**Study regulations for the Master's Programme in Physics in the Department of Physics at the Freie Universität Berlin**

## Preamble

On the basis of Section 14 paragraph 1 no. 2 of the Partial University Constitution (Trial version) of the Freie Universität Berlin of 27 October 1998 (FU Mitteilungen [Gazette of the Freie Universität Berlin] 24/1998), the Department Council of the Department of Physics of the Freie Universität Berlin issued the following study regulations for the Master's programme in Physics in the Department of Physics at the Freie Universität Berlin on 30 January 2013[1]:

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## Annexes



[1] The executive board of the Freie Universität Berlin confirmed these regulations on 26 August 2013.

## Section 1
## Area of application

(1) These regulations apply to the aims, content and structure of the Master's programme in Physics in the Department of Physics at the Freie Universität Berlin (Master's programme) on the basis of the examination regulations for the Master's programme of 30 January 2013.

(2) This is a consecutive Master's programme in accordance with Section 23 paragraph 3 No. 1 a) of the law regulating higher education institutions in Berlin (Berlin Higher Education Act – BerlHG) in the amended version of 26 July 2011 (Law and Ordinance Gazette (GVBI) p. 378).

## Section 2
## Qualification aims

(1) Graduates of the Master's programme have profound specialist knowledge and are proficient in scientific methods in Physics and related subject areas, depending on the students' choices. Graduates have specialised knowledge in fields of modern experimental and theoretical physics and thorough skills in physics methodology. They are familiar with the current state of research in one of the core modern research areas of the physics department and are capable of penetrating deeper into issues in physics in independent scientific work, to order this knowledge and present it in lectures or texts. In particular, as generalists in science they are able to work successfully on issues in a wide range of fields of science and technology.

(2) Graduates of the programme have basic skills in scientific research, in reading and writing scientific texts in the English language and in lecture and presentation techniques. They have a modern approach to gender and diversity issues and have gained skills in teamwork, communication and the ability to apply their knowledge in other contexts. In addition they have basic knowledge in the fields of project management and project planning in research. They can apply these skills in independent work, present their planning in writing, giving reasons for it and defending it in the face of critical questions. The graduates are capable of scientific thinking, critical judgement, responsible action, communication and cooperation. In some cases the graduates may also have skills in related scientific, interdisciplinary, cross-disciplinary or complementary professional preparation disciplines. Participants on the German-French Double Master's programmes with the École Polytechnique also have intercultural language and management skills.

(3) The professional field for graduates of the Master's programme is wide-ranging, extending from fundamental or industrial research to application-related development and technical marketing, planning, examination and management tasks in industry or administration. Successful completion of the Master's programme qualifies the graduate to embark on doctoral studies in compliance with the relevant admissions requirements, in particular in scientific or technological fields.

## Section 3
## Programme content

(1) The Master's programme equips the students with a deepened and expanded specialist knowledge of physics and knowledge of related disciplines, depending on the students' choices. The Master's programme focuses on advanced concepts, current methodology and topics and methods of current research. The study programme enables the students to carry out independent work in a special field of physics, in particular the scientific areas focused on by the physics department such as nanophysics, surface physics, biophysics, ultrafast physics or the physics of complex quantum systems, as well as the rules of good scientific practice and the opening up of innovative issues e.g. in research laboratories or theoretical working groups.

(2) Gender and diversity aspects are taken into account in an appropriate way in the Master's programme, wherever this seems sensible from a scientific and/or didactic or educational point

of view in relation to the topic, in particular in the history of physics. In addition, regular events with relevant content are provided. Further soft skills beyond the purely scientific in the sense of Section 2 paragraph 2 are gained principally through independent work on current issues and guided research work.

## Section 4
## Structure and organisation

(1) The Master's programme consists of an advanced phase and a research phase, comprising a total of 120 credit points (CP) of which 30 CP are allocated to the Master's thesis with its accompanying seminar.

(2) The advanced phase is structured into a compulsory area comprising 15 CP, a compulsory elective area comprising 20 CP and an elective area comprising 25 CP as follows:

1. Compulsory area: in the compulsory area comprising 15 CP the following modules must be taken:
   - Module: Advanced Laboratory Course for Master Students (10 CP) and
   - Module: Selected Topics in Physics (5 CP).

2. Compulsory elective area: in the compulsory elective area comprising 20 CP, two modules comprising 10 CP each must be taken.

a. At least one of the following modules from the field of theoretical physics must be selected:
- Module: Advanced Quantum Mechanics (10 CP),
- Module: Statistical Physics and Thermodynamics (10 CP),
- Module: Advanced Statistical Physics (10 CP) or/and
- Module: Quantum Field Theory and Many-Body Physics (10 CP).

b. If the student has not selected two modules from the field of theoretical physics, one of the following modules from the field of experimental physics must be selected:
- Module: Advanced Solid State Physics (10 CP),
- Module: Advanced Atomic and Molecular Physics (10 CP) or
- Module: Advanced Biophysics (10 CP).

3. Elective area: in the elective area comprising 25 CP, modules totalling 25 CP altogether must be selected and taken.

a. The following modules from central research fields of the Physics department may be taken:
- Module: Theoretical Solid State Physics (10 CP),
- Module: Advanced Theoretical Biophysics (8 CP),
- Module: Nanophysics (5 CP),
- Module: Ultrafast Spectroscopy and Nonlinear Optics (5 CP),
- Module: Spectroscopy with Synchrotron Radiation (8 CP),
- Module: Photobiophysics and Photosynthesis (5 CP),
- Module: Semiconductor Physics (5 CP),
- Module: General Relativity (5 CP) or/and
- Module: History of Physics (5 CP).

b. In addition the following supplementary modules are also offered:
- Module: Advanced Topics in Theoretical Condensed Matter Physics (5 CP),
- Module: Special Topics in Magnetism (5 CP),
- Module: Special Topics in Molecular Physics (5 CP),
- Module: Special Topics in Molecular Biophysics (5 CP),
- Module: Advanced Astronomy and Astrophysics (12 CP),
- Module: Modern Methods in Theoretical Physics A (5 CP),
- Module: Modern Methods in Theoretical Physics B (8 CP),
- Module: Modern Methods in Theoretical Physics C (10 CP),

- Module: Modern Methods in Experimental Physics A (5 CP),
- Module: Modern Methods in Experimental Physics B (8 CP) or/and
- Module: Modern Methods in Experimental Physics C (10 CP).

The modules in the elective area are offered in an irregular sequence. At least seven of the modules listed under a) and b) in the elective area will be held in each academic year. Additional modules from the compulsory elective area may also be taken in the elective area; supplementary modules from non-physics subjects which are related to the major subject may also be taken on application to the examination committee, giving reasons. The application must include an explanation of how the module relates to the overall qualification aim. The relevant examination committee takes the decision on the application.

Modules which are identical to or very similar in content to a module which has already been taken and recognised as part of a degree in a previous study programme may not be selected for the Master's programme.

(3) In the research phase, the students first take the parallel modules "Scientific Specialization" (15 CP) and "Methodology and Project Planning" (15 CP). Immediately afterwards, the Master's thesis with accompanying seminar will be taken. Students will be admitted to the research phase on application when they have:

1. successfully taken the module "Advanced Laboratory Course for Master Students" (10 CP) in accordance with paragraph 2 no. 1 and a module of theoretical physics from the compulsory elective area comprising 10 CP in accordance with paragraph 2 no. 2 and further modules of the Master's programme in accordance with paragraph 2 comprising at least 25 CP

2. submitted their application for admission to the Master's thesis.

If the examination committee approves, the research phase may also be taken externally in a suitable company or scientific institution, on condition that scientific supervision by a lecturer who is an authorised examiner for the Master's programme is guaranteed.

(4) The language of instruction in the Master's programme is English. Written reports, records, examinations and the Master's thesis may be presented in German if the relevant lecturer agrees. If none of the participating students objects, individual events may be held in German.

(5) The module descriptions of each module in Annex 1 give information about content, qualification aims, teaching and learning units, time required, forms of active participation, usual duration and how often the module is offered.

(6) The sample study schedule in Annex 2 gives information about the recommended study plan.

## Section 5
## Double Master's programme with the École Polytechnique

(1) Qualified students on the Master's programme have the opportunity of taking a Double Master's programme from the start of a winter semester, which the Physics department at the Freie Universität Berlin offers in collaboration with the École Polytechnique in Palaiseau, France (École Polytechnique). A joint admissions committee decides on the admission of candidates to the Double Master's programme. The Freie Universität Berlin and the École Polytechnique each nominate two members to the joint admissions committee. The members nominated by the Freie Universität Berlin must be authorised examiners for the Master's programme in Physics. The application deadline is 30 April of each year. Application for the Double Master's programme usually takes place after the first study semester. Applicants may submit a preliminary request for participation in the Double Master's programme alongside their application to the Master's programme. The selection committee also decides on such preliminary requests. It may declare provisional acceptance on condition of admission to the

Master's programme and the attainments to be achieved in the first semester. The examination committee will announce the acceptance criteria in good time and in an appropriate form.

(2) The Double Master's programme comprises an advanced phase at the Freie Universität Berlin and a research phase at the École Polytechnique; it comprises a total of 120 CP of which 30 CP are allocated to the Master's thesis and the accompanying seminar.

(3) In the advanced phase, students complete all modules of the compulsory area in accordance with section 4 paragraph 2 no. 1. In the compulsory elective area in accordance with section 4 paragraph 2 no. 2, the module "Statistical Physics and Thermodynamics" (10 CP) must be selected and completed if the student has not already completed this module or an equivalent module in his/her Bachelor programme; apart from this, section 4 paragraph 2 no. 2 applies to the selection and completion of modules in the compulsory elective area. The modules of the elective area are to be selected and completed in accordance with section 4 paragraph 2 no. 3.

(4) In the research phase the students complete an M2 programme at the École Polytechnique including a Master's thesis with accompanying seminar, whereby a continuous research phase of at least 12 months is to be completed. The M2 programme "Nanoscience" is recommended. Compulsory modules and modules of this programme comprising 30 CP are taken in this M2 programme. Instead of the M2 programme "Nanoscience", other M2 programmes in the field of physics offered by the École Polytechnique may be selected.

## Section 6
## Teaching and learning units

The following types of teaching units are provided in the Master's programme:

1. Lectures give either an overview of a larger area of the subject and its methodological/theoretical principles or knowledge of a specialised subject area and related research issues. The principle teaching unit is the lecture by the relevant lecturers.

2. Practice seminars are intended to convey application-oriented knowledge of a defined subject area and enable the students to gain practical skills, to work on a task independently, present the results and to discuss them critically. The principle work form is the solving of practice tasks. The lecturer guides and monitors the activities.

3. Practicals are intended to enable students to work independently on issues and possible solutions on selected objects with appropriate methods and to learn practical and analytical skills. Under guidance, the students gain experience in applying the scientific knowledge of the subject and the methodology which they have learnt and can test their suitability for particular professional fields. The teaching units which may be part of a practical give the opportunity to examine the teaching content of the practical, to clear up any confusion and to reflect on practical experience.

4. Seminars are intended to give knowledge of a defined subject area and to develop the ability to work independently on an issue, to present the findings and to discuss them critically. The principle work forms are seminar discussions on the basis of teaching materials, preparatory reading (specialist literature and sources), work assignments and group work.

5. Project work is intended to enable each student to gain active practical skills, taking into account their individual strengths and weaknesses. The students work independently on an internal or external project over a fixed period. The principle teaching unit is supervision of the project planning and implementation.

## Section 7
## Academic advisory centre and departmental advisory service

(1) General student advisory services are provided by the central academic advisory centre and

the psychological counselling service of the Freie Universität Berlin.

(2) In addition, the departmental advisory service comprising all full-time lecturers in the Physics department of the Freie Universität Berlin supports all students throughout the programme with subject-specific individual advice, in particular about how to structure and carry out their studies and the examinations, about scientific work and opportunities for specialisation and the planning for participating in the Double Master's programme.

(3) In addition a student's departmental advisory service is provided in all semesters (throughout the entire programme duration).

## Section 8
## Study abroad

(1) Students are recommended to take a period of study abroad. In the course of their studies abroad, students should take courses and examinations (attainments) which can be credited as equivalent to the modules which they would have taken during the same period at the Freie Universität Berlin.

(2) Before starting to study abroad, the student should reach an agreement with the chair of the examination board responsible for the programme and the relevant position at the university to be visited, covering the duration of the study period abroad, the attainments to be completed during the study period abroad which must be equivalent to the attainments in the Master's programme and the credit points allocated to the attainments. Attainments which comply with the agreement will be credited.

(3) The second semester is recommended as a suitable time for a period of study abroad.

(4) Within the scope of the Master's programme students also have the opportunity to apply for a Double Master's programme in collaboration with the École Polytechnique in accordance with section 5 paragraph 1. The structure and organisation of the Double Master's programme are laid down in section 5 paragraphs 2 to 4 in conjunction with section 4 paragraphs 2 to 6.

## Section 9

## Coming into effect and interim regulations

(1) These regulations come into effect on the day after their publication in the Mitteilung (Gazette of the Freie Universität Berlin).

(2) At the same time the study regulations for the Master's programme in Physics from 31 March and 4 May 2009 (FU Mitteilungen [Gazette of the Freie Universität Berlin] No. 36/2009 p 536) expire.

(3) These regulations apply to students who enrol for the Master's programme at the Freie Universität Berlin after these regulations come into effect. Students who enrolled for the Master's programme at the Freie Universität Berlin before these regulations came into effect continue their studies on the basis of the study regulations in accordance with paragraph 2, unless they apply to the responsible examination committee to continue their studies on the basis of these regulations. On the occasion of their re-registration following their application, the examination committee decides to what extent the modules completed or started at the time of the application will be taken into account or how they are to be credited as attainments in accordance with the attainments to be credited according to these regulations, whereby the requirements of protection of confidence and non-discrimination will be observed. The decision cannot be revised.

(4) It will be possible to gain a degree on the basis of the study regulations in accordance with paragraph 2 up to the end of the winter semester 2015/16.

**Annex 1: Module descriptions**

Explanations:

The following module descriptions specify the following for every module in the Master's programme in physics:

- Module name
- Module content and qualification aims
- Module teaching and learning units
- Students' study time estimated as necessary to complete the module successfully
- Forms of active participation
-The usual duration of the module
-How often the module is offered
- The applicability of the module

Statements on students' study time required take into account the following in particular:

- Active participation in the compulsory attendance phase
- Students' study time required to complete small tasks in the compulsory attendance phase
- Time for independent preparation and follow-up
- Working on study units in online study phases
- Preparation time for examinations
- the examinations.

The notional times given for independent study (including preparation, follow-up and preparation for examinations) are intended as guidance to help the students in managing the time required for the module.

The statements on study hours correspond to the number of credit points allocated to the module as a unit of measurement for the student's approximate study hours required to complete the module successfully.

Active participation, regular attendance at the teaching and learning units and successful completion of the examinations in a module are all prerequisites for gaining the credit points allocated to each module. For modules without an examination, the prerequisites for gaining the credit points allocated to the module are active participation and regular attendance at the teaching and learning units.

The number of credit points and other examination-related information on each module can be found in Annex 1 of the examination regulations for the Master's programme.

## 1. Compulsory Modules

| **Module:** Advanced Laboratory Course for Master Students | | | | |
|---|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims:** The students have mastered more complex issues in physics. They are familiar with and can apply the more advanced experimental methods used in current physics research to solve these issues. They are able to master a new field of work in a short time from current specialist literature and to communicate it comprehensibly in presentations. | | | | |
| **Content:** Study of literature as introduction to a new field; close study of physics issues, modern experimental methods and measurement technologies; documentation of experimental process; critical evaluation and discussion of findings; written presentation of issues, evaluation and findings; presentation and explanation of experimental methods, their possibilities and limitations. Topic fields: solid state physics (magnetism, surface physics, superconductivity), atomic and molecular physics, nuclear physics, biophysics. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Practical | 6 | Carrying out and documenting practical experiments | Attendance at practical<br>Practical preparation and follow-up | 90<br>150 |
| Seminar | 2 | Lecture of approx. 20 mins, participation in discussion | Attendance at seminar, seminar preparation and follow-up | 30<br>30 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Yes | | |
| **Study time, total hours** | | 300 hours | | 10 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every semester | | |
| **Application** | | Master's programme in Physics | | |

| **Module:** Selected Topics in Physics | | | | |
|---|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims:** The students have a deeper knowledge of a topic in physics and are able to prepare it for a scientific presentation and convey their knowledge to others through a scientific lecture and chairing a scientific discussion. They are able to adapt a scientific presentation to suit the audience's level of knowledge. They are able to reflect on the literature and to answer critical questions in detail on the basis of their reading. | | | | |
| **Content:** Guided by their lecturers, the students work on, present and discuss topics from a variety of fields relating to current issues and methods of modern physics on the basis of specialist literature. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Seminar | 2 | Lecture of approx. 30 mins, participation in discussion | Attendance at seminar, seminar preparation and follow-up | 30<br>120 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Yes | | |
| **Study time, total hours** | | 150 hours | | 5 CP |

| | |
|---|---|
| **Duration of module** | One semester |
| **Module offered** | Every semester |
| **Application** | Master's programme in Physics |

## 2. Compulsory elective

*2.1. Modules from the field of Theoretical Physics*

| **Module**: Advanced Quantum Mechanics | | | | |
|---|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The students deepen their knowledge of quantum mechanics. They understand the concepts and methods of advanced quantum mechanics and can describe these verbally and in mathematical terms and apply them confidently to fundamental issues in physics. | | | | |
| **Content**: Advanced concepts of quantum mechanics are explored in depth in the module. The content includes a selection from the following topics: many-particle systems, second quantisation formalism, approximation methods, Bose and Fermi statistics, field quantisation, correlation functions, relativistic quantum theory and Dirac equations, scattering theory, current issues and methods of quantum theory (e.g. path integral formulation, quantum information). | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 4 | – | Attendance at lecture<br>Lecture preparation and follow-up | 60<br>60 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar<br>Work on practice tasks<br>Preparation for examination<br>Examination | 30<br>90<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 300 hours | | 10 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | At least every second semester | | |
| **Application** | | Master's programme in Physics | | |

| **Module**: Statistical Physics and Thermodynamics | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturer | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The students are able to name and describe the principle concepts and theorems of statistical physics and thermodynamics. They are also capable of applying the methods they have learnt to existing problems and to solve them.<br>The students have also mastered the calculation methods necessary for dealing with statistical physics and thermodynamics and are able to apply them. | | | |
| **Content**: Elementary statistics and the laws of large numbers, equilibrium ensembles, the principle of maximum entropy, main theorems of thermodynamics, thermodynamic potentials, thermodynamic processes, phase transition, ideal quantum gases, interactive systems. | | | |
| **Teaching and learning units** | **Compulsory attendance** | **Forms of active participation** | **Study time** (hours) |

| | | | |
|---|---|---|---|
| | (Semester hours per week = SH) | | |
| Lecture | 4 | – | Attendance at lecture 60<br>Lecture preparation and follow-up 60 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar 30<br>Work on practice tasks 90<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | At least every second semester | |
| **Application** | | Master's programme in Physics | |

| | | | |
|---|---|---|---|
| **Module**: Advanced Statistical Physics | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: the students have further deepened their knowledge of the fundamental concepts and theorems of statistical physics. They can name, describe and apply them and apply the methods they have learnt to existing problems to solve them. The students have extended their knowledge of methods and calculation methods in the field of statistical physics and are now able to apply these to more complex issues. Using the methods they have learnt, they are also able to derive and analyse microscopic physical processes / laws at the macroscopic level. | | | |
| **Content**: A selection of the following advanced topics of statistical physics: non-equilibrium thermodynamics (entropy production, Onsager relations), linear response theory and fluctuation-dissipation theorem, stochastic processes (Markov processes, master equation, Langevin equation and Fokker-Planck equation), kinetic theory, phase transition (Landau theory, Gauss fluctuations, correlation functions, renorming groups), theory of liquids, hydrodynamics and elasticity, statistical quantum mechanics, exactly solvable models. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lecture | 4 | – | Attendance at lecture 60<br>Lecture preparation and follow-up 60 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar 30<br>Work on practice tasks 90<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | At least every second semester | |
| **Application** | | Master's programme in Physics | |

| **Module**: Quantum Field Theory and Many-Body Physics | | | | |
|---|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: Students understand the concepts and methods of quantum field theory with the focus on many-body physics. They can reproduce these verbally, present them mathematically and apply them to issues of many-body physics. | | | | |
| **Content**: Green's functions, diagrammatic perturbation theory and Feynam diagrams, non-perturbative methods, selected applications in condensed matter or relativistic field theory. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 4 | – | Attendance at lectures<br>Lecture preparation and follow-up | 60<br>60 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar<br>Work on practice tasks<br>Examination preparation, examination | 30<br>90<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 300 hours | | 10 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | At least every second semester | | |
| **Application** | | Master's programme in Physics | | |

*2.2. Modules from the field of Experimental Physics*

| **Module**: Advanced Solid State Physics | | | | |
|---|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: Students have a detailed, critical understanding of some areas of solid state physics and of the most up-to-date commonly used experimental methods. Students can apply their knowledge to concrete issues. | | | | |
| **Content**: This module deepens the students' knowledge of fundamental concepts of solid state physics (describing the geometrical structure, electronic and vibronic conditions, elementary excitations, collective phenomena) on the basis of one or more relevant areas of solid state physics (semiconductor physics, physics of boundary layers and nanostructures, photonics, superconductivity, magnetism, ferroelectricity). | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 4 | – | Attendance at lectures<br>Lecture preparation and | 60<br>60 |

| | | | |
|---|---|---|---|
| Practice seminar | 2 | Successful work on practice tasks | follow-up 30<br>Attendance at practice seminar 90<br>Work on practice tasks 60<br>Examination preparation, examination |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | At least every second semester | |
| **Application** | | Master's programme in Physics | |

| **Module**: Advanced Atomic and Molecular Physics | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims:** Students have a detailed and critical understanding of some areas of atomic and molecular physics and of modern spectroscopic methods. They can apply their knowledge to concrete issues. | | | |
| **Content**: The module covers in more depth the fundamental concepts of atomic and molecular physics (quantum mechanical description of atoms and molecules, the interaction of atoms and molecules with electromagnetic fields) on the basis of one or more relevant areas of atomic and molecular physics (e.g. single atoms and molecules in traps, spectroscopy of atomic clusters, biomolecules, single molecule experiments in the condensed phase). | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 4 | – | Attendance at lectures 60<br>Lecture preparation and follow-up 60 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar 30<br>Work on practice tasks 90<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | At least every second semester | |
| **Application** | | Master's programme in Physics | |

| **Module**: Advanced Biophysics |
|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik |
| **Responsible for the module:** module lecturers |
| **Admission requirements:** none |
| **Qualification aims**: Students have a detailed and critical understanding of some areas of molecular biophysics and of modern spectroscopic methods. They can apply their knowledge to concrete issues. |

| | | | |
|---|---|---|---|
| **Content**: In this module, a range of biophysical concepts and methods are introduced or covered in more depth. The module focuses particularly on the application of selected methods of spectroscopy and diffraction to biologically relevant systems such as proteins, nucleic acid and membranes. The experimental approaches discussed include a selection of the methods listed below: absorption spectroscopy in the visible range, UV and IR, fluorescence spectroscopy, time-resolved emission and absorption spectroscopy, spectroscopy with linearly and circularly polarised light, vibrational spectroscopy: Fourier transform infrared spectroscopy, resonance Raman spectroscopy;, x-ray and neutron diffraction, magnetic resonance and x-ray spectroscopy, dynamic light scattering, single molecule spectroscopy, optical tweezers. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 4 | – | Attendance at lectures 60<br>Lecture preparation and follow-up 90 |
| Practicals | 4 | Carrying out practical experiments and documentation | Attendance at practicals 60<br>Preparation and follow-up of experiments 30<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Practicals: yes; lectures: attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | At least every second semester | |
| **Application** | | Master's programme in Physics | |

**3. Electives**

(* At least seven elective modules will be offered in each academic year)

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|---|---|---|---|
| **Module**: Theoretical Solid State Physics | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: Students understand the concepts and methods of theoretical solid state physics. They can present these verbally and mathematically and apply them to current issues of solid state physics. | | | |
| **Content**: Phonons, electrons, Fermi liquid theory, electron-phonon interaction, magnetism, transport theory, disordered systems, fundamental concepts for the description of solids and their excitations, applications (e.g. superconductivity, magnetism), quantum field theory methods for the description of solids, (perturbation theory, molecular field approximation, functional integrals), linear answer and transport properties, highly correlated systems, current topics. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study hours** (hours) |
| Lectures | 4 | – | Attendance at lectures 60<br>Lecture preparation and follow-up 60 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminars 30<br>Work on practice tasks 90<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |

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|---|---|---|
| **Compulsory regular attendance** | Attendance recommended | |
| **Study time, total hours** | 300 hours | 10 CP |
| **Duration of module** | One semester | |
| **Module offered** | Not regularly* | |
| **Application** | Master's programme in Physics | |

**Module**: Advanced Theoretical Biophysics

**University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: The module enables the students to select the field they wish to concentrate on. They have an overview of theoretical methods which are currently applied in biophysical research, are able to apply them and can critically assess the advantages and disadvantages of various methods for biologically relevant issues.

**Content**: The module covers a selection of the following topics: calculation of the conformational potentials of biomolecules; classical, quantum-mechanical and combined classical-quantum mechanical molecular modelling methods; modelling biochemical reactions, electrostatic models of biomolecules; basic methods in bioinformatics.

| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practical | 2 | Successful work on numeric modelling and practical tasks, documentation of findings | Attendance at practicals<br>Preparation and follow-up of experiments<br>Examination preparation, examination | 30<br>75<br>60 |

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|---|---|---|
| **Language of instruction** | English (or German) | |
| **Compulsory regular attendance** | Practicals: yes; lectures: attendance recommended | |
| **Study time, total hours** | 240 hours | 8 CP |
| **Duration of module** | One semester | |
| **Module offered** | Not regularly* | |
| **Application** | Master's programme in Physics | |

**Module**: Nanophysics

**University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik

**Responsible for the module:** module lecturers

**Admission requirements:** none

**Qualification aims**: Students are familiar with the current state of research and the future challenges in the modern, interdisciplinary research field of nanophysics. They are able to interpret and evaluate experimental and theoretical findings.

**Content**: The module uses examples to introduce the principles of nanophysical systems, important investigation methods and possible applications. The teaching unit may be oriented on particular nanosystems, groups of physics topics or investigation methods. Alongside textbooks, original literature is also used to discuss the current state of research.

| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
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|---|---|---|---|
| Lecture | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminars 15<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

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|---|---|---|---|
| **Module**: Ultrafast Spectroscopy and Nonlinear Optics | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The students gain fundamental knowledge in the field of nonlinear optics and the dynamics of elementary optically induced processes. They have an overview of modern methods of ultrafast spectroscopy and nonlinear optics and how to apply them to particular problems. | | | |
| **Content**: Principles of the interaction of light and matter, wave packet dynamics, electron dynamics and elementary scattering processes, collective excitations in solids. Experimental methods of ultrafast spectroscopy and selected applications, e.g. femtochemistry, coherent control, photoelectron spectroscopy, attosecond physics, diffraction methods, structural dynamics. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar 15<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

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| **Module**: Spectroscopy with Synchrotron Radiation |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik |
| **Responsible for the module:** module lecturers |
| **Admission requirements:** none |
| **Qualification aims**: The module enables the students to select the field they wish to concentrate on. They have an overview of the spectroscopic methods which are applied in current experimental research with synchrotron radiation and are able to independently assess their advantages and disadvantages for a particular issue. |

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| **Content**: A selection of the following topics is covered: X-ray sources and emissions of intensive X-rays, physical principles of nanometer optics, nanometer technologies, modern spectroscopic methods with micro/nano structural resolution such as µEXAFS/µXANES, µXRF, µXBIC, space and time-resolved spectroscopic methods. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lecture | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practical | 2 | Carrying out practical experiments and documentation | Attendance at practicals<br>Preparation and follow-up of experiments<br>Examination preparation, examination | 30<br>75<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Practical: yes; lectures: attendance recommended | | |
| **Study time, total hours** | | 240 hours | | 8 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly* | | |
| **Application** | | Master's programme in Physics | | |

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|---|---|---|---|---|
| **Module**: Photobiophysics and Photosynthesis | | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: On the basis of selected examples, students are familiar with current issues of biophysics research in the field of photobiophysics and photosynthesis. They know the new methods and the possibilities they offer and are able to interpret and critically evaluate findings in relation to the current state of knowledge. | | | | |
| **Content**: The conversion and utilisation of light in biological systems is of fundamental importance for life on earth. Topics are: overview of photosynthesis and photosynthetic organisms; photophysical principles of light absorption, fluorescence emission and energy transfer in photosynthetic antenna systems, light-driven processes in co-factor protein complexes, selected methods of photobiophysics, photosensors, signal transduction, proton and electron transfer in biological systems, time-resolved spectroscopy. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>30 |
| Practice seminar | 1 | Laboratory experiments, documentation and parallel discussions | Attendance at practice seminar<br>Practice seminar preparation and follow-up<br>Examination preparation, examination | 15<br>15<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly* | | |

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| **Application** | Master's programme in Physics |

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|---|---|
| **Module**: Semiconductor Physics | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: The students have a detailed, critical understanding of some areas of semiconductor physics and aspects of their application. They are able to apply their knowledge to concrete issues. | |
| **Content**: The module covers in depth the fundamental concepts of electronic conditions in semiconductors and their realisation with inorganic or organic materials, of charge carriers transport in semiconductors and contact systems and of the influence of structural dimensions on the properties of semiconductors. Special aspects in the application of semiconductors and selected characterisation methods of semiconductors and semiconductor boundary layer properties are examined. | |

| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar<br>Examination preparation, examination | 15<br>60 |

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| **Language of instruction** | English (or German) | |
| **Compulsory regular attendance** | Attendance recommended | |
| **Study time, total hours** | 150 hours | 5 CP |
| **Duration of module** | One semester | |
| **Module offered** | Not regularly* | |
| **Application** | Master's programme in Physics | |

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|---|---|
| **Module**: General Relativity | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |
| **Qualification aims**: Students understand the concepts and methods of the general theory of relativity and can apply them. They are able to describe the mathematical prerequisites and physical assumptions for the general theory of relativity and to present fundamental conclusions. | |
| **Content**: Riemannian geometry, the equivalence principle, Einstein equations, applications of the general theory of relativity, (Schwarzschild solution, gravitational collapse and black holes, gravitational waves), cosmology | |

| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
|---|---|---|---|---|
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar<br>Examination preparation, | 15<br>60 |

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|---|---|---|---|
| | | | examination |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

| **Module**: History of Physics | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The students gain a historical understanding of the basic terms of physics and its methods of operation. This understanding is intended to contribute in particular to maintaining the awareness of the mutability of these basic terms and to get to know innovative research perspectives on the basis of historical examples. In addition, students gain an overview of the development of physics from its beginnings up to the present; the overview is deepened on the technological level by particular examples. The module also aims to give students an understanding of how research in physics is embedded in its particular cultural and social structures. The most important aims include a thoughtful use of terms and methods, an eye for development potential and a keen sense of the links between physical knowledge and its contexts. | | | |
| **Content**:<br>- knowledge of physics in classical times: Aristotle and Archimedes<br>- the development of physics in non-European cultures: the Chinese example<br>- the heritage of classical physics in the Arabic and Latin Middle Ages<br>- the scientific revolution of the early modern period<br>- the analytical tradition of the 18th and 19th centuries<br>- the consolidation of classical physics<br>- reflection on the culture of the discipline in relation to gender aspects<br>- the 20th century revolution in physics | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45 |
| Practice seminars | 1 | Participation in discussion | Attendance at practice seminars 15<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

| **Module**: Advanced Topics in Theoretical Condensed Matter Physics | |
|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** none | |

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| **Qualification aims**: The module enables the students to select the field they wish to concentrate on. They learn theoretical approaches and concepts which are used in current condensed matter theory and are able to master them and apply them. | | | |
| **Content**: The module covers a selection of the following current topics in condensed matter theory: phase transitions, low-dimensional and mesoscopic systems, correlated electron systems, condensed matter in non-equilibrium. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar 15<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

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|---|---|---|---|
| **Module**: Special Topics in Magnetism | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: Students are familiar with current research issues in the field of magnetism and currently used methods and their possibilities. They are able to interpret and critically evaluate findings in relation to the current state of knowledge. | | | |
| **Content**: On the basis of selected examples, the module identifies the principles and applications, the current state of research and the possibilities and limitations of modern experimental methods in the field of research into magnetism. Topics covered may include: magnetic nanostructures, new magnetic materials, magneto-transport phenomena / spin electronics, magnetisation dynamics, magnetic interface phenomena / magnetic interfaces, micromagnetism / magnetic domains, molecular magnetism. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45<br>Attendance at practice seminar 15<br>Examination preparation, examination 60 |
| Practice seminar | 1 | Participation in discussion | |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |

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| **Module offered** | Not regularly* |
| **Application** | Master's programme in Physics |

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|---|---|---|---|---|
| **Module**: Special Topics in Molecular Physics | | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: Students are familiar with current issues in molecular physics and in particular the application of modern spectroscopy technologies to the examination of issues in molecular physics. They are able to interpret and critically evaluate findings in relation to the current state of knowledge. | | | | |
| **Content**:<br>The module gives a more thorough introduction to selected modern concepts in molecular physics, using examples. Specific topics may include single molecule technologies, electron and nuclear magnetic resonance spectroscopy, oscillation spectroscopy and ultrafast spectroscopy. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar<br>Examination preparation, examination | 15<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly* | | |
| **Application** | | Master's programme in Physics | | |

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|---|---|---|---|---|
| **Module**: Special Topics in Molecular Biophysics | | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: Students are familiar with current research issues in the field of molecular biophysics and with new methods and the possibilities they offer. They are able to interpret and critically evaluate findings in relation to the current state of knowledge. | | | | |
| **Content**:<br>On the basis of selected examples, the module identifies the principles and applications, the current state of research and the possibilities and limitations of modern concepts and methods in the field of molecular biophysics. Topics covered are oriented on the main current research issues in biophysics in the faculty and may include: advanced approaches in vibrational, x-ray or electron spin resonance spectroscopy into biomolecules; biomolecules on surfaces or in membranes; tracing the function of photoreceptors or biocatalysts at atomic level. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and | 30<br>45 |

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|---|---|---|---|
| Practice seminar | 1 | Participation in discussion | follow-up<br>Attendance at practice seminar 15<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

| | | | |
|---|---|---|---|
| **Module**: Advanced Astronomy and Astrophysics | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**:<br>The module conveys deeper knowledge in modern areas of astronomy and astrophysics through alternating wide-ranging lectures. In the laboratory work, students acquire practical skills relating to astronomic observation methods and learn numerical methods applicable to astrophysical issues. | | | |
| **Content**:<br>- alternating lectures on various special topics in astronomy and astrophysics (e.g. relativistic astrophysics, cosmology, physics of stellar atmospheres, cosmic electrodynamics, ISM, astronomical observation methods, planetary physics, stellar structure and stellar development)<br>- practical exercises in astronomy (e.g. astrometry, stellar spectroscopy, determining distances, galactic rotation, observations with the centre's own telescopes)<br>- numerical methods for astrophysical issues | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lecture 1 | 2 | – | Attendance at lectures 60<br>Lecture preparation and follow-up 90 |
| Lecture 2 | 2 | – | Attendance at practical 60<br>Work on practical tasks/ documentation of experiments 120<br>Examination preparation, examination 30 |
| Practical | 4 | Practical experiments with written documentation | |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Practical: yes; lectures: attendance recommended | |
| **Study time, total hours** | | 360 hours | 12 CP |
| **Duration of module** | | One or two semesters | |
| **Module offered** | | At least every second semester | |
| **Application** | | Master's programme in Physics | |

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|---|---|
| **Module**: Modern Methods in Theoretical Physics A | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | |
| **Responsible for the module:** module lecturers | |

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| **Admission requirements:** none | | | | |
| **Qualification aims**: The module enables the students to select the field they wish to concentrate on. Students master selected methods applied in current theoretical research and are able to apply them independently. | | | | |
| **Content**: A selection of the following topics is covered: group theory and symmetries in physics, density functional theory, path integral formulation, density matrix theory, quantum optics, field theory, equilibrium and non-equilibrium theory. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar<br>Examination preparation, examination | 15<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 150 hours | | 5 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly* | | |
| **Application** | | Master's programme in Physics | | |

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|---|---|---|---|---|
| **Module**: Modern Methods in Theoretical Physics B | | | | |
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | | |
| **Responsible for the module:** module lecturers | | | | |
| **Admission requirements:** none | | | | |
| **Qualification aims**: The module enables the students to select the field they wish to concentrate on. Students master selected methods applied in current theoretical research and are able to analyse concrete issues independently and to solve them using the methods they have learnt. | | | | |
| **Content**: A selection of the following topics is covered: group theory and symmetries in physics, density functional theory, path integral formulation, density matrix theory, quantum optics, field theory, equilibrium and non-equilibrium theory. | | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) | |
| Lectures | 2 | – | Attendance at lectures<br>Lecture preparation and follow-up | 30<br>45 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar<br>Work on practice tasks<br>Examination preparation, examination | 30<br>75<br>60 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Attendance recommended | | |
| **Study time, total hours** | | 240 hours | | 8 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Not regularly* | | |
| **Application** | | Master's programme in Physics | | |

| **Module**: Modern Methods in Theoretical Physics C | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims:** The module enables the students to select the field they wish to concentrate on. Students master a wide range of methods applied in current theoretical research and are able to analyse concrete issues, to select appropriate methods to solve them and to apply these methods successfully. | | | |
| **Content**: A selection of the following topics is covered: group theory and symmetries in physics, density functional theory, path integral formulation, density matrix theory, quantum optics, field theory, equilibrium and non-equilibrium theory. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 4 | – | Attendance at lectures 60<br>Lecture preparation and follow-up 60<br>Attendance at practice seminar 30<br>Work on practice tasks 90 |
| Practice seminar | 2 | Successful work on practice tasks | Examination preparation, examination 60 |
| **Language of instruction** | | English (German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

| **Module**: Modern Methods in Experimental Physics A | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The module enables the students to select the field they wish to concentrate on. Students gain an overview of selected methods currently applied in experimental research and are able to independently evaluate their advantages and disadvantages for a particular issue. | | | |
| **Content**: A selection of the following topics is covered: spectroscopic methods (optical spectroscopy, electron spectroscopy, x-ray spectroscopy, magnetic resonance spectroscopy), diffraction methods, imaging methods, correlation measurements, time-resolved methods, transport measurements. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45 |
| Practice seminar | 1 | Participation in discussion | Attendance at practice seminar 15<br>Examination preparation, 60 |

| | | | |
|---|---|---|---|
| | | | examination |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 150 hours | 5 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

| **Module**: Modern Methods in Experimental Physics B | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims:** The module enables the students to select the field they wish to concentrate on. Students gain an overview of the methods currently applied in experimental research and are able to independently evaluate their advantages and disadvantages for a particular issue. They are able to analyse concrete issues independently and interpret measurement results. | | | |
| **Content**: A selection of the following topics is covered: spectroscopic methods (optical spectroscopy, electron spectroscopy, x-ray spectroscopy, magnetic resonance spectroscopy), diffraction methods, imaging methods, correlation measurements, time-resolved methods, transport measurements. | | | |
| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
| Lectures | 2 | – | Attendance at lectures 30<br>Lecture preparation and follow-up 45 |
| Practice seminar | 2 | Successful work on practice tasks | Attendance at practice seminar 30<br>Work on practice tasks 75<br>Examination preparation, examination 60 |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 240 hours | 8 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

| **Module**: Modern Methods in Experimental Physics C | | | |
|---|---|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | | | |
| **Responsible for the module:** module lecturers | | | |
| **Admission requirements:** none | | | |
| **Qualification aims**: The module enables the students to select the field they wish to concentrate on. Students gain an overview of a range of the methods currently applied in experimental research and are able to independently evaluate their advantages and disadvantages for a particular issue. They are able to analyse concrete issues independently and interpret measurement results. | | | |
| **Content**: A selection of the following topics is covered: spectroscopic methods (optical spectroscopy, electron spectroscopy, x-ray spectroscopy, magnetic resonance spectroscopy), diffraction methods, imaging methods, correlation measurements, time-resolved methods, transport measurements. | | | |
| **Teaching and learning units** | **Compulsory** | **Forms of active participation** | **Study time** (hours) |

| | **attendance** (Semester hours per week = SH) | | |
|---|---|---|---|
| Lectures | 4 | – | Attendance at lectures 60<br>Lecture preparation and follow-up 60<br><br>Attendance at practice seminar 30<br>Work on practice tasks 90<br><br>Examination preparation, examination 60 |
| Practice seminar | 2 | Successful work on practice tasks | |
| **Language of instruction** | | English (or German) | |
| **Compulsory regular attendance** | | Attendance recommended | |
| **Study time, total hours** | | 300 hours | 10 CP |
| **Duration of module** | | One semester | |
| **Module offered** | | Not regularly* | |
| **Application** | | Master's programme in Physics | |

**4. Research phase**

| **Module**: Scientific Specialization | |
|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** Successful completion of the module "Advanced Laboratory Course for Master Students" (10 CP) and one module in theoretical physics from the compulsory elective area comprising 10 CP and additional Master's programme modules comprising at least 25 CP. | |
| **Qualification aims**: Independent orientation in the scientific research field of the Master's thesis. Students are familiar with the current state of scientific knowledge in this field and are able to assess the advantages and disadvantages of various approaches to a particular current issue and to argue for these in discussion, giving reasons. They have the special knowledge of the discipline necessary to complete their Master's thesis. | |
| **Content**: In this module, the students familiarise themselves in detail with a modern field of research prescribed by their research phase supervisor on the basis of original literature (scientific journals and monographs). The focus is on the scientific content, the critical evaluation of literature, scientifically correct presentation and the rules of good scientific practice. On the basis of the literature studies, open issues are defined and the investigations necessary to answer them are discussed and planned. The skills of expert presentation and critical discussion are practised in seminars. | |

| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
|---|---|---|---|
| Project work | 4 | Documentation and evaluation of original literature, calculations | Attendance at mentoring 60<br>Independent study 180<br><br>Attendance at seminar 30<br>Seminar preparation and follow-up 30<br><br>Examination preparation, examination 150 |
| Seminar | 2 | Participation in discussion | |

| | | |
|---|---|---|
| **Language of instruction** | English (or German) | |
| **Compulsory regular attendance** | Yes | |
| **Study time, total hours** | 450 hours | 15 CP |
| **Duration of module** | One semester | |
| **Module offered** | Every semester | |
| **Application** | Master's programme in Physics | |

| **Module**: Methodology and Project Planning | |
|---|---|
| **University/Department/Institute:** Freie Universität Berlin/Physics/Institut für Experimentalphysik and Institut für Theoretische Physik | |
| **Responsible for the module:** module lecturers | |
| **Admission requirements:** Successful completion of the module "Advanced Laboratory Course for Master Students" (10 CP) and one module in theoretical physics from the compulsory elective area comprising 10 CP and additional Master's programme modules comprising at least 25 CP. | |
| **Qualification aims**: Students are familiar with the particular physics-specific methods and skills necessary to complete their Master's thesis and can apply them in practice. They are able to plan a research project, to present the planning in written form giving reasons and to defend it in the face of critical questions. | |
| **Content**: In this module, students learn selected theoretical and/or experimental methods and skills necessary to complete their Master's thesis under expert guidance. Depending on whether the work is experimental or theoretical in orientation, the focus is on the confident and precise use of measurement apparatus, algorithms, programmes and aids and the reliable application of the necessary skills. Building on the mastery of these methods, the planning of a sample scientific project is drawn up and presented in written form. | |

| **Teaching and learning units** | **Compulsory attendance** (Semester hours per week = SH) | **Forms of active participation** | **Study time** (hours) |
|---|---|---|---|

| | | | | |
|---|---|---|---|---|
| Project work | 4 | Presentation of planned project, participation in discussion | Attendance at project work<br>Individual study | 60<br>180<br>105 |
| Practical (experimental or theoretical) | 7 | Carrying out experiments, written documentation approx. 20 pages | Attendance at practical<br>Writing up documentation | 105 |
| **Language of instruction** | | English (or German) | | |
| **Compulsory regular attendance** | | Yes | | |
| **Study time, total hours** | | 450 hours | | 15 CP |
| **Duration of module** | | One semester | | |
| **Module offered** | | Every semester | | |
| **Application** | | Master's programme in Physics | | |

**Annex 2: Sample programme plan**

**2.1. Sample programme plan for the Master's programme in Physics**

The modules of the first and second semesters may be taken in any order. Students are recommended to divide the work load evenly between the two semesters.

<table>
<tr><th>1st semester<br>30 CP</th><th>2nd semester<br>30 CP</th><th>3rd semester<br>30 CP</th><th>4th semester<br>30 CP</th></tr>
<tr><td colspan="2">Advanced phase</td><td colspan="2">Research phase</td></tr>
<tr><td>Compulsory module<br>Advanced Laboratory Course<br>for Master Students<br>(10 CP)</td><td>Compulsory module<br>Selected Topics in Physics<br>(5 CP)</td><td>Compulsory module Scientific<br>Specialisation<br>(15 CP)</td><td rowspan="3">Master's thesis<br>with accompanying seminar<br>(30 CP)</td></tr>
<tr><td colspan="2">Compulsory elective area 20 CP<br>(at least one module from Theoretical Physics 10 CP)</td><td rowspan="2">Compulsory module Methodology and<br>Project Planning<br>(15 CP)</td></tr>
<tr><td>Elective area<br>10 CP</td><td>Elective area<br>15 CP</td></tr>
</table>

**2.2. Sample programme plan for the Double Master's programme in Physics**

<table>
<tr><th>1st semester<br>30 CP</th><th>2nd semester<br>30 CP</th><th>3rd semester<br>30 CP</th><th>4th semester<br>30 CP</th></tr>
<tr><td colspan="2">Advanced phase</td><td colspan="2">Research phase<br>École Polytechnique in Palaiseau</td></tr>
<tr><td>Compulsory module<br>Advanced Laboratory Course<br>for Master Students<br>(10 CP)</td><td>Compulsory module<br>Selected Topics in Physics<br>(5 CP)</td><td rowspan="3">e.g.<br>M2 programme "Nanoscience"<br>30 CP</td><td rowspan="3">Master's thesis<br>with accompanying seminar<br>(30 CP)</td></tr>
<tr><td>Compulsory module<br>Statistical Physics and Thermodynamics<br>(10 CP)</td><td>Compulsory elective area 10 CP</td></tr>
<tr><td>Elective area 10 CP</td><td>Elective area<br>15 CP</td></tr>
</table>