Faculty of mathematics and physics offers twelve English programmes of doctoral studies, which cover completely this discipline including related interdisciplinary fields.

P4F1A Theoretical Physics, Astronomy and Astrophysics
P4F2A Physics of Plasmas and Ionized Media
P4F3A Physics of Condensed Matter and Materials Research
P4F4A Biophysics, Chemical and Macromolecular Physics
P4F5A Physics of Surfaces and Interfaces
P4F6A Quantum Optics and Optoelectronics
P4F7A Physics of the Earth and Planets
P4F8A Atmospheric Physics, Meteorology and Climatology
P4F9A Particle and Nuclear Physics
P4F11A Mathematical and Computer Modeling
P4F12A Physics Education and General Problems of Physics
P4F13A Physics of Nanostructures and Nanomaterials

Besides departments and institutes of the faculty, fifteen institutes of the Czech Academy of Sciences (CAS) participate in the education of doctoral students.

Available topics of the dissertations are listed in the student information system (SIS) at http://mff.cuni.cz/phd/temata/kód programu.

The most of doctoral programmes offer selected dissertation topics with extended financial support. They are described in details at https://www.mff.cuni.cz/en/physicsphd/. The candidates apply for these topics in advance and pass a preliminary admission procedure. Successful applicants undergo then simplified admission procedure.

Study programme P4F1A Theoretical Physics, Astronomy and Astrophysics

Annotation

The programme P4F1A covers two broad areas: 1) theoretical physics and 2) astronomy and astrophysics. In the former area, it focuses mainly on gravitational and relativistic physics, cosmology, theoretical astrophysics, atomic and molecular physics, mathematical physics, theoretical aspects of plasma, high energy physics including string theory and ADS/ CFT correspondence, and some aspects of particle physics. In the latter area, it is focused on applied astrophysics and both theoretical and observational astronomy.

Board of the doctoral programme

Members of the board: http://mff.cuni.cz/phd/or/p4f1.
Cooperating institutes

- Astronomical Institute, CAS  
  Fričova 298, 251 65 Ondřejov  
  [http://www.asu.cas.cz/]

- Institute of Physics, CAS  
  Na Slovance 2, 182 21 Praha 8  
  [http://www.fzu.cz/]

- Institute of Mathematics, CAS  
  Žitná 25, 115 67 Praha 1  
  [http://www.math.cas.cz]

- J. Heyrovsky Institute of Physical Chemistry, CAS  
  Dolejškova 2155/3, 182 23 Praha 8  
  [http://www.jh-inst.cas.cz/]

- Nuclear Physics Institute, CAS  
  Husinec – Řež č. p. 130, PSČ 250 68  
  [http://www.ujf.cas.cz/]

Available topics of the dissertation

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f1].

Courses

The student must complete the compulsory lectures of the master’s study program at the FMP CU in the field corresponding to her/his specialization if she/he has not already completed them within his master’s degree. In addition, the student chooses from advanced Master’s and doctoral lectures offered by the study programs Astronomy and Astrophysics, Theoretical Physics, Physics of Condensed Matter and Materials Research, Particle and Nuclear Physics, and Mathematical and Computer Modeling. Doctoral students can choose especially among the following advanced lectures:

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NAST002</td>
<td>Galactic and Extragalactic Astronomy II</td>
<td>3/0 Ex</td>
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<tr>
<td>NAST003</td>
<td>Cosmic Electrodynamics</td>
<td>3/1 C+Ex</td>
<td>—</td>
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<tr>
<td>NAST011</td>
<td>Celestial Mechanics II</td>
<td>—</td>
<td>4/0 Ex</td>
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<tr>
<td>NAST021</td>
<td>Selected chapters on astrophysics</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>NAST030</td>
<td>Active Galaxies</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NAST035</td>
<td>Advanced methods of solar physics</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NAST050</td>
<td>Introduction to radioastronomy</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>NMAF006</td>
<td>Selected Topics on Mathematics for Physicists</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NTMF022</td>
<td>Theory of Gauge Fields</td>
<td>3/0 Ex</td>
<td>—</td>
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<tr>
<td>NTMF023</td>
<td>Advanced Simulations in Many-particle Physics</td>
<td>—</td>
<td>2/0 Ex</td>
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<td>Course Code</td>
<td>Course Title</td>
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<td>NTMF025</td>
<td>Selected Chapters on Mathematical Physics</td>
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<tr>
<td>NTMF030</td>
<td>Quantum scattering theory</td>
<td>3/1 C+Ex</td>
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<tr>
<td>NTMF038</td>
<td>Relativistic Physics II</td>
<td>—</td>
<td>4/2 C+Ex</td>
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<td>NTMF059</td>
<td>Computer Methods in Theoretical Physics II</td>
<td>—</td>
<td>2/1 C+Ex</td>
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<tr>
<td>NTMF054</td>
<td>Geometrical Methods of Theoretical Physics I</td>
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<td>NTMF053</td>
<td>Geometrical Methods of Theoretical Physics II</td>
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<tr>
<td>NTMF061</td>
<td>Group Theory and its Applications in Physics</td>
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<td>NTMF062</td>
<td>Selected Topics on General Relativity I</td>
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<tr>
<td>NTMF063</td>
<td>Symmetries of Equations of Mathematical Physics and Conservation Laws</td>
<td>—</td>
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<tr>
<td>NTMF065</td>
<td>Introduction to quantum field theory on curved background</td>
<td>2/1 Ex</td>
<td>—</td>
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<tr>
<td>NTMF067</td>
<td>Selected Chapters on Nonequilibrium Statistical Physics II</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NTMF070</td>
<td>Radiative Processes in Astrophysics</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NTMF072</td>
<td>Selected Topics on General Relativity II</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NTMF082</td>
<td>Exact Spacetimes</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NTMF083</td>
<td>Gravitational Waves I</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NTMF084</td>
<td>Astrophysics of gravitational wave sources</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NTMF097</td>
<td>Black hole thermodynamics: classical and quantum</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NTMF099</td>
<td>Advanced topics in quantum field theory on curved background</td>
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<tr>
<td>NTMF090</td>
<td>Gravitational Waves II</td>
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<td>2/0 Ex</td>
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<tr>
<td>NTMF102</td>
<td>New developments in astrophysics and theoretical physics</td>
<td>0/1 C</td>
<td>0/1 C</td>
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<tr>
<td>NTMF096</td>
<td>Foundations of Numerical Study of Spacetimes</td>
<td>3/0 Ex</td>
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<tr>
<td>NTMF139</td>
<td>Theory of collisions of atoms and molecules</td>
<td>—</td>
<td>3/1 C+Ex</td>
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<tr>
<td>NTMF086</td>
<td>Theoretical Cosmology II</td>
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<tr>
<td>NJSF044</td>
<td>Condensed Matter Theory II</td>
<td>2/0 Ex</td>
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<tr>
<td>NJSF061</td>
<td>Mathematical Methods of Quantum Theory II</td>
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<td>NJSF072</td>
<td>Selected topics on the superstring theory</td>
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<td>2/1 Ex</td>
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<td>NJSF001</td>
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<td>4/2 C+Ex</td>
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<td>NJSF068</td>
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<tr>
<td>NJSF071</td>
<td>Introduction to supersymmetry</td>
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<tr>
<td>NJSF074</td>
<td>Electroweak Interactions II</td>
<td>2/1 Ex</td>
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</tr>
<tr>
<td>NJSF079</td>
<td>Quantum Field Theory III</td>
<td>4/2 C+Ex</td>
<td>—</td>
</tr>
</tbody>
</table>
Requirements for the course of doctoral studies

a) In the first year, students should:
   - complete 2 obligations* (typically by passing an exam);
   - attend a regular seminar in their specialization;
   - give a presentation at the Week of Doctoral Students conference organized by the faculty, or at an international conference in the field.

b) The student can enroll for the state doctoral examination after passing 4 obligations* and presenting her/his research results at the specialization seminar or at an international conference.

c) The condition for the defense and the completion of studies is a publication of two papers in international journals with an impact factor. The student should be the main author of at least one of the published works. The standard length of the study is 4 years.

d) It is expected (although it is not an obligatory condition for graduation) that the student will spend several months at a foreign institution during her/his studies. As an alternative, the student can attend summer or winter schools in the field.

*An obligation is typically a course listed in SIS concluded by an exam. It can be also a supervised reading (an individual lecture on a specialized topic). A fulfillment of such an exam is confirmed in SIS by the supervisor.

The Board will assess compliance individually. For example, it can accept that the student has only one exceptional publication in content or scope at the time of the defense.

Requirements for the doctoral exam

A doctoral student working in Theoretical Physics chooses two of the physical areas 1-6, one of which covers the area of her/his dissertation. The student also chooses one of the mathematical areas M1-M3.
A doctoral student working in Astrophysics or Astronomy chooses the area given by the topic of her/his work, one of the general areas A1, A2, and one of the physical areas 1-6.

Within the question concerning the thesis, the student acquaints the examination commission with the topic of her/his work and answers related questions.

1 Relativity and Cosmology
2 Quantum Field Theory and Particle Physics
3 Non-relativistic Quantum Theory
4 Solid State Physics
5 Hydrodynamics, Magnetohydrodynamics and Plasma Physics
6 Statistical Physics and Thermodynamics

M1 Differential Geometry, Lie Groups and Algebras
M2 Functional Analysis, Theory of Distributions, and Partial Differential Equations
M3 Numerical Methods

A1 Classical Astronomy, Astrodynamical and Experimental Methods in Astronomy
A2 Classical Astronomy, Astrodynamical and Theoretical Astrophysics

The exact scope of the examined areas is specified individually before the exam by the examiner. It depends on the completed lectures and the focus of the student research.

Physical areas cover in particular:

1 - Relativity and Cosmology

2 - Quantum Field Theory and Particle Physics

3 - Non-relativistic Quantum Theory
   Selfadjoint operators and their spectrum. Schrödinger equation, quasiclassical approximation, principle of superposition, uncertainty relations, stationary states, motion in spherically symmetric potential, perturbation theory, spin and spin states, identical particles, electronic structure of atoms, fine structure of atomic levels, atoms in electrical and magnetic fields, probability flux, elastic collisions, scattering amplitude, optical
PHYSICS

theorem, Born series, S-matrix and its properties and analytic structure, resonances, Jost function and Levinson theorem. Interpretation of quantum mechanics; decoherence and effective reduction, hidden-variable theory. Feynman formulation of quantum mechanics.

4 - Solid State Physics


5 - Hydrodynamics, Magnetohydrodynamics and Plasma Physics

Boltzmann and Vlasov kinetic equations; general equations of (magneto)hydrodynamics; drift approximation of particle motions in electromagnetic fields; equilibrium and stability of plasma; dispersion relations for different types of waves in cold plasma; kinetic theory of waves in hot plasma; Landau damping and wave instability; non-linear wave interactions with plasma; trapped particles and quasilinear approximation of ponderomotive force in plasma; weak and strong turbulence in plasma; mutual interactions of waves; deterministic chaos – introduction to the theory and applications of anomalous phenomena in plasma; low-temperature, thermonuclear, and astrophysical plasmas.

6 - Statistical Physics and Thermodynamics

Statistical mechanics of interacting systems: classical and quantum liquids and gases, distribution function and perturbation methods — virial and cluster expansions, perturbation techniques in quantum statistical mechanics. Theory and models of phase transitions: Ising and Heisenberg models of magnetism, mean-field theory, scaling hypothesis, phase transitions and the renormalization group.

A1,A2 - Classical Astronomy...


A1 - ... and Experimental Methods

Telescope types, point-spread function, transfer function. aberration, diffraction, seeing, extinction. Definition of photometric quantities, signal and noise theory; CCD detectors, super-conducting detectors, photomultipliers, primary reduction. Direct imaging, adaptive optics, wavefront sensor, deconvolution. Photometry (aperture, PSF), standard system; astrometry; spectroscopy, reduction and calibration of spectra; polarimetry, Stokes parameters. Interferometry, visibility, van Cittert-Zernike theorem, supersynthesis. Radioastronomy, diagram, heterodyne receiver; radio interferometer, correlator, image reconstruction algorithms. Differences of IR, UV, X, gamma spectral bands; detectors of neutrinos and cosmic radiation; detectors of gravity waves, Michelson interferometer. Analysis of time series, light curve solution, radial velocity curve
solution, Doppler tomography. Comparison of models and observations, inverse problem, chi² metric, random and systematic uncertainties, Bayes theorem. Astronomical databases, archiving, Big Data.

A2 - … and Theoretical Astrophysics


Recommended literature


**Study programme P4F2A Physics of Plasmas and Ionized Media**

**Annotation**

The study program covers all aspects of plasma physics and naturally follows to a broader master’s degree in “Physics of surfaces and ionized media.” Thanks to the focus of the field, which includes not only an extensive area of plasma physics, but also extends to theoretical physics (elementary processes) and some topics of astrophysics (plasma of interplanetary space, problems of dust / ice clusters in the solar system), it is also attractive for students who follow-up master’s studies in these fields. The program is unique in Charles University thanks to a comprehensive view of plasma physics, including the experimental study of laboratory and cosmic, low-temperature and hot plasma, and often supported by numerical simulations.

**Board of the doctoral programme**

Members of the board: [http://mff.cuni.cz/phd/or/p4f2](http://mff.cuni.cz/phd/or/p4f2).

**Cooperating institutions**

- Astronomical Institute, CAS
  Fričova 298, 251 65 Ondřejov
Home page of the study programme

http://physics.mff.cuni.cz/kfpp/4F2/

Available topics of the dissertation

Topics are listed in SIS at http://mff.cuni.cz/phd/temata/p4f2/.

Applicants are advised to register in advance on the selected topics with an offer of extended financial support: https://www.mff.cuni.cz/en/physicsphd/f2/. The pre-selected candidates will facilitate the passage through the admission procedure.

Available courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
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<tr>
<td>NEVE501</td>
<td>Low Temperature Plasma and Its Applications</td>
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<tr>
<td>NEVE502</td>
<td>Elementary Processes in Plasma</td>
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<tr>
<td>NEVE503</td>
<td>Measurement Methods, Modelling and Processing of Experimental Data</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NEVE504</td>
<td>Physical Processes in Solar System</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NEVE505</td>
<td>Plasma Diagnostics</td>
<td>2/0 Ex</td>
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<td>NEVE506</td>
<td>Magnetohydrodynamics, Hot and Laser Plasma</td>
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<td>NEVE507</td>
<td>Introduction to Plasma Physics</td>
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<td>NEVE508</td>
<td>Fusion Plasma</td>
<td>2/0 Ex</td>
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<td>NEVE509</td>
<td>Seminar on Computation and Measuring Techniques</td>
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<td>NEVE510</td>
<td>Seminar on Modern Trends in Physics</td>
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<td>NEVE511</td>
<td>Course of Special Experimental Method in Plasmas and Chemical Physics</td>
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<tr>
<td>NEVE512</td>
<td>Selected Topics from Space Plasmas</td>
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</table>
Student chooses courses and further obligations from the offer of the study programme.

**Requirements for the course of doctoral studies**

   a) 1st and 2nd year of study: in each year 1 joint extension course, 2 lectures according to the individual study plan in the agreement with topic of the dissertation.

   b) 1st-4th year of study: in each year an attendance at professional seminar and active participation in a winter professional workshop.

   c) Presentation at WDS (Week of Doctoral Students) every year of study. Publication in the WDS proceedings in the first 4 years of study (can be replaced by a publication in a journal). Review of a contribution to the WDS proceedings.

   d) Active participation in an international conference.

   e) The condition for passing the state doctoral exam is the completion in total of 4 lecture courses completed by the examination.

   f) During the study, the student is expected to complete a several-month stay at a foreign research group. Alternatively, he/she can participate in summer/winter school concerning the field of the dissertation at the beginning of the study.

   g) The condition for the defense and completion of the study is the publication of student’s own results in two publications in international impact journals. In both publications, the student’s contribution should be crucial.

The board of the programme will assess the compliance of the requirements individually.

**Requirements for the doctoral exam**

The state doctoral exam is synthetic in nature, i.e., 3 broader questions are asked out of the 7 thematic areas that correspond to the content of the course lectures organized by the board (it is taken into account what lectures the student attended).

1. **Low-temperature plasma and its applications**


2. **Elementary processes in plasma**

   Introduction to physical chemistry (molecular structure, states, ions, etc.), collisional processes (ionization, excitation, deexcitation, chemical reactions, recombination, etc.), thermodynamics and statistical thermodynamics in terms of physical chemistry, reaction kinetics and dynamics, ion–molecular reactions, introduction to plasma chemistry and laser chemistry.
3 Methods of measurement, modelling, and processing of experimental data
   Analogue and digital signals, analogue and digital noise (continuous and discrete random processes), digital filtering (overview of methodologies, types of filters, design of integration and derivative filters, smoothing methods, etc.), estimation of model parameters, errors of estimations. Optimal detection (statistical properties, implementation methods). Random processes, fluctuations, and noise. Correlation, frequency spectrum of the signal and its measurement.

4 Physical processes in the solar system
   Basic concepts from magnetohydrodynamics, particle motion in fields, analytical solution of particle motion in adiabatic approach, Solar system, description of Earth–Sun relations, interplanetary magnetic field, plasma in interplanetary system, solar wind, shock waves, magnetopause and Earth’s magnetosphere, particle transport in Earth’s surroundings. The interaction of the solar wind with the magnetosphere, reconnection of magnetic fields. Waves in cosmic plasma.

5 Plasma diagnostics
   Overview of diagnostic methods, optical methods, microwave measurement technique, resonator method, interference method, probe methods, particle diagnostics. Diagnostic methods used in outer space.

6 Magnetohydrodynamics, hot and laser plasmas
   Magnetohydrodynamic approach, one and two-fluid model, frozen field and diffusion of force lines, magnetic energy and magnetic pressure, examples. Introduction to the physics of fusion. Fusion device principles: tokamak, stellerator, z-pinch, inertial retention. Processes of interaction of high laser radiation flows with plasma, characteristics and problems of theoretical description of high energy density systems, principles of X-ray laser, inertial fusion.

7 Nuclear fusion, tokamak
   Fusion fundamentals, tokamak principle. Tokamak — magnetic topology, plasma stability, heating methods, influence of impurities. Edge plasma, its interaction with the wall, the formation of plasma. Turbulence and instabilities, methods of their suppression. Tokamak plasma simulation methods. Diagnostic methods in tokamaks (of both plasma and magnetic fields). Materials used in tokamaks, tokamak operation and control.

Recommended literature


Study programme P4F3A Physics of Condensed Matter and Materials Research

Annotation

The programme prepares specialists qualified for independent activity in basic and applied research in the field of physical properties of condensed matter and materials. The students gain broad knowledge of relevant theoretical approaches (quantum theory, thermodynamic and statistical physics) and of their employment in theoretical and experimental physics of condensed matter, and become familiar with up-to-date experimental methods and technological procedures. Beside the basic education common for the whole study programme, the student gain a deep knowledge according to the dissertation topic and to the choice of optional specialized courses. This pattern guarantees that the graduate has an overview of the whole field at the current level of the knowledge and is an expert in the chosen specialty.
Board of the doctoral programme

Members of the board: [http://mff.cuni.cz/phd/or/p4f3](http://mff.cuni.cz/phd/or/p4f3).

Cooperating institutes

- Institute of Physics, CAS
  Na Slovance 2, 182 21 Praha 8

- Institute of Photonics and Electronics, CAS
  Chaberská 57, 182 51 Praha 8

- Nuclear Physics Institute, CAS
  Husinec – Řež č. p. 130, PSČ 250 68

- Institute of Macromolecular Chemistry, CAS
  Heyrovského nám. 2, 162 06 Praha 6

- Institute of Thermomechanics, CAS
  Dolejškova 1402/5, 182 00 Praha 8
  [http://www.it.cas.cz/](http://www.it.cas.cz/)

Homepage of the board


Available topics of the dissertation

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f3](http://mff.cuni.cz/phd/temata/p4f3).

Selected topics for the preliminary admission procedure


Courses and other requirements for the course of doctoral study

In agreement with the supervisor, the student enrolls the compulsory lecture courses of the corresponding Master’s programme if he/she has not completed these or analogous courses during his/her Master study.

During the doctoral study, the student passes the compulsory courses and according the topic of his/her dissertation chooses the elective courses and eventually other optional courses according the recommendation of his/her supervisor. He/she participates in regular seminars.

Compulsory courses

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Selected Topics on Quantum Theory</td>
<td>2/1 C+Ex</td>
<td></td>
</tr>
</tbody>
</table>
Requirements for the course of doctoral studies

1) A pre-requisite for the enrollment for the doctoral exam is a completion of all compulsory courses listed in the table, one course from the table of elective courses, and participation in two seminars (two times one semester). The student is also obliged to give a lecture at WDS (Week of Doctoral Students).

2) The student regularly attends other seminars (in total number of 4 semesters during the study) and under the circumstances, he/she attends a suitable summer or winter school.

3) According the supervisor advice, the student can enroll for other proper elective or optional courses.

4) During all the study, the student works intensively on a solution of the dissertation tasks, presents his/her results at seminars and scientific conferences and participates in preparation of scientific publications. According to the directions of the supervisor, the student is involved in an international cooperation.

Requirements for the doctoral exam

Wider focused questions are asked with the aim to test the ability of the student to be oriented in the given issue. The exam consists of three parts: I — Broader background, II — Advanced parts of the field, III — Specialization. The student is asked one question from each part.

I. Broader background

I.1. Quantum-mechanical description of atoms and condensed matter
I.2. Many-particle systems
I.3. Electronic states in atom and condensed matter
I.4. Interaction of quantum system with electromagnetic radiation
I.5. Classical and quantum statistical ensembles
I.6. Thermodynamic quantities
I.7. Ideal, classical, and quantum gases
I.8. Fermions and bosons at low temperatures
I.9. Phase transitions
I.10. Non-equilibrium processes in condensed matter

II. Advanced parts

II.1. Structure and microstructure of condensed systems
II.2. Phonons
II.3. Electronic and atomic structure and interactions in condensed systems
II.4. Metals and semiconductors
II.5. Dielectrics and ferroelectrics
II.6. Magnetism
II.7. Physics of condensed systems at low temperatures, superconductivity, superfluidity

III. Specialization

Questions from the subject of the specialization will be proposed by the supervisor. The Commission selects one of at least three issues proposed.

Recommended literature

Study programme P4F4A Biophysics, Chemical and Macromolecular Physics

Annotation

The study programme follows the Master’s program ”Biophysics and Chemical Physics” and the specialization ”Physics of Macromolecular Substances” of the Master’s programme ”Physics of Condensed Matter and Materials”. Its aim is education in an interdisciplinary area at interface of physics, chemistry and biology from the position of physical description and in physical experimental and theoretical approaches; thereby its a unique within CU study programme. Graduates are successful in both basic and applied research in fields of Biophysics, Biochemistry, Physical Chemistry and Chemical Physics, Macromolecular Physics and Chemistry, Microbiology, Physiology and Biological Medical research.

Board of the doctoral programme

Members of the board: [http://mff.cuni.cz/phd/or/p4f4](http://mff.cuni.cz/phd/or/p4f4).

Cooperating institutes

- Institute of Physics, CAS
  Na Slovance 2, 182 21 Praha 8

- Institute of Physiology, CAS
  Vídeňská 1083, 142 20 Praha 4
  [https://www.fgu.cas.cz/](https://www.fgu.cas.cz/)

- Institute of Microbiology, CAS
  Vídeňská 1083, 142 20 Praha 4 - Krč
  [https://mbucas.cz/](https://mbucas.cz/)

- Institute of Photonics and Electronics, CAS
  Chaberská 57, 182 51 Praha 8

- J. Heyrovsky Institute of Physical Chemistry, CAS
  Dolejškova 2155/3, 182 23 Praha 8
Available topics of the dissertation

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f4](http://mff.cuni.cz/phd/temata/p4f4).

Selected topics for the preliminary admission procedure


Homepage of the board


Available courses

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<td>Quantum Theory of Molecules</td>
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<td>NBCM041</td>
<td>Fundamentals of Energy Transfer in Molecular Systems I</td>
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<tr>
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<td>Seminar on Theoretical Chemical Physics</td>
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<td>NBCM057</td>
<td>Molecular Simulations for solving of material structure</td>
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<td>2/1 C+Ex</td>
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<tr>
<td>NBCM058</td>
<td>Relaxation Behaviour of Polymers</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NBCM059</td>
<td>Application of Low Temperature Plasma</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>NBCM060</td>
<td>Introduction to Macromolecular Chemistry</td>
<td>2/1 C+Ex</td>
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<tr>
<td>NBCM076</td>
<td>Theory of Polymer Structures</td>
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<td>NBCM081</td>
<td>Seminar on Polymer Physics</td>
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<td>0/2 C</td>
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<td>NBCM096</td>
<td>Surface-Enhanced Raman Spectroscopy</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NBCM099</td>
<td>X-ray and Electron Structure Analysis of Biomolecules and Macromolecules</td>
<td>2/0 Ex</td>
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<td>NBCM127</td>
<td>Biophysical Methods in Photosynthesis Studies</td>
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<td>2/0 Ex</td>
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<td>NBCM128</td>
<td>Advanced Methods in Molecular Spectroscopy</td>
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<td>2/0 Ex</td>
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<tr>
<td>NBCM129</td>
<td>Experimental Technology in Optical Spectroscopy and Radiometry</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NBCM130</td>
<td>Seminar on Optical Spectroscopy</td>
<td>—</td>
<td>0/2 C</td>
</tr>
</tbody>
</table>
Requirements for the course of doctoral studies

a) The lecture courses should be passed during the first and the second year of the studies. In agreement with the supervisor, the student enrolls for courses that are coherent with the dissertation topic and for those extending his/her general knowledge in respect to the requirements for the doctoral exam. Beside the above-mentioned courses, students may choose from the whole offer of courses provided by CU, in the reasoned cases also courses at other universities.

b) The student is obliged to give a presentation at the Week of Doctoral Students before the end of the second (the third in the case of the doctoral study starting in the spring date) semester. He/she also participates in a regular seminar organized by the department and/or the research group.

c) It is recommended to pass the doctoral exam at the end of the second year of the study. A pre-requisite for the enrollment for the doctoral exam is a completion by a successful exam of at least three lecture courses.

d) The involvement of the student in an international cooperation via stays in foreign research groups and/or attending summer/winter schools and international scientific conferences is highly desirable.

d) For the defense of the dissertation, it is required that its results are published in international scientific journals. The extend and quality of publications should correspond to the level of two papers in impacted journals (WOS) with the main contribution of the student.

Requirements for the doctoral exam

The exam consists of 3 questions, two of which concern two thematic areas chosen by the student and one in focused to the field of the dissertation topic. The latter is usually formulated by the supervisor in a respect to the study plan. According to the student’s responses, additional questions concerning the general physical terms and relations may be asked at the level corresponding to the final exam in the Bachelor study programme ”Physics” and the requirements for the final exams in the Master’s
study programme "Biophysics and Chemical Physics" and/or in the Master’s study programme "Physics of Condensed Matter and Materials" - specialization "Physics of Macromolecular Substances".

**Thematic area 1. Quantum theory and statistical physics of molecular systems**


**Thematic area 2. Physics and chemistry of molecular structures**


**Thematic area 3. Experimental methods**


**Basic recommended literature**


Prosser, V. a kol.: **Experimentální metody biofyziky.** *Academia, Praha, 1989.*
Skála, L.: **Úvod do kvantové mechaniky.** *Academia, Praha, 2005.*

**Study programme P4F5A Physics of Surfaces and Interfaces**

**Annotation**

The program naturally follows up on the field of master’s studies "Surface and Plasma Physics", but it can also follow on from another master’s degree in solid state physics. The study program covers all aspects of physics of surfaces and thin films. It is leaning on knowledge of physical and chemical properties of solid surfaces and interfaces and related physical processes. The study includes problems of basic research in material science and nanophysics, study of surface structures and processes at atomic level, surface catalysis as well as frontier disciplines such as fuel cell technology. The experimental approach is closely related to the theoretical study of the problem. Program prepares experts with a broad foundation in physics, with rich experience in advanced surface experimental techniques and with deep knowledge of surface physics and chemistry.

**Board of the doctoral programme**

Members of the board: [http://mff.cuni.cz/phd/or/p4f5](http://mff.cuni.cz/phd/or/p4f5).

**Cooperating institutes**

- Institute of Physics, CAS  
  Na Slovance 2, 182 21 Praha 8  

- Institute of Photonics and Electronics, CAS  
  Chaberská 57, 182 51 Praha 8  

- J. Heyrovsky Institute of Physical Chemistry, CAS  
  Dolejškova 2155/3, 182 23 Praha 8  
Homepage of the study programme

Available topics of the dissertation
Topics are listed in SIS at http://mff.cuni.cz/phd/temata/p4f5.

Selected topics for the preliminary admission procedure

Available courses

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<td>NEVF514</td>
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<tr>
<td>NEVF515</td>
<td>Methods of Physics of Surfaces and Thin Films I</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NEVF516</td>
<td>Methods of Physics of Surfaces and Thin Films II</td>
<td>2/0 Ex</td>
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<tr>
<td>NEVF517</td>
<td>Seminar on Physics of Surfaces and Thin Films</td>
<td>—</td>
<td>0/2 C</td>
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<tr>
<td>NEVF550</td>
<td>Workshop</td>
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<td>—</td>
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<tr>
<td>NEVF555</td>
<td>Student Conference</td>
<td>—</td>
<td>0/3 C</td>
</tr>
</tbody>
</table>

Requirements for the course of doctoral study

a) Study duties
   1.-2. year: completion of compulsory lectures
   1.-4. year: Seminar on Physics of Surfaces and Thin Films
   In addition to compulsory lectures, the student enrolls in the individual study plan the lectures recommended by the supervisor according to the topic of the dissertation.

b) Requirements for creative activity:
   - research work on the topic of the dissertation
   - presentation at WDS (Week of Doctoral Studies) in the 1st or 2nd year of study
   - presentation of results at the KFPP winter camp during full-time study
   - at least one first authorship on a publication on the topic of the dissertation in an impact journal

c) Requirements for completing internships
   In accordance with the standards of study programs at Charles University, part of the study obligations in the doctoral SP is the completion of part of the study at a foreign institution for a total of at least one month or another form of direct student participation in international cooperation. Another internship abroad is desirable, but not a condition.

d) Additional study duties
   - participation at a suitable winter or summer school or conference
-English language exam

The board of the programme will assess the compliance of the requirements individually.

Requirements for the state doctoral exam

I. General basis


II. Physical foundations of the field

Volume and surface processes in vacuum systems, evaporation and condensation, interaction of gas with solid (surface, volume), pumping process, limit pressure. Physical principles of methods for obtaining and measuring of low pressures. Movement of charged particles in electric and magnetic fields, basic electron ion optical systems. Mass spectroscopy. Interfaces of two solids (metal-metal, metal-semiconductor, semiconductor-semiconductor), electronic processes at interfaces, physical principles and functions of electronic components. Solid surface (structure, purity, phenomena of reconstruction and relaxation), electronic surface structure (metals and semiconductors), surface conditions, band bending, work function. Physical phenomena at surfaces (adsorption, emission of charged particles - thermoemission, thermionic emission, surface ionization, tunnel emission, ionization in a strong field, photoemission; interaction of radiation and particles with a solid). Thin film growth theory, epitaxy. Properties of thin films, transport in thin films.

III. Experimental methods of physics of surfaces, thin films and interfaces

Formation of defined surfaces and thin films, basic methods and techniques. Methods of analysis of surfaces, thin films and interfaces (microscopy - TEM, SEM, FEM, FIM, STM, AFM, electron and ion spectroscopy - AES, XPS, APS, ..., diffraction methods - LEED, RHEED, X-ray).

Recommended literature


Study programme P4F6A Quantum Optics and Optoelectronics

Annotation

The programme Quantum Optics and Optoelectronics offers individually guided study in which students gain extensive knowledge and skills for future independent scientific and research work in the field. According to the individual study plan, they focus on the area of their dissertation. The topics are closely connected with the scientific work of the supervisors who are active, e.g., in the fields of femtosecond laser spectroscopy, opto-spintronics, light detection, semiconductor optoelectronics, terahertz spectroscopy, and laser physics.

Board of the doctoral programme

Members of the board [http://mff.cuni.cz/phd/or/p4f6].

Cooperating institutes

- Institute of Physics, CAS
  Na Slovance 2, 182 21 Praha 8
Available topics of the dissertation

Topics are listed in SIS at http://mff.cuni.cz/phd/temata/p4f6.

Selected topics for the preliminary admission procedure


Courses

Compulsory courses:

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<thead>
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<tbody>
<tr>
<td>NOOE100</td>
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</table>

Elective courses (their extent has to correspond to at least 15 credits from lectures during the first three semesters of study): the student together with his/her supervisor selects lectures from the list of lectures provided by the Faculty of Mathematics and Physics, in accordance with the topic of the dissertation and requirements for the state examination.

Requirements for the state doctoral exam

I. Broader Background


II. Advanced topics

II.1. Wave and Quantum Optics


II.2. Laser Physics


II.3. Optoelectronics


III. Special part

One of the three questions, which is proposed in advance by the supervisor according to the student’s narrower focus, is asked. Part of this section is also a discussion of dissertation theses, which the student submits in writing in the range of several pages.

Recommended literature

Study programme P4F7A Physics of the Earth and Planets

Annotation

The programme provides advanced theoretical knowledge of the physics of the Earth and planetary bodies and trains students in theoretical and numerical solutions of the forward and inverse problems. It includes earthquake physics, seismic waves propagation, studies of thermal evolution and deformation and of the gravity and magnetic fields of the Earth and planetary bodies. The graduate is able to carry out independent scientific research focused on the physical processes in the Earth, planets and satellites. He/she can pursue career in the research institutions focused on Earth and planetary evolution, but also in the industrial research focused on the issues of continuum mechanics.

Board of the doctoral programme

Members of the board: [http://mff.cuni.cz/phd/or/p4f7](http://mff.cuni.cz/phd/or/p4f7).

Cooperating institutes

- Institute of Geophysics, CAS
  Boční II/1401, 141 31 Praha 4 - Spořilov
  [http://www.ig.cas.cz/](http://www.ig.cas.cz/)

- Institute of Rock Structure and Mechanics, CAS
  V Holešovičkách 41, 182 09, Praha 8

Available topics of the dissertation

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f7](http://mff.cuni.cz/phd/temata/p4f7).

Selected topics for the preliminary admission procedure


Courses

The student chooses from advanced Master’s and doctoral lectures, especially among the following courses:

<table>
<thead>
<tr>
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<th>Winter</th>
<th>Summer</th>
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<td>NGEO111</td>
<td>Continuum Mechanics</td>
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<td>2/1 C+Ex</td>
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<tr>
<td>NGEO112</td>
<td>Continuum Mechanics II</td>
<td>2/2 C+Ex</td>
<td>—</td>
</tr>
<tr>
<td>NGEO110</td>
<td>Fourier Spectral Analysis</td>
<td>—</td>
<td>2/1 C+Ex</td>
</tr>
<tr>
<td>NGEO113</td>
<td>Review of Geophysics</td>
<td>2/1 C+Ex</td>
<td>—</td>
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<tr>
<td>NGEO114</td>
<td>Gravity field of the Earth and planets</td>
<td>2/1 C+Ex</td>
<td>—</td>
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<tr>
<td>NGEO116</td>
<td>Seismology</td>
<td>2/1 C+Ex</td>
<td>—</td>
</tr>
<tr>
<td>NGEO117</td>
<td>Earthquake source physics</td>
<td>—</td>
<td>2/1 C+Ex</td>
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</table>
### Requirements for the course of doctoral study

a) In the first year students should attend 1-3 courses according to their individual study plan. In the first or second year, they give presentation at the Week of Doctoral Students, Doctoral day or international conference. They should attend and present their results at department seminars during the course of study.

b) Before defending the thesis its results must be published in at least two papers in international journals with impact factor.

c) During PhD studies students should participate in international collaboration. Preferably by visiting foreign scientific institution (stay should be at least one month), but some other forms of international cooperation may be considered if necessary.

### Requirements for the state doctoral exam

Doctoral exam has three parts. First question is focused on the topic of doctoral thesis. Second question is from obligatory part including fundamentals of geophysics and structure of the Earth (see part 1 below) and third question is from optional subject (see part 2 below).

#### 1. Obligatory part

1.1 Fundamentals of geophysics

Earth motion. Gravity field, gravity measurements. Earth tides. Basic characteristics of earthquakes. Earth seismicity. Propagation of seismic waves. Earth magnetic field, internal and external field, variations. Paleomagnetism. Heat sources and heat...

1.2 Structure of the Earth


2. Optional part

Student will choose one of the following blocks:

2.1 Seismology


2.2 Geodynamics


2.3 Geomagnetism and geoelectricity

Characteristics of electromagnetic field and its time variations. Models of electric conductivity in the crust and mantle. Dynamo theory of the geomagnetic field origin. Physics of ionosphere and magnetosphere.

2.4 Planetology


Recommended literature


Study programme P4F8A Atmospheric Physics, Meteorology and Climatology

Annotation

In the Czech Republic, this program is the only one to provide education in atmospheric physics, meteorology and climatology. It is possible to focus on a number of atmospheric research topics, including issues such as prognostic models, climate system, climate change and climate modeling, modeling of atmospheric chemistry and air quality, modeling of turbulent flow at small scales or research of higher layers of the atmosphere. The studied topics reflect the development of basic research as well as applications in the commercial and public spheres. Details of the program and workplace can be found at [http://kfa.mff.cuni.cz/](http://kfa.mff.cuni.cz/).

Board of the doctoral programme

Members of the board: [http://mff.cuni.cz/phd/or/p4f8](http://mff.cuni.cz/phd/or/p4f8).

Cooperating institutes

- Institute of Atmospheric Physics, CAS
  Boční II/1401, 141 31 Praha 4

- Institute of Thermomechanics, CAS
  Dolejškova 1402/5, 182 00 Praha 8
  [http://www.it.cas.cz/](http://www.it.cas.cz/)

Available topics of the dissertation

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f8](http://mff.cuni.cz/phd/temata/p4f8).

Available courses

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<td>NMET501</td>
<td>Radiation-active Gases in Atmosphere</td>
<td>2/0 Ex</td>
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<tr>
<td>NMET502</td>
<td>Selected Topics on Dynamic Meteorology</td>
<td>2/0 Ex</td>
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</tr>
<tr>
<td>NMET504</td>
<td>Predictability of Atmospheric Processes</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NMET505</td>
<td>Numerical Forecasting Methods</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NMET506</td>
<td>Dynamics of Ocean-Atmosphere System</td>
<td>2/0 Ex</td>
<td>—</td>
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</tbody>
</table>
Requirements for the course of doctoral study

It is strongly recommended not to extend the duration of the study beyond four years. The extension of studies makes sense in clearly justified cases. Any extension of the study beyond the four years period will be assessed individually and continuation will be recommended only in justified cases. The individual study plan (ISP) schedule should state the finalization of the dissertation for the fourth year of study. Students should have at least three peer-reviewed publications (published or accepted for publication) when defending their dissertations. Among those papers, the student should be the main author of at least two, and two papers should be published in a journal with IF. The expected schedule of publishing activity should be part of the ISP proposal. It is recommended to strive to obtain student projects from the Charles University Grant Agency. Submission of a student project proposal should be part of the ISP proposal. During the study, it is also recommended to complete an internship at a foreign institution lasting at least three months. The doctoral students should enroll in a project seminar (NMET061, NMET062) every year for the entire period of study. At least once a year, each doctoral student should present the progress of his/her dissertation at the seminar. It is recommended to pass the English exam during the first year of study. Passing the state doctoral examination is recommended during the second or third year of study after completing all ISP courses.

Requirements for the doctoral exam

The exam typically takes place in the 4th or 5th semester of the study and includes three questions.
I. Basic concepts of physics

Knowledge of general laws and concepts of physics is assumed. Knowledge of mechanics, molecular physics and thermals, thermodynamics, hydrodynamics, continuum mechanics and optics will be tested primarily in questions from subjects profiling the field.

II. Advanced parts of the field

II.1. Mandatory part

II.1.1 Dynamic meteorology

Thermodynamics of open and closed systems, phase transitions. Types of atmospheric flow, interpretation of ageostrophic components, current function and divergence potential. Theory of pressure changes, interpretation of basic equations of atmospheric dynamics, potential vorticity theorem, circulation theorems, gravitational and inertial oscillations, waves in zonal flow, baroclinic instability, energy transformation in the atmosphere, predictability of atmospheric processes, circulation at different atmospheric scales.

II.1.2 Synoptic meteorology

Use of numerical forecasting methods in weather forecasting, peculiarities of synoptic processes over Central Europe, predictions of dangerous phenomena and states, regional influences on atmospheric fronts and weather inside air masses, quasi-gostrophic approach in synoptic analysis, use of PV thinking for synoptic analysis, principles of isentropic analysis.

II.1.3 Boundary layer of the atmosphere

Turbulence in the atmosphere, transformation of kinetic energy in the boundary layer, solution of the closure problem, turbulence models, Monin’s and Obuchov’s similarity theory, stability parameters, interactions between the Earth’s surface and the atmosphere, flow over mountain obstacles, transport and reactions of pollutants in the atmosphere.

II.1.4 Climatology

Climate system, feedback, climate predictability. Physical and chemical processes in the climate system, horizontal and vertical structure of the atmospheric and ocean circulation, interactions between the atmosphere and the ocean. Variability in the climate system, circulation indices, modes of variability. Structure of climate models, global circulation models, models for limited areas. Influences of anthropogenic activity on the climate system. The impact of urbanization on the climate.

II.2. Optional part

The doctoral student chooses one of the following thematic areas:

II.2.1 Numerical prediction methods


II.2.2 Physics of clouds and precipitation

Physical properties of cloud and precipitation particles, microphysical processes in clouds, dynamics of layered and convection clouds, mesosynoptic convection systems,
chemistry of clouds and precipitation, cloud electricity, use of meteorological radars in measuring precipitation, interaction of aerosols with clouds and influence on precipitation intensity - indirect radiation effects aerosols, parameterization and models of cloud formation and precipitation.

II.2.3 Atmospheric optics and acoustics

Scattering and absorption of electromagnetic radiation in the atmosphere, interpretation of basic optical and acoustic phenomena in the atmosphere, meteorological application of radars, sodars and remote sensing methods.

II.2.4 Transport of pollutants in the atmosphere

Pollutants and their sources, dispersion of pollution, deposition on the earth’s surface, precipitation, basics of atmospheric chemistry, ozone chemistry, air pollution monitoring, emission measurement methods, models of pollutant propagation at various spatial scales, ecological consequences of air pollution, microphysics and aerosol chemistry.

II.2.5 Upper atmosphere


II. 2. 6 Applied climatology


The required content of exam can be modified in relation to the student’s dissertation topic.

Recommended literature


The list of recommended literature can be modified in respect to the study plan and the dissertation topic.

**Study programme P4F9A Particle and Nuclear Physics**

**Board of the doctoral programme**

Members of the board: [http://mff.cuni.cz/phd/or/p4f9](http://mff.cuni.cz/phd/or/p4f9).

**Cooperating institutes**

- Institute of Physics, CAS
  Na Slovance 2, 182 21 Praha 8

- Nuclear Physics Institute, CAS
  Husinec – Řež č. p. 130, PSČ 250 68

**Available topics of the dissertation**

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f9](http://mff.cuni.cz/phd/temata/p4f9).
Courses

The student has to pass the compulsory lectures of the Master’s programme at the faculty corresponding to his/her specialization, if they have not been passed during his/her Master study. Beside this, he/she chooses elective courses, preferably from the following list of advanced lecture courses:

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<td>N.JSF008</td>
<td>Biological Effects of Ionizing Radiation</td>
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<tr>
<td>N.JSF024</td>
<td>Radioanalytical Methods</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>N.JSF030</td>
<td>Quantum Field Theory at Finite Temperature</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>N.JSF031</td>
<td>Classical and Quantum Chaos</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>N.JSF040</td>
<td>Many Body Problem in Nuclear Structure</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>N.JSF058</td>
<td>Nuclear Reactions with Heavy Ions</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>N.JSF060</td>
<td>Quantum Field Theory II</td>
<td>—</td>
<td>4/2 C+Ex</td>
</tr>
<tr>
<td>N.JSF064</td>
<td>Quantum Field Theory II</td>
<td>—</td>
<td>4/2 C+Ex</td>
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<tr>
<td>N.JSF070</td>
<td>Particle Detectors and Accelerators</td>
<td>2/0 Ex</td>
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<td>N.JSF077</td>
<td>Introduction to supersymmetry</td>
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<td>Electroweak Interactions II</td>
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<td>Detectors for High Energy Physics</td>
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<td>N.JSF088</td>
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<td>N.JSF093</td>
<td>Chiral Symmetry or Strong Interactions</td>
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<td>2/0 Ex</td>
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<td>N.JSF095</td>
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<td>0/2 C</td>
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<td>N.JSF097</td>
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<td>N.JSF100</td>
<td>Semiconductor Detectors in Nuclear and Subnuclear Physics</td>
<td>2/0 Ex</td>
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<tr>
<td>N.JSF102</td>
<td>Nuclear Astrophysics</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>N.JSF107</td>
<td>Statistical Nuclear Physics</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>N.JSF112</td>
<td>Nuclear Processes in the Space</td>
<td>2/0 Ex</td>
<td>—</td>
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<td>—</td>
<td>0/2 C</td>
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<tr>
<td>N.JSF123</td>
<td>Advanced Concepts of Symmetry</td>
<td>—</td>
<td>2/2 Ex</td>
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<tr>
<td>N.JSF120</td>
<td>Cosmic Rays</td>
<td>—</td>
<td>2/0 Ex</td>
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<td>N.JSF130</td>
<td>Theory of nanoscopic systems I</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>N.JSF132</td>
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<tr>
<td>N.JSF136</td>
<td>Beyond Standard Model Physics I</td>
<td>2/1 Ex</td>
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<td>N.JSF137</td>
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<td>—</td>
<td>2/1 Ex</td>
</tr>
<tr>
<td>N.JSF139</td>
<td>Experimental data evaluation</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>N.JSF140</td>
<td>Theory of groups and algebras in particle physics</td>
<td>—</td>
<td>2/1 Ex</td>
</tr>
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</table>
Requirements for the course of doctoral studies

1) Study duties
In the first two years, students should attend and pass at least two specialized lectures with an exam; on an ongoing basis, attend a regular seminar of IPNP.

2) Requirements for creative activity
Research work on the topics of dissertation work; presentation at WDS (Week of Doctoral Studies) in the 1st or 2nd year of study; at least one journal publication related to the dissertation topic; presentation of results at a seminar or appropriate conference.

3) Internship requirements
In agreement with the standards of the study programmes at Charles University, part of the study obligations should be done at a foreign institution for a total duration of at least one month, or another form of direct participation in international cooperation. A longer internship abroad is desirable but not a requirement.

4) Other obligations
Participation at an appropriate winter or summer school or conference; English language exam; supervision of undergraduate tutorial classes, or in a practical course in nuclear physics.

Requirements for the state doctoral exam
The selection of questions takes into account the student’s specialization and the topic of the doctoral thesis.

I. Broader basis

II. Particle Physics
Detection methods for registration of elementary particles. Particle accelerators and detectors. Systematics and measurement of elementary particle characteristics.

### III. Nuclear Physics


### Recommended literature

Study programme P4F11A Mathematical and Computer Modeling

Annotation

This study branch is a combined one between mathematics and physics. It is focused on modelling in physics of solids, liquids, gases and plasma, with applications in material sciences, chemistry, biology and medicine. According to the subject of the thesis, it is possible to devote to continuum, particle or hybrid modelling with accents either in mathematics or in physics. The continuum modelling is focused on the study of models of continuum mechanics and thermodynamics of fluids (i.e., liquids or gases) and solids or on the related mathematical and numerical analysis of the corresponding systems of partial differential equations and possibly on their numerical solution. The particle and hybrid modelling are focused on the study of macromolecules, thin layers and surfaces and on the study of low- or high-temperature plasma in close connection to experimental data, often with the aim to help with interpretation of the obtained experimental results and developments of new diagnostic methods.

Board of the doctoral programme

Members of the board: [http://mff.cuni.cz/phd/or/p4f11](http://mff.cuni.cz/phd/or/p4f11).

Cooperating institutes

- Institute of Mathematics, CAS
  Žitná 25, 115 67 Praha 1

- Institute of Thermomechanics, CAS
  Dolejškova 1402/5, 182 00 Praha 8
  [http://www.it.cas.cz/](http://www.it.cas.cz/)

Available topics of the dissertation

Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f11](http://mff.cuni.cz/phd/temata/p4f11).

Courses

The student chooses the subjects in collaboration with the supervisor with the agreement of the Board of the study programme. It is possible to take any subject
taught at the Charles University, in case of need after agreement also at other universities (Czech Technical University, University of Chemistry and Technology etc.) The offer includes, in particular, subjects of the master-degree studies of mathematical modelling and numerical mathematics that the student has not passed in the previous study. Their list is given below, in the frame of requirements for the state doctoral exam.

<table>
<thead>
<tr>
<th>Code</th>
<th>Subject</th>
<th>Winter</th>
<th>Summer</th>
</tr>
</thead>
<tbody>
<tr>
<td>NMMO561</td>
<td>Regularity of solutions of Navier-Stokes equations</td>
<td>2/0 Ex</td>
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<tr>
<td>NMMO533</td>
<td>Nonlinear Differential Equations and Inequalities 1</td>
<td>3/1 C+Ex</td>
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<tr>
<td>NMMO534</td>
<td>Nonlinear Differential Equations and Inequalities 2</td>
<td>—</td>
<td>3/1 C+Ex</td>
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<tr>
<td>NMMO521</td>
<td>Seminar on Partial Differential Equations</td>
<td>0/2 C</td>
<td>0/2 C</td>
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<tr>
<td>NMMO522</td>
<td>Seminar on Differential Equations</td>
<td>0/2 C</td>
<td>0/2 C</td>
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<tr>
<td>NMMO523</td>
<td>Qualitative Properties of Weak Solutions to Partial Differential Equations</td>
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</tr>
<tr>
<td>NMMO524</td>
<td>Regularity of Weak Solutions to Partial Differential Equations</td>
<td>—</td>
<td>0/2 C</td>
</tr>
<tr>
<td>NMMO525</td>
<td>Analysis of Mathematical Models of Bodies Moving through Fluids I</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>NMMO526</td>
<td>Analysis of Mathematical Models of Bodies Moving through Fluids II</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMMO527</td>
<td>New results in the theory of Euler equations</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMMO528</td>
<td>Techniques for a posteriori error estimation</td>
<td>2/0 Ex</td>
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<tr>
<td>NMMO529</td>
<td>Numerical Modelling of Electrical Engineering Problems</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMMO530</td>
<td>Modelling of materials — theory, model reduction and efficient numerical methods</td>
<td>0/2 C</td>
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<tr>
<td>NMMO531</td>
<td>A Posteriori Numerical Analysis Based on the Method of Equilibrated Fluxes</td>
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<tr>
<td>NMMO532</td>
<td>Bifurcation Analysis of Dynamical Systems 1</td>
<td>2/0 Ex</td>
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<td>NMMO533</td>
<td>Bifurcation Analysis of Dynamical Systems 2</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMMO627</td>
<td>Modern Algorithms in Numerical Optimisation</td>
<td>2/0 Ex</td>
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<tr>
<td>NGEO112</td>
<td>Fourier Spectral Analysis</td>
<td>—</td>
<td>2/1 C+Ex</td>
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<td>NGEO107</td>
<td>Inverse Problems and Modelling in Physics</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NGEO108</td>
<td>Inverse modeling in geodynamics</td>
<td>2/0 Ex</td>
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<tr>
<td>NEVF160</td>
<td>Modern Computational Physics I</td>
<td>2/1 MC</td>
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</tr>
<tr>
<td>NEVF161</td>
<td>Modern Computational Physics II</td>
<td>—</td>
<td>2/1 MC</td>
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</table>
Requirements for the state doctoral exam

The exam consists of three parts:

I — Methods of analysis of partial differential equations
II — Methods of numerical mathematics and scientific computations
III — Methods of continuum physics and plasma physics

The supervisor in coordination with the student and the guarantor of the programme chooses from each part one subject. One subject (so called the special one) is directed towards the contents of the doctoral thesis; it typically concerns the study of newest articles or books in the given field. It is assumed that this subject is contained in one of the parts I, II or III. The subjects chosen from the remaining parts are typically such that they form extra knowledge above the knowledge of the student from the master-degree. It is usually a part covered by one or two advanced lectures which the student passed during the doctoral studies or whose content the student studied by him/herself. The nowadays offer includes, e.g., the following lectures:

I Methods of analysis of partial differential equations

<table>
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<tr>
<th>Code</th>
<th>Subject</th>
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<th>Summer</th>
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<tr>
<td>NMMO539</td>
<td>Mathematical Methods in Mechanics of Non-Newtonian Fluids</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>NMMO539</td>
<td>Mathematical Methods in Mechanics of Solids</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NMMO539</td>
<td>Mathematical Theory of Navier-Stokes Equations</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NMMO539</td>
<td>Mathematical Methods in Mechanics of Compressible Fluids</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NMMO541</td>
<td>Regularity of solutions of Navier-Stokes equations</td>
<td>2/0 Ex</td>
<td>—</td>
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<tr>
<td>NMMO538</td>
<td>Nonlinear Differential Equations and Inequalities 1</td>
<td>—</td>
<td>3/1 C+Ex</td>
</tr>
<tr>
<td>NMMO538</td>
<td>Nonlinear Differential Equations and Inequalities 2</td>
<td>—</td>
<td>3/1 C+Ex</td>
</tr>
<tr>
<td>NMMO531</td>
<td>Partial Differential Equations 3</td>
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</table>
### II Methods of numerical mathematics and scientific computations

<table>
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<th>Summer</th>
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<tbody>
<tr>
<td>NMMO537</td>
<td>Saddle Point Problems and Their Solution</td>
<td>—</td>
<td>2/2 C+Ex</td>
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<tr>
<td>NMNV407</td>
<td>Matrix Iterative Methods 1</td>
<td>4/0 Ex</td>
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<tr>
<td>NMNV436</td>
<td>Finite Element Method 2</td>
<td>—</td>
<td>2/2 C+Ex</td>
</tr>
<tr>
<td>NMNV537</td>
<td>Mathematical Methods in Fluid Mechanics 1</td>
<td>2/0 Ex</td>
<td>—</td>
</tr>
<tr>
<td>NMNV538</td>
<td>Mathematical Methods in Fluid Mechanics 2</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMNV469</td>
<td>A Posteriori Numerical Analysis Based on the Method of Equilibrated Fluxes</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NMNV541</td>
<td>Fundamentals of Discontinuous Galerkin Method</td>
<td>—</td>
<td>2/0 Ex</td>
</tr>
<tr>
<td>NEVF528</td>
<td>Numerical Methods of Computational Physics I</td>
<td>2/2 Ex</td>
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<tr>
<td>NEVF529</td>
<td>Numerical Methods of Computational Physics II</td>
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<td>2/2 Ex</td>
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### III Methods of continuum physics and plasma physics

<table>
<thead>
<tr>
<th>Code</th>
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<th>Summer</th>
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<td>NMMO432</td>
<td>Classical Problems of Continuum Mechanics</td>
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<tr>
<td>NMMO539</td>
<td>Modelling in biomechanics</td>
<td>3/0 C+Ex</td>
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</tr>
<tr>
<td>NMMO541</td>
<td>Theory of Mixtures</td>
<td>2/1 C+Ex</td>
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<tr>
<td>NMYL026</td>
<td>Classical Electrodynamics</td>
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<td>2/2 C+Ex</td>
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<tr>
<td>NMYL035</td>
<td>Electromagnetic Field and Special Theory of Relativity</td>
<td>—</td>
<td>2/1 Ex</td>
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<tr>
<td>NEVF525</td>
<td>Plasma Physics and Computer Plasma Modelling I</td>
<td>2/2 C</td>
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<tr>
<td>NEVF557</td>
<td>Computer modelling in plasma physics II</td>
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<td>1/1 MC</td>
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<tr>
<td>NEVF570</td>
<td>Computational Physics I</td>
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<td>NRCA322</td>
<td>Fundamentals of Computer Physics II</td>
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<td>NGE0102</td>
<td>Inverse modeling in geodynamics</td>
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### Recommended literature


Study programme P4F12A Physics
Education and General Problems of Physics

Board of the doctoral programme
Members of the board: [http://mff.cuni.cz/phd/or/p4f12](http://mff.cuni.cz/phd/or/p4f12).

Cooperating institutes

- Astronomical Institute, CAS
  Fričova 298, 251 65 Ondřejov

Available topics of the dissertation
Topics are listed in SIS at [http://mff.cuni.cz/phd/temata/p4f12](http://mff.cuni.cz/phd/temata/p4f12).

Available courses

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<td>NDFY029</td>
<td>Problems of Physics Education</td>
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<td>NDFY051</td>
<td>Modern Trends in Physics Education</td>
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<td>0/2 C</td>
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<td>NDFY052</td>
<td>Ph.D. Students’ Seminar f12 I</td>
<td>0/1 C</td>
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<tr>
<td>NDFY053</td>
<td>Ph.D. Students’ Seminar f12 II</td>
<td></td>
<td>0/1 C</td>
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<tr>
<td>NDFY064</td>
<td>Physical Worldview II</td>
<td></td>
<td>0/2 C</td>
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<tr>
<td>NDFY071</td>
<td>Introduction to Bibliographic and Scientific Research I</td>
<td>0/1 C</td>
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<tr>
<td>NDFY072</td>
<td>Introduction to Bibliographic and Scientific Research II</td>
<td></td>
<td>0/1 C</td>
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<tr>
<td>NDFY075</td>
<td>Development of Physical Experiments</td>
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<tr>
<td>NDFY076</td>
<td>Development of Physical Experiments II</td>
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<td>NPED015</td>
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<td>NPED016</td>
<td>Seminar on Pedagogy II</td>
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<tr>
<td>NPOZ026</td>
<td>Physics as an Adventure of Discovery</td>
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</table>

Requirements for the doctoral exam
The exam consists of three parts: I. Broader basis, II. Parts of physics related to the topic of the dissertation, III. Specialization.

I. Broader basis
1. Space and time, inertial and non-inertial systems, relativistic kinematics and dynamics.
2. Energy, momentum and angular momentum in various fields of physics.
3. Dynamical description of various systems (equations of motion, variational formulation of physics laws, field equations).
4. Oscillator in both classical and quantum physics.
5. Basics of classical electrodynamics (building theory from experiments as well as deductive derivation from the Maxwell’s equations).
7. Waves (mechanical and electromagnetic, properties, propagation, excitation).
8. Interaction of electromagnetic radiation with matter (classical and quantum level).
10. Basic principles and applications of thermodynamics and statistical description.
12. Measurements of physical quantities (quantities and their units, measurement methods, fundamental physical constants and their measurement).
13. Physical nature of phenomena from everyday life and technical practice (the ability of theories to explain the observed phenomena, applications of physics results).
14. Limits of validity of physical theories (relation of classical, quantum and relativistic physics, other examples such as electrostatics-electrodynamics).

A general overview of physics as in the Feynman course is assumed. This includes an explanation of basic physical laws and their consequences with experimental results and applications. Emphasis is also placed on the ability to explain the topic in more elementary ways.

II. II. Parts of physics related to the topic of the dissertation

Due to the breadth of the topics of theses falling within the given field, the commission can determine the requirements for every student individually. In this part of the exam, the candidate must demonstrate a deeper physical insight into the chosen part of physics related to the topic of his/her dissertation.

III. Specialization

In the specialization the applicant chooses one of the following: a) didactics of physics, b) philosophy and methodology of physics, c) history of physics. The student must demonstrate a general overview of the area, be able to explain its starting points, basic concepts and their connections (including links to individual fields of physics), methodology of relevant research and the most important results. Following the more specific focus of the dissertation, the commissions can adjust the requirements in the field of specialization for each student individually.

The adept must demonstrate a general overview of the field, be able to explain its background, basic concepts and their context (including links to individual fields of physics), methods of work as well as the most important results. In the case of didactics of physics also their applications in education, e.g., settings goals of teaching, choosing teaching methods, problem-solving methods, didactic functions of the experiment, and evaluation of the teaching results.

The extent is given by the literature below. Following the most specific focus of the dissertation, the commission can adjust the requirements in the field of specialization for every student individually.

Recommended literature

Following the focus of the dissertation, the list of recommended literature can be adjusted for each student individually.


Study programme P4F13A Physics of Nanostructures and Nanomaterials

Board of the doctoral programme
Members of the board: http://mff.cuni.cz/phd/or/p4f13.

Cooperating institutes

• Institute of Physics, CAS
  Na Slovance 2, 182 21 Praha 8
  http://www.fzu.cz/

• Institute of Photonics and Electronics, CAS
  Chaberská 57, 182 51 Praha 8
  http://www.ufe.cz/

• J. Heyrovsky Institute of Physical Chemistry, CAS
  Dolejškova 2155/3, 182 23 Praha 8
  http://www.jh-inst.cas.cz/

Available topics of the dissertation
Topics are listed in SIS at http://mff.cuni.cz/phd/temata/p4f13.

Courses

Compulsory courses

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<th>Code</th>
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<tr>
<td>NEVF534</td>
<td>Physics of Low-dimensional Structures</td>
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<td>NFPL199</td>
<td>Physical Methods in Nanostructure Studies</td>
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<tr>
<td>NEVF555</td>
<td>Nanomaterials I</td>
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<td>NEVF583</td>
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<td>NFPL187</td>
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<tr>
<td>NFPL188</td>
<td>Seminar on Nanomaterials: Physics, Technology, Applications II</td>
<td>—</td>
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</table>

Other lecture courses and seminars from related fields, elective in respect to the dissertation topic, e.g.:

<table>
<thead>
<tr>
<th>Code</th>
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<th>Summer</th>
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<tbody>
<tr>
<td>NOOE070</td>
<td>Optics of Nanomaterials and Nanostructures</td>
<td>—</td>
<td>2/0 Ex</td>
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<tr>
<td>NOOE121</td>
<td>Methods of Laser Spectroscopy in Semiconductor Spintronics</td>
<td>2/0 Ex</td>
<td>2/0 Ex</td>
</tr>
</tbody>
</table>
Requirements for the state doctoral exam

During the examination, the student will receive three questions from the areas defined below: I. Broad base, II. Important physical and technological aspects of nanostuctures, and III. A question related to the topic of the theses (a list of up to five questions will be provided by the supervisor, e.g., via email to the student at the study school's chair at least two weeks before the date of the examination).

I. Broad base

I.1. Structural properties and dynamics of the nanoscale systems

General symmetry in solids; crystallography of 3D, 2D, and 1D nanomaterials. Relaxation and reconstruction of surfaces.

Vibrational properties of the lattice - phonons in nanostructures and surface phonon states.

Mechanical properties of nanostructures; plastic, and elastic deformation.

I.2. Electronic structure, optical and magnetic properties

Electrons in the periodic medium, band structure, chemical bonding. Consequences of the reduced dimensions to electronic states of solids (size effect, quantum confinement).

Surface electronic states, electronic states in low-dimensional systems. Linear response theory, optical transitions.

Transport properties - transport equations, scattering mechanisms, quantum Hall effect.

Magnetic properties of low-dimensional structures.

II. Important physical and technological aspects of nanostructures

II.1. Preparation methods

Physical and chemical methods of growth of thin films, nanoparticles, and other important classes of nanomaterials.

Methods of preparation of nanostructures used in the dissertation.

II.2. Characterization methods

Diffraction methods (X-ray and electron diffraction, neutron scattering).
Electron microscopy, ion microscopy, AFM, STM, and other scanning methods.
Methods of surface electron and ion spectroscopy (UPS, XPS, AR PES, AES, etc.).
Optical methods of studying nanostructures (UV / VIS, FTIR spectroscopy, ellipsometry, Raman scattering, nonlinear optical spectroscopy).
Transport methods (electrical conductivity, magnetoresistance, and Hall effect).
Electrochemical methods and other special experimental techniques according to the focus of the doctoral thesis.

III. Selected parts of the problem solved within the topic of the dissertation thesis.

Recommanded literature


A lecturer and supervisor may expand the list of suggested literature by publications and review articles related to the topic of the dissertation.