physics lecture series and two Physics Natural Science Lab courses.

Learning goals

- In the lecture, an overview of classical and modern physics is taught. Students learn the basic laws and concepts governing physics, its historical development and its relation and influence to other fields such as biology or engineering. Experimental and theoretical aspects are combined in the lectures.
- Students learn to describe nature and its physical phenomena by a mathematical formalism. In parallel, their problem solving skills get trained by homeworks.

- The module serves for non-physics majors as basis for their further studies (in particular earth&space-physics and electrical engineering majors) and helps physics majors to define a common ground and to recognize gaps in their knowledge for further in-depth studies in following semesters.
- In the lab courses, students learn the basic experimental methods and scientific data analysis (including error analysis). They get trained on basic software for data analysis and presentation.
- Students learn to prepare and organize their work, to work concentrated and thoroughly in a team on a common task.
- Their communication skills, capability of expression, their ability to focus and identify important aspects of a problem are trained in oral quizzes and reports of the lab courses.

Courses
200101 General Physics I – Mechanics, Thermodynamics
200102 General Physics IIA – Electromagnetism, Optics
200103 General Physics IIB – Modern Physics
200111 Natural Science Lab Unit Physics I
200112 Natural Science Lab Unit Physics II

200200 – Physics Laboratory Module

Short Name: ModPhysLab
Semester: 3 – 4
Credit Points: 15 ECTS

General Information In this module, students gain practical knowledge about advanced classical and modern methods of physics experiments.

Learning goals

- Topics of this course are part of or related to the accompanying lectures of module 200300. Thus, the chosen experiments of the course serve to transfer theoretical knowledge to practical applications.
- Students apply and deepen their knowledge in experimental methods gained during the first year lab courses. They are expected to optimize set-ups and evaluation methods on their own.
- The focus is on a critical analysis of data and results. Students are taught to detect inconsistencies, to find solutions for experimental problems and to distinguish between significant and non-relevant influences.
- Students usually work in teams of two, with the benefit that they learn to organize teamwork in an efficient way.
- Skills of oral and written presentation are extensively trained in quizzes and reports. Students learn to summarize complex background information, give clear presentations of data and present their results in a form similar to a scientific publication.

Courses
200221 Advanced Physics Lab I
200222 Advanced Physics Lab II

200200 – ADVANCED PHYSICS MODULE

Short Name: ModPhysAdv
Semester: 3 – 6
Credit Points: 40 ECTS

General Information This module comprises the Advanced Physics lectures (2nd and 3rd year). The lectures provide the core physics education over a period of 4 semesters.

Learning goals

- This module provides the core physics education for students majoring in physics. Concepts and theories of classical and modern physics are treated in depth and students gain expert knowledge in physics.
- Students are trained to describe nature and physical phenomena by mathematical formalism. In parallel, their problem solving skills are strengthened by homework and in class discussions. Important aspect is here also the critical reviewing of own results and reasoning.
- Students learn to approach given problems by scientific methods. They apply the knowledge that they have acquired to new unknown problems and improve their analytical skills.
- Students learn to organize their work, to work focused and thoroughly.

Courses
200201 Advanced Physics A I – Analytical Mechanics
200202 Advanced Physics A II – Quantum Mechanics
200211 Advanced Physics B I – Electrodynamics
200212 Advanced Physics B II – Thermodynamics, Statistical Physics
200301 Advanced Physics A III – Applied Quantum and Statistical Physics
200302 Advanced Physics A IV – Elementary Particles and Fields
200311 Advanced Physics B III – Condensed Matter and Solid State Physics
200312 Advanced Physics B IV – Semiconductor Devices, Advanced Optics

200300 – PHYSICS SPECIALIZATION MODULE

Short Name: ModPhysSpec
Semester: 5 – 6
Credit Points: 15 ECTS

General Information This module contains major-specific specialization lectures and a literature review seminar on special topics.

Learning goals

- In the major specific lectures, students obtain specific knowledge about various directions that are suited for specialization in later research. Special fields go often along with special methods, to which the students are introduced.
- Some of the courses cover interdisciplinary fields of research. Here the students learn to take different viewpoints on one and the same subject, depending on the discipline that is involved.
- Students apply their fundamental knowledge from the core physics courses and adapt the generic methods to the special ones.
- Most specialization subject courses involve short projects and student presentations in addition to regular lectures.
- Topics of the literature review seminar are taken from seminal papers of the past as well as from current research. The students have to give an oral presentation and write a term paper. They learn to communicate the results to an audience with less background knowledge, presenting them in a pedagogical way, and improve their oral and written presentation skills.

Courses List of recent Physics Specialization Subject Courses and alternatives. Note that not all the courses listed here are offered every year. While the dedicated physics specialization subject courses are recommended, students are encouraged to consider also suitable courses of other majors and graduate level courses.[6] Some examples are included in the following list. Other courses are also possible but require prior consultation and approval of a physics program coordinator (see graduation requirements in section 3). Generally, not all specialization courses should be chosen from a single field and the consent of the instructor is required in cases of missing prerequisites and for graduate level courses.

200331 Computational Physics
200341 Physics Seminar I (literature reviews)
200342 Physics Seminar II (literature reviews)
200352 Principles and Applications of Optical Spectroscopy
200381 Statistical Physics of Networks
200391 Cosmology
200421 Strings, Branes and Matrices
200432 Advanced Solid State Physics

[6] Note that courses can only count for a single degree (BSc/MSc). This applies in particular to graduate level courses, which may be chosen as undergraduate specialization subject courses.

201231 Renewable Energy [7]
201302 Applications of Statistical Physics
201312 Electronic Structure of Condensed Matter
201321 Biophysics
201322 Topics in Mathematical Physics
201332 Advanced Quantum Physics
201342 Statistical Quantum Mechanics
201362 Computational Materials Science
201472 General Relativity
100311 Foundations of Mathematical Physics
100361 Ordinary Differential Equations and Dynamical Systems
100362 Introductory Partial Differential Equations
110361 Mathematical Modeling in Biomedical Applications
210331 Physics of Planetary Interiors and Surface Processes
210312 Seismic and Electromagnetic Methods in Geophysics
210322 Gravity in Geophysics and Planetary Sciences
210332 Magnetism in Geophysics and Planetary Sciences
210392 Earth and Planetary Physics
420433 Introduction to Quantum Chemistry and Electronic Structure
420471 Transport Physics and Electronic Devices
420501 Theory of Spectroscopic Simulations
420551 Computational Solid State and Surface Physics

200320 – Guided Research and BSc Thesis Physics Module

Short Name: ModGRPhys
Semester: 5 – 6
Credit Points: 15 ECTS

General Information The Thesis Module comprises two full semester-length courses in which students work independently, but under supervision, on assigned research problems. This is considerably more than is found in typical other physics BSc programs and is in concordance with Jacobs Universities focus on research. Learning goals of this module build on those of all other modules. Students need to mobilize everything they have learned so far in order to master the tasks in the Thesis Module.

- Students learn how to clearly define the issues behind a general research problem. This includes the identification and definition of key goals to be achieved.
- Students learn how to mobilize all of their relevant knowledge (foundations of physics and other natural sciences, specialized knowledge in a range of disciplines, methodological knowledge) and to apply it to the problem at hand.
- Students learn how to plan and manage a scientific project (including efficient organization and time management, definition of milestones, controlling).
- Students learn how to work self-motivated as member of a larger team which follows a common goal.

[7] There is also a project-based companion course 201241 Advanced Renewable Energy. Only one of the two renewable energy courses will count toward the physics specialization subject graduation requirement.

- Students train target-oriented work. Resources can be relevant literature, which may be incomplete, scattered and/or fragmented, and which can be searched and accessed through electronic databases, abstract services etc. Opening up relevant resources can also mean looking for suitable cooperation partners.
- Students learn how to work on problems which cross traditional subject boundaries.
- In writing their bachelor thesis, students train scientific writing to the point that they can author a complete scientific publication conforming to internationally accepted standards. A seminar in which students present their findings further develops students' oral presentation skills.

Courses
200321 Guided Research Physics
200322 Guided Research and BSc Thesis Physics

3 Requirements for a B.Sc. in Physics

3.1 General Requirements

To obtain a B.Sc. degree at Jacobs University a minimum of 180 ECTS credit points must be earned over a period of 6 semesters.

- 140 ECTS credits must be earned in the School of Engineering and Science.
- 30 ECTS credits must be earned through transdisciplinary courses, comprised of courses in the School of Humanities and Social Sciences (**HSS**) and University Study Courses (**USC**). Students can choose how many USCs or SHSS courses they take.
- 10 ECTS credits (4 courses) are accredited either for language courses or additional Home School electives. Students can decide whether they take language courses or not.

3.2 Mandatory Courses for the Major

Requirements of the Major

Students choose 140 ECTS credits out of the following courses:

- **Year 1 level courses**:
  - Two courses from the Engineering and Science Mathematics (ESM) series (typically 120111, 120112, 10 ECTS credits),
  - General Physics I/IIA/IIB (200101, 200102, 200103, 15 ECTS credits),
  - Natural Science Lab Units (NatSciLabs) Physics I/II (200111, 200112, 5 ECTS credits),
  - Programming Lab course (see Remarks, 2.5 ECTS credits),
  - Additional ESc General Lecture and associated Natural Science Lab Unit (7.5 ECTS credits).

  Remarks and exceptions:
  - The recommended ESM courses are ESM IB and ESM IIB.
  - In exceptional cases suitable mathematics courses may be substituted for the ESM course graduation requirement. Prior consultation and approval of a physics program coordinator and the consent of the instructor(s) is required.
  - The programming lab course can be taken in Fall or Spring of the first or second year of study. Recommended courses are 320111, 110111, or 110112; other suitable programming courses (e.g. 350111) are possible.
  - The additional ESC General Lecture can be chosen from any first year general lecture series (e.g. General Biology, General Chemistry, General Earth and Space Sciences, General Mathematics).

- **Year 2 level courses**:
  - Advanced Physics A I/II (200201, 200202, 10 ECTS credits),
  - Advanced Physics B I/II (200211, 200212, 10 ECTS credits),
  - Advanced Physics I/II Lab Courses (200221, 200222, 15 ECTS credits).
  - Two second year courses from the ESM series (typically 120211, 120212, 10 ECTS credits).

Remarks:
- The recommended ESM courses are ESM IIIB and ESM IVB.

- **Year 3 level courses**:
  - Advanced Physics A III/IV (200301, 200302, 10 ECTS credits),
  - Advanced Physics B III/IV (200311, 200312, 10 ECTS credits),
  - A choice of courses with a total of 20 ECTS credit points from: Physics specialization subject courses (see *Remarks*) and Physics Seminar (literature reviews) (200341, 2.5 ECTS credits),
  - Guided Research Physics (200321, 7.5 ECTS credits),
  - Guided Research and BSc Thesis Physics (200322, 7.5 ECTS credits).

  Remarks:
  - The two guided research courses require prior consultation with physics faculty.
  - Physics specialization subject courses: It is recommended to choose from the dedicated courses offered by the physics faculty. The course descriptions can be found in section 5.4 of the handbook. General lectures and labs cannot be used as specialization subjects. A list of possible specialization subject courses can be found in the module description on page 9, some require the consent of the instructor(s). Any course not listed there requires prior consultation and approval of a physics program coordinator.
    At least one of the specialization subject courses must involve student presentations as a major component (please consult the course instructor). The recommended Seminar (literature reviews) 200341 does satisfy this requirement.

- **Additional courses**
  - Home School Electives, 10 ECTS credits in total.

  Remarks:
  - Home school electives are any ESc courses or language courses.

4 Recommended Course Plan

Year 1 Courses	**Fall**	**C**	**T**	**Spring**	**C**	**T**
General Physics I/IIA	200101	*5*	m	200102	*5*	m
ESc General Lecture I / General Physics IIB		*5*	m	200103	*5*	m
Natural Science Lab Units - Physics I/II	200111	*2.5*	m	200112	*2.5*	m
Natural Science Lab I / Programming Lab		*2.5*	m		*2.5*	m
ESc Mathematics I B, II B [1]	120111	*5*	m	120112	*5*	m
Language Courses or Home School Electives [2]		*5*	e		*5*	e
Transdisciplinary Courses		*5*	u		*5*	u
Running Total / *Semester Total*	30	*30*		60	*30*	

Year 2 Courses	**Fall**	**C**	**T**	**Spring**	**C**	**T**
Advanced Physics A I/II	200201	*5*	m	200202	*5*	m
Advanced Physics B I/II	200211	*5*	m	200212	*5*	m
Advanced Physics Lab Course I/II	200221	*7.5*	m	200222	*7.5*	m
ESc Mathematics III B, IV B	120211	*5*	m	120212	*5*	m
Transdisciplinary Courses		*5*	u		*5*	u
Running Total / *Semester Total*	87.5	*27.5*		115	*27.5*	

Year 3 Courses	**Fall**	**C**	**T**	**Spring**	**C**	**T**
Advanced Physics A III/IV	200301	*5*	m	200302	*5*	m
Advanced Physics B III/IV	200311	*5*	m	200312	*5*	m
Physics Specialization Subjects [3]		*10*	me		*10*	me
Guided Research Physics [4]	200321	*7.5*	m			
Guided Research and BSc Thesis Physics [4]				200322	*7.5*	m
Transdisciplinary Courses		*5*	u		*5*	u
Running Total / *Semester Total*	147.5	*32.5*		180	*32.5*	

C = ECTS credit points, T=type (m=mandatory, e=elective, u=university, me=mandatory elective), Transdisciplinary Courses are School of Humanities and Social Sciences and University Studies Courses

Notes:

1. It is recommended that all students taking General Physics I/II also take ESM IB (120111), ESM IIB (120122). Students who's mathematics background form high school is not adequate to start with multi variable calculus (ESM IB), can consider also the ESM A track starting with single variable calculus.
2. Recommended are either a second General Lecture (5 ECTS credits) or two Language courses (2.5 ECTS credits each).
3. Choice of specialization subject courses with a total of 20 ECTS credit points. At least one of the courses must involve student presentations as a major component. This is in particular the case for the recommended course 200341 Physics Seminar (literature reviews). Please see the graduation requirements in section 3.2 for further details and

rules.

4. Guided Research (7.5 credits) is one part of two courses leading to the BSc thesis. This course and the course Guided Research and BSc Thesis (7.5 credits) can be either taken subsequently in the 5th and 6th semester or concurrently in the 6th semester. The latter possibility is in particular of interest for experimental projects.
   Guided Research and BSc Thesis (7.5 credits) comprises work in an experimental research lab or in a theory group at Jacobs University on topics of current interest. A written thesis (20 pages suggested) and an oral presentation of the results are required. Students should contact faculty regarding a research topic. The final assignment of topics will be done at the beginning of the 5th semester.

4.1 Recommendation Professional Skills

The SES highly recommends attending the Professional Skills seminars offered by the Career Services Center. Those seminars include soft skills development seminars and application training which will help you to cope with your studies and master your internship and job search.

All undergraduate students are required to complete an internship, normally to be accomplished between the second and third year of study. Information about the internship will be listed on the transcript. The internship must last at least two consecutive months. No credits are connected to the internship requirement. For more information on internships see http://www.jacobs-university.de/career-services/internship .

5 Content of Physics courses

5.1 First Year of Study

200101 – General Physics I (Mechanics, Thermodynamics)

Short Name: GenPhys I
Type: Lecture
Semester: 1
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: Yes

Course contents This course is an introduction to physics and its basic principles, covering classical mechanics and thermodynamics. It is a mandatory course for physics majors but can also serve as a general introduction to physics for all other majors. It is neither the traditional experimental physics lecture, nor a pure theoretical physics course. Both aspects are combined and special emphasis is laid on general principles, not on extensive mathematical derivations. Nevertheless, the course teaches calculus based physics so that some basic mathematical knowledge will be required. Experiments are integrated into the lectures.
The course consists of the following two parts:

- Mechanics, including: motion and coordinate systems; forces and Newton laws; work and energy; collisions and momentum; rotations, torque, angular momentum; gravitation and Kepler laws; continuum mechanics and elasticity; fluid mechanics; harmonic oscillator, damping, resonance; waves.
- Thermodynamics, including: temperature, heat, heat capacity; transport phenomena; ideal gas, kinetic gas theory, MB distribution; Brownian motion, diffusion; 1st law, energy, heat and work; 2nd law, cyclic processes, engines; entropy and statistical interpretation; thermodynamic potentials.

200111 – Natural Science Lab Unit Physics I

Short Name: NatSciLab Phys I
Type: Lab
Semester: 1
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: 200101
Tutorial: No

Course contents The Natural Science Laboratory Course Unit in Physics forms an integral part of first-year physics education at Jacobs University. The physics unit occupies 8 of the 24 afternoon sessions of the first year Natural Science Laboratory Course. For students planning to major in the School of Engineering and Science, participation in the Natural Science Lab Course is mandatory (lectures and lab course units have to correspond). For all other students wishing to enroll in the physics lab unit, attendance of the General Physics lecture is co-requisite, since the lab course is taught in coordination with the lecture. In the physics unit, participants carry out 7 experiments in total covering topics of mechanics and thermodynamics. Aims of the lab course are: (1) to gain hands on experience of the material taught in General Physics, (2) to learn how scientific experiments are planned, carried out, analysed, and reported, (3) to learn about technical aspects of measuring and measuring devices.

200102 – General Physics IIA (Electromagnetism, Optics)

Short Name:	GenPhys IIA
Type:	Lecture
Semester:	2
Credit Points:	5 ECTS
Prerequisites:	200101
Corequisites:	None
Tutorial:	Yes

Course contents This course is a continuation of General Physics I (200101). It is mandatory for physics majors but also interesting for e.g. life science or electrical engineering majors. It is an introduction to physics, covering electromagnetism and optics. It is neither the traditional experimental physics lecture, nor a pure theoretical physics course. Both aspects are combined, special emphasis is laid on general principles, not on mathematical derivations. Nevertheless, the course teaches calculus based physics so that some basic mathematical knowledge will be required. Experiments are integrated into the lectures.
The course consists of the following two parts:

- Electromagnetism: electric charge, field and potential; capacitance and dielectrics; resistance and current; magnetic force and field; magnetization and induction; AC/DC circuits; Maxwell equations and electromagnetic waves.
- Optics: waves and acoustics; refractive index, reflection, dispersion, polarization, scattering; lenses, geometrical optics, optical instruments; interference, interferometers, diffraction, resolving power.

200103 – General Physics IIB (Modern Physics)

Short Name:	GenPhys IIB
Type:	Lecture
Semester:	2
Credit Points:	5 ECTS
Prerequisites:	200101
Corequisites:	None
Tutorial:	Yes

Course contents This course is a continuation of General Physics I (200101). It is mandatory for physics majors but also interesting for other majors. It is an introduction to physics, covering all aspects of modern physics such as quantum physics, atomic and nuclear physics, particle physics and relativity. It is neither the traditional experimental physics lecture, nor a pure theoretical physics course. Both aspects are combined, special emphasis is laid on general

principles, not on mathematical derivations. Nevertheless, the course teaches calculus based physics and some basic mathematical knowledge will be required. Experiments are integrated into the lectures.
The course introduces the following topics:

- Special relativity: Lorentz transformation, relativistic momentum and rest mass, principle of relativity, mass-energy-equivalence
- Quantum Physics: particle-like nature of electromagnetic radiation (photons, blackbody radiation, photoelectric effect, Compton effect), wave-like properties of particles (de Broglie hypothesis, electron interference and diffraction, Heisenberg uncertainty principle, wave packets), Schrödinger equation with applications
- Atomic Physics: Hydrogen atom (atomic wave functions, angular momentum, intrinsic spin, energy levels, spectroscopic notation, Zeeman effect, fine structure), many electron atoms (Pauli exclusion principle, electronic structure, periodic table, properties of elements, X-rays, optical spectra, lasers)
- Molecules and condensed matter: molecular bonds, crystals, semiconductors
- Nuclear Physics: nuclear physics and nuclear energy (types of radiation and radioactivity, structure of nucleus, radioactive decay, biological impact, fission, chain reaction, nuclear reactor, nuclear fuel cycle)
- Particle Physics: elementary particles and the standard model (elementary particles, quarks, leptons and forces), accelerators and detectors
- Gravitation and Cosmology: general relativity and cosmology (gravity, space-time, equivalence principle, Einstein equations, experimental confirmation of general relativity)

200112 – Natural Science Lab Unit Physics II

Short Name:	NatSciLab Phys II
Type:	Lab
Semester:	2
Credit Points:	2.5 ECTS
Prerequisites:	200111
Corequisites:	200102 or 200103
Tutorial:	No

Course contents The Natural Science Laboratory Course Module in Physics forms an integral part of first-year physics education at Jacobs University. The physics unit occupies 8 of the 24 afternoon sessions of the first year Natural Science Laboratory Course. For students planning to major in the School of Engineering and Science, participation in the Natural Science Lab Course is mandatory (lectures and lab course units have to correspond). For all other students wishing to enroll in the physics lab unit, attendance of the General Physics lecture is a co-requisite, since the lab course is taught in coordination with the lecture. In the physics unit, participants carry out 8 experiments in total covering topics in electromagnetism, optics and quantum physics. Aims of the lab course are: (1) to gain hands on experience of the material taught in General Physics, (2) to learn how scientific experiments are planned, carried out, analyzed, and reported, (3) to learn about technical aspects of measuring and measuring devices.

5.2 Second Year of Study

200201 – Advanced Physics A I (Analytical Mechanics)

Short Name: AdvPhys A I
Type: Lecture
Semester: 3
Credit Points: 5 ECTS
Prerequisites: None (200101 recommended)
Corequisites: None
Tutorial: Yes

Course contents The Advanced Physics courses build on the General Physics courses and deepen the knowledge of particular fundamental topics in physics.
Classical mechanics provides the foundation for many fields of modern physics; it is indispensable for physics in general. Topics of the course include single particle dynamics, energy and potential, planetary orbits, systems of particles, statics, rigid body dynamics, analytical mechanics (variational principle, Lagrange's and Hamilton's equations), small oscillations, an introduction to relativistic mechanics, and a selection of more advanced topics. Mathematical concepts that we will encounter include vector calculus, ordinary and partial differential equations, linear algebra (vectors, tensors, eigenvalue problems) and elementary group theory.

200211 – Advanced Physics B I (Electrodynamics, Relativity)

Short Name: AdvPhys B I
Type: Lecture
Semester: 3
Credit Points: 5 ECTS
Prerequisites: 200102
Corequisites: None
Tutorial: Yes

Course contents The Advanced Physics courses build on the General Physics courses and deepen the knowledge of particular fundamental topics in physics.
The course provides an introduction to the classical theory of one of the four fundamental forces in nature: the electromagnetic force. Well understood and very apparent in everyday life, the electromagnetic field is described by the Maxwell equations. We will discuss these equations in detail, use it to describe diverse phenomena and show that Special Relativity is one of the fundamental ingredients to describe the electromagnetic field. Topics include: electromagnetic fields in free space, metals, dielectrics, wave guides, Laplace and Poisson equation, the response of solid state material to electromagnetic fields, electromagnetic radiation, dipole radiation, Green's function, multipoles. The relativistic formulation of electrodynamics includes an introduction to special relativity covering: Einstein's postulates, time dilation, length contraction, simultaneity, Lorentz transformation, relativistic effects and paradoxes.

200221 – Advanced Physics Lab I

Short Name:	AdvPhys Lab I
Type:	Lab
Semester:	3
Credit Points:	5 ECTS
Prerequisites:	200112
Corequisites:	200201, 200211
Tutorial:	No

Course contents This second-year laboratory course occupies in total two afternoons each week. The course accompanies the physics lectures and therefore, a close relationship between laboratory and lectures exists during the whole semester.
Participants carry out twelve experiments chosen from mechanics and non-linear dynamics, continuum mechanics, electromagnetism and optics. The experiments are more advanced than those offered in the first-year Natural Science Laboratory Course Module in Physics. Skills learned there can now be applied to gain a deeper insight into different aspects of advanced physics, partly already pointing to modern applications.

120211 – ESc Mathematics III B (Complex Variables, PDEs)

Short Name:	ESM III B
Type:	Lecture
Semester:	3
Credit Points:	5 ECTS
Prerequisites:	120112
Corequisites:	None
Tutorial:	No

Course contents The course provides advanced mathematical methods for students of physics, computational science, geo/astro, and electrical engineering. Topics include functions of a complex variable and partial differential equations. The topics have applications to electrodynamics, hydrodynamics, quantum mechanics and provide the basis for more specialized topics.

200202 – Advanced Physics A II (Quantum Mechanics)

Short Name:	AdvPhys A II
Type:	Lecture
Semester:	4
Credit Points:	5 ECTS
Prerequisites:	200201
Corequisites:	None
Tutorial:	Yes

Course contents The Advanced Physics courses build on the General Physics courses and deepen the knowledge of particular fundamental topics in physics. Advanced Physics A II deals with an intensive introduction to quantum mechanics. The following topics are covered: Foundation and postulates of quantum mechanics, Schrdinger Equation; one-dimensional problems (harmonic oscillator; potential steps, barrier, and wells); uncertainty relation; angular momentum; central potential (hydrogen atom); operators, matrices, states (Dirac notation, representations); spin and addition of angular momentum; stationary approximation methods (time-independent perturbation theory, variational principle).

200212 – Advanced Physics B II (Thermodynamics, Statistical Physics)

Short Name:	AdvPhys B II
Type:	Lecture
Semester:	4
Credit Points:	5 ECTS
Prerequisites:	200201
Corequisites:	None
Tutorial:	Yes

Course contents The Advanced Physics courses build on the General Physics courses and deepen the knowledge of particular fundamental topics in physics. Advanced Physics B II deals with an intensive introduction to thermodynamics and statistical physics.
The course starts with concepts already encountered in the General Physics lectures, such as thermodynamic equilibrium, temperature, entropy, specific heat and other response functions, the laws of thermodynamics, equation of state and heat engines. The statistical physics part of the course extends these notions towards their microscopic definitions. The approach from statistical physics then includes the micro-canonical, canonical and grand-canonical ensembles, the derivation of macroscopic observables from microscopic input, illustrated with classical gases, semiclassical models and other physical applications.

200222 – Advanced Physics Lab II

Short Name:	AdvPhys Lab II
Type:	Lab
Semester:	4
Credit Points:	7.5 ECTS
Prerequisites:	200221
Corequisites:	200202, 200212
Tutorial:	No

Course contents This second-year laboratory course accompanies the physics lectures (Advanced Physics A II and Advanced Physics B II) and therefore, a close relationship between laboratory and lecture exists during the semester. The tasks are more advanced than those offered in the first-year Natural Science Laboratory Course Module in Physics. Skills learned there now can be applied to gain a deeper insight into different aspects of advanced physics. The experiments performed in this course cover the topics Thermodynamics and Statistical Physics, Condensed Matter Physics, Quantum Mechanics and Atoms and Molecules. Twelve experiments of different topics are offered during the laboratory course and each experiment is carried out during two afternoons in one week.

120212 – ESc Mathematics IV B (Orthogonal Functions, Transforms, Groups)

Short Name:	ESM IV B
Type:	Lecture
Semester:	4
Credit Points:	5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents This course is primarily addressing students of physics. Topics covered are function spaces and orthogonal polynomials, special functions of physics and Fourier transforms, and group theory. The topics have applications to electrodynamics, quantum mechanics, particle physics, solid state physics and provide the basis for more specialized topics.

5.3 Third Year of Study

200301 – Advanced Physics A III (Applied Quantum and Statistical Physics)

Short Name:	AdvPhys A III
Type:	Lecture
Semester:	5
Credit Points:	5 ECTS
Prerequisites:	200202
Corequisites:	None
Tutorial:	Yes

Course contents This course is a continuation of the quantum mechanics as taught in Advanced Physics A II. It deals with an in depth introduction to applications of quantum and statistical physics. Topics include Fermi and Bose quantum gases, time dependent perturbation theory, quantization of the light field and light matter interactions including laser theory, phase transitions and critical phenomena, Bose-Einstein condensates and superfluidity.

200311 – Advanced Physics B III (Condensed Matter and Solid State Physics)

Short Name:	AdvPhys B III
Type:	Lecture
Semester:	5
Credit Points:	5 ECTS
Prerequisites:	200202 (200212 recommended)
Corequisites:	None
Tutorial:	Yes

Course contents This course deals with an in depth introduction to condensed matter and solid state physics. Topics include forms of condensed matter, crystal types and crystal structure, density-functional theory, the models by Drude and Sommerfeld, Bose/Fermi distribution, Fermi sphere, cohesive energy, classical and quantum harmonic crystal, phonons and quasi-particles; the structure and dynamics of solids, band theory and electronic properties, optical properties, magnetism, superconductivity.

200321 – Guided Research Physics

Short Name: GR Physics
Type: Lab
Semester: 5
Credit Points: 7.5 ECTS
Prerequisites: 200222
Corequisites: None
Tutorial: No

Course contents This course is an introduction to research and methods in physics and in preparation for the BSc thesis and future scientific work. It comprises either an experimental or a theoretical project. Each student will work individually under the guidance of a physics faculty member. Depending on the actual project the course can be taken either in the 5th semester or in the 6th semester. The latter possibility is in particular relevant for experimental projects where the course is typically taken in parallel to the Guided Research and BSc Thesis Physics course. To organize and select a suitable research project students need to contact faculty at latest at the beginning of the 5th semester.

200302 – Advanced Physics A IV (Particles and Fields)

Short Name: AdvPhys A IV
Type: Lecture
Semester: 6
Credit Points: 5 ECTS
Prerequisites: 200211, 200202 (200201, 200301 recommended)
Corequisites: None
Tutorial: Yes

Course contents This is the final course in the Advanced Physics A-series. It provides an introductory overview about theoretical and experimental aspects of elementary particle physics, quantum field theory and nuclear physics. The Standard Model of particle physics is introduced and experimental and phenomenological aspects of particle physics are discussed. Theoretical topics include gauge theories of the fundamental forces of nature, an introduction to quantum field theory and Feynman diagrams.

200312 – Advanced Physics B IV (Semiconductor Devices, Advanced Optics)

Short Name:	AdvPhys B IV
Type:	Lecture
Semester:	6
Credit Points:	5 ECTS
Prerequisites:	200311, (200301 recommended)
Corequisites:	None
Tutorial:	Yes

Course contents This is the final course in the Advanced Physics B-series. Topics include semiconductors and devices like transistors, LED's, and solar cells for semiconductor devices. The optics part deepens and extends the optics taught in the General Physics courses. Important issues from modern optics (e.g. dielectric coatings, nonlinear optics, time- domain properties) as well as advanced theoretical descriptions (e.g. Jones vectors, ray matrices) will be introduced.

200322 – Guided Research and BSc Thesis Physics

Short Name:	BScThePhys
Type:	Research
Semester:	6
Credit Points:	7.5 ECTS
Prerequisites:	200321
Corequisites:	200321
Tutorial:	No

Course contents This course comprises scientific work in a physics lab or in a theoretical physics group at Jacobs University on topics of current research. It continues the research work of the Guided Research Physics course and will further develop the research skills of students under the guidance of a Jacobs physics faculty member. Students have to write a BSc thesis (20 pages suggested) as a concluding scientific report of their guided research work at Jacobs. The thesis has to be submitted before the final exam period and its title will appear in the student transcript. A short presentation on the guided research work in the framework of a BSc Thesis Physics Colloquium is also required.

5.4 Specialization subject courses

In the following we provide the course content of recent physics specialization subject courses. Note that not all these courses are offered each semester. Please see also page 9 for a list including also alternative courses. The courses of type 2004xx and 2014xx are graduate level but can also be chosen as specialization subjects for the BSc.[8]

[8]See also: `http://ses.jacobs-university.de/ses/physical-sciences`.

200331 – Computational Physics

Short Name:	CompPhys
Type:	Lecture
Semester:	6
Credit Points:	5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents Computational physics discusses a number of practical, numerical solutions for typical problems in physics. While the very nature of physics is to express relationships between physical quantities in mathematical terms, an analytic solution of the resulting formulas is often not available. Instead, numerical solutions based on computer programs are required to obtain useful results for real-life physics problems. The first part introduces basic numerical techniques such as for integration, interpolation, root finding, function optimization, and solving differential equations which are important tools in any numerical approach not only in physics. In the second half of the course, modern applications like molecular dynamics and Monte-Carlo techniques are discussed, including analysis of data resulting from such approaches.
Since the course includes numerous examples and exercises for programming codes, some programming skills in Fortran or C are strongly recommended as prerequisites.

200341/200342 – Physics Seminar I/II (literature reviews)

Short Name:	PhysSem I/II
Type:	Seminar
Semester:	5/6
Credit Points:	2.5 ECTS each
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents Student seminars on topics of current interest in physics and also on seminal past work. This course involves preparing and giving lectures under the guidance of physics faculty. The goal of the course is to introduce the students to original scientific work (as opposed to textbooks) and to develop presentation skills.

200352 – Principles and Applications of Optical Spectroscopy

Short Name:	OptSpec
Type:	Lecture
Semester:	6
Credit Points:	5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents Advances of Laser Spectroscopy, Fundamentals of Absorption and Emission of Light, Widths and Profiles of Spectral Lines, Fundamentals of Lasers, Doppler-Limited Laser Spectroscopy, High-Resolution Doppler-Free Laser Spectroscopy, Femtosecond Time-Resolved Spectroscopy.

200381 – Statistical Physics of Networks

Short Name:	StatPhysNet
Type:	Lecture
Semester:	5/6
Credit Points:	2.5 ECTS
Prerequisites:	200212
Corequisites:	None
Tutorial:	No

Course contents We introduce into the so-called science of networks, a topical interdisciplinary field of research, which was initiated by physicists. Networks may be natural data sets like genetic, proteomic, metabolic, cellular or neural systems, or artificial nets such as the internet, the world-wide web, trade or traffic relations. We shall review common aspects and questions for which physics is predestinated to address them. We shall first point on static characteristic features that are used to classify these systems. We then focus on growth algorithms for graphs, some of them are able to reproduce the experimentally observed topological structure of networks. In particular we discuss mechanisms to generate the famous scale-free degree distributions that determine the probability for finding a certain number of edges attached to a given node. More generally, we discuss origins for power-law behavior in contrast to exponential decay as typical universal laws found in very different areas of science. Finally we give examples for out-of-equilibrium processes running on top of the topological structure and capturing gross features of the observed stationary dynamics.

200391 – Cosmology

Short Name:	Cosmology
Type:	Lecture
Semester:	5/6
Credit Points:	5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents While particle physics deals with physics on the smallest scales, cosmology is mainly concerned with physics on the largest scales. To understand the structure we see in the universe today, it is vital to have knowledge about the early universe. Due to the extreme conditions in the early universe, especially the high energies, which (up to now) cannot be simulated in terrestrial accelerators, it is a very good testing ground for theories beyond the standard model such as Grand Unified Theories (GUTs) or even String Theory. In this sense, the early universe is the main ground to understand the interplay between cosmology and astrophysics on the one hand and particle physics on the other hand. In this lecture, we will start with a brief overview of what is known about the universe today. Topics include the cosmic microwave background, the large-scale structure of the universe as well as the abundance of different elements. In what follows, we will illustrate how these observations can be explained in the so-called ”Hot Big Bang” model of the universe. Topics here are nucleosynthesis, baryogenesis as well as phase transitions and the inflationary epoch.

200421 – Strings, Branes, and Matrices

Short Name: StringBranMat
Type: Lecture
Semester: 6
Credit Points: 5 ECTS
Prerequisites: Consult instructor
Corequisites: None
Tutorial: No

Course contents This course offers an overview and guideline to understand modern problems of solid state physics including Superconductivity, Bose-Einstein condensation, Ferromagnetism, Spintronics, (Fractional) Quantum Hall Effects, Kondo Effect, Strongly Correlated Systems, and Quantum Phase Transitions, and Topological Insulators

200432 – Advanced Solid State Physics

Short Name: StringBranMat
Type: Lecture
Semester: 5
Credit Points: 5 ECTS
Prerequisites: Consult instructor
Corequisites: None
Tutorial: No

Course contents A contemporary introduction to selected topics of high-energy physics with focus on string theory: background on path integrals, quantum field theory, and super symmetry; choice of advanced topics from M-theory, matrix theory, and non-commutative geometry.

201231 – Renewable Energy

Short Name: RenewEnergy
Type: Lecture
Semester: 2 - 4
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: No

Course contents 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 course gives an overview of the potential and limitations of energy resources. we start with an overview of energy scenarios based on current energy needs and available energy resources. After an introduction to the basic physics of solar energy we cover 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. We also give an introduction to the basic physics of other energy resources, in particular nuclear energy.

201241 – Advanced Renewable Energy

Short Name:	AdvRenewEnergy
Type:	Lab/Lecture, Seminar
Semester:	6
Credit Points:	5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents "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 aim of the course is to give an overview of renewable energy related research at Jacobs university, as presented by the professors, and to work on a specific project the students choose, during the semester. The result will be presented by the students in the last two weeks of the course, This course is an advanced course building on the course 201231 Renewable Energy and can be attended in parallel.

201302 – Applications of Statistical Physics

Short Name:	Statistical Physics
Type:	Lecture
Semester:	6
Credit Points:	2.5 ECTS
Prerequisites:	200212
Corequisites:	None
Tutorial:	No

Course contents The first part of the course provides a smooth continuation of the second-year course on Advanced Physics BII, introducing to the widely spread phenomenon of classical phase transitions, along with critical phenomena and the concept of the renormalization group. In the second part we study modern, interdisciplinary applications of statistical physics. The tools from physics will provide solutions to various kind of optimization problems, predict spreading phenomena like epidemics, or traffic jams in generic transport processes. They further allow to determine conditions for the onset of synchronization that is a ubiquitous collective phenomenon in technical, biological and medical applications.

201312 – Electronic Structure of Condensed Matter

Short Name: Electronic Structure
Type: Lecture
Semester: 6
Credit Points: 2.5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: No

Course contents This course is about the theory of the electronic structure of condensed-matter systems, like molecules, crystals, surfaces, or polymers. The first part will deal with the quantum mechanics of many-electron systems, including electron-electron interaction, exchange effects, and correlation. To this end, appropriate techniques (second quantization, Green functions, response functions, ...) will be introduced. The second part discusses the resulting properties of real systems (chemical bonds, electronic and optical spectra, etc.) and computational techniques to calculate them (density-functional theory, quantum chemistry, ab-initio many-body perturbation techniques, dynamical mean-field techniques, etc.).
Prerequisites: basic knowledge of single-particle quantum mechanics and quantum statistics. Furthermore, some computer experience will be useful for several practical exercises.

201321 – Biophysics

Short Name: Biophys
Type: Lecture
Semester: 5/6
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: No

Course contents The course gives an introduction and overview of the interdisciplinary field of molecular biophysics for 3rd year Physics majors. It can serve as a physics specialization subject but also as an introduction for graduate students to biophysics. Prerequisites are all General Physics Lectures but also advanced electromagnetism and thermodynamics as taught in the 2nd year physics courses. Topics covered in this course include: basic biomolecular systems from a physics perspective, molecular forces and interactions, aqueous solutions, thermodynamics and kinetics of molecular interactions, major instrumentation to separate and investigate biomolecules such as electrophoresis, microscopy and spectroscopy, NMR, X-ray, and biosensors. Special emphasis is laid on physical properties of lipid membranes, ion channels, and modern applications of biophysics in medical physics and nanotechnology. The course will be a mixture of presenting ideas and experimental concepts in biophysics and of a mathematical description of biological systems.

201322 – Topics in Mathematical Physics

Short Name: MathPhys
Type: Lecture
Semester: 5/6
Credit Points: 5 ECTS
Prerequisites: None
Corequisites: None
Tutorial: No

Course contents Selected topics in classical and modern mathematical physics, e.g.:
Tools and tricks of mathematical physics with an introduction to groundbreaking mathematically rigorous works in various fields of physics. ranging from solid state theory, over statistical mechanics to elementary particles.

201332 – Advanced Quantum Physics

Short Name: AdvQuantPhys
Type: Lecture
Semester: 6
Credit Points: 2.5 ECTS
Prerequisites: 200201, 200202, 200211
Corequisites: none
Tutorial: no

Course contents The course introduces methods which are applicable over a wide range of areas from particle physics and condensed matter to statistical physics. Starting from classical field theories (including gauge theories) we employ path integrals to compute Feynman graphs of perturbation theory. Further subjects include renormalization, anomalies, thermal field theory and non-perturbative effects such as solitons. We may furthermore cover coherent states and representations of the Poincare group.

201342 – Statistical Quantum Mechanics

Short Name: StatQuantMech
Type: Lecture
Semester: 6
Credit Points: 2.5 ECTS
Prerequisites: 200202, 200212, 200311
Corequisites: none
Tutorial: no

Course contents The course is an extension of the statistical physics part of the Experimental & Theoretical Physics course which focuses mainly on classical statistical physics. The subjects of this course include density operators, many-particle wave functions, the grand canonical description of the ideal quantum gas, etc. Applied are these general techniques to the ideal Fermi gas and to free bosons including the Bose-Einstein condensation and the photon gas.

Furthermore it will be shown how the concepts of quantum statistical mechanics can be used to describe dissipation in a quantum system.

200472 – General Relativity

Short Name:	GenRel
Type:	Lecture
Semester:	5/6
Credit Points:	5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents General Relativity describes Gravitation in terms of the curvature of space-time. While in Special Relativity, space-time is rigid, it becomes dynamical in General Relativity and interacts with matter/energy. The interaction between matter and space-time is governed by the famous Einstein equations. The first part of the course is concerned with the mathematical and geometrical aspects of General Relativity, while the second part will contain consequences of the theory such as black holes and cosmological models.

5.5 Other Courses

In addition to the courses offered in Physics there are many courses of direct interest to physics students that are offered by the other majors, in particular in Earth and Space Sciences, Mathematics, Electronics, Chemistry, or Biophysics. For the course descriptions we refer to the handbooks of the respective majors. Graduate level courses may also be of interest for some physics students and if taken "on top" of the BSc graduation requirements, they can later be used for the fast track option of the graduate program.[9]

200232 – Reductionism in Physics and its Relation to Philosophy

Short Name:	PhilPhys Reduct
Type:	Lecture
Semester:	4 or 6
Credit Points:	2.5 ECTS
Prerequisites:	None
Corequisites:	None
Tutorial:	No

Course contents (This course counts for the transdisciplinary course requirements.) The aim of the course is to discuss both the success and the limitations of methodological reductionism in physics. The assessment of the explanatory power of reductionism is a controversial issue, even between two Nobel prize winners from Physics, Steven Weinberg and Phil Anderson. We shall first illustrate reductionism's success in different areas of physics: relativity theory, gauge theories of the standard model, self-organized processes like pattern formation in cosmology,

[9] For more information see: `http://ses.jacobs-university.de/ses/physical-sciences`.

the renormalization group approach in condensed matter theory, and more generally in topics of multi-scale modeling. The success becomes possible due to a few guiding principles, the exploitation of symmetries, but also due to large-scale computer simulations. Therefore one may be tempted to jump to conclusions and postulate the existence of a "world formula" or a "theory of everything", such postulates are found in the literature until recently. Pointing out the limitations of reductionism in the second part of the course, it will become clear why such postulates are not meaningful. Limitations show up when the goal is to predict not only a single aspect, but the whole variety of emergent phenomena on a higher level of description when starting from a more fundamental one. We shall also review the very formulation of physical laws in stochastic and deterministic versions, the increasing complexity in the description that one has to face if the goal is to capture distinct aspects at the same time. Along with a comparison of stochastic and deterministic formulations, an important topic in the theory of evolution will be discussed. It is related to the role of contingency and necessity in time evolutions, in particular in the evolution of the universe. Here well-known representatives of opposing viewpoints are the paleontologists and biologists S. J. Gould and S. C. Morris. The reviews on topics from physics will be supplemented by a few presentations from the philosophical side. From illustrations of the successful application of reductionism in different branches of physics, undergraduate students are expected to receive first reviews on achievements rather than a detailed understanding. A deeper understanding can be gained upon specialization on the graduate level. On the other hand, pointing out the limitations of reductionism opens the view for the need to include other disciplines than physics to approach complex systems in all their facets.