Physics

Study plan for third-cycle subject

The subject plan was approved by Fakultetsnämnden (Faculty Board) November 30, 2010. Valid from Spring 11.

Subject title

Physics (Fysik)

Subject description and programme outcomes

Scientific field

Physics is the science that describes the structure of matter, the interaction and relationships between matter and energy, and the basic processes of nature. The Doctoral Program in Physics include a number of different research areas in physics, ranging from fundamental and theoretical research within modern physics, applied and strategic research in nuclear technology, to interdisciplinary research in biological and biomedical physics.

Description of possible specialisation

1. Atomic, Subatomic and Astrophysics
2. Theoretical Physics
3. Material and Nano Physics
4. Optics and Photonics
5. Biological and Biomedical Physics
6. Nuclear Engineering

Specification of how the programme outcomes are to be achieved

The aim of the doctoral level education in Physics is to provide deeper knowledge in some of the main areas of Physics, and further in-depth knowledge in one of the fields in Physics that are represented within the Doctoral Program in Physics at KTH.

The goal is that the students after completing the doctoral education will be well prepared for their future roles in society, both nationally and internationally.

Furthermore, the goal of the doctoral level education is that the Ph.D. students will become independent and well-educated scientists that after completion of the education should have the ability to:
• describe and explain theories and empirical results within the area in question
• formulate specific research questions within the area in question
• use scientific methods and develop new knowledge through their own scientific studies
• produce critical analyses and evaluate methods applied and results from their own and others’ scientific studies
• present and discuss research results in the scientific community
• present research in a pedagogical manner outside the scientific community and in an educational context
• assess ethical aspects of research within the area in question and act on that basis, and
• identify needs for new knowledge and have the knowledge to initiate and lead research

Third-cycle studies must also endeavor to ensure that doctoral students will have the ability, after completing the studies, to:

• take part in multi-disciplinary scientific cooperation within the area in question, and
• analyze the role of research in the development of society

Atomic, Subatomic and Astrophysics

Description of the specialisation

Current research

Nuclear Physics

The research focuses on experimental and theoretical research on the atomic nucleus and the multifaceted interaction between nucleons. The experimental research is conducted at international accelerator facilities, with the use of large gamma-ray and particle detector system. Detector development is conducted in strategic research projects, such as Advanced Gamma Tracking Array (AGATA), and for applications in medical technology.

Particle and Astroparticle Physics

Research into particle physics is focused on studies of high-energy collisions, especially at CERN's Large Hadron Collider, to search for signs of new physics such as supersymmetry which could explain the universe's dark matter, and the development of new instrumentation including future upgrades of existing experiments. Astroparticle Physics is focused on studies of X-rays, gamma and charged cosmic rays in which the basic research questions concerning particle acceleration and radiation processes in cosmic plasmas, in our galaxy and around compact objects. Research directed specifically against that contribute to the understanding of dark matter, gamma-ray objects, the origin of cosmic rays and the emission mechanisms of compact stellar objects. The research includes design and development of strategic satellite-and balloon-borne instrumentation as well as analysis and astrophysical interpretation of the data obtained with these instruments.

Applied Atomic and Molecular Physics

Using techniques from atomic and molecular physics the research is focused on the development of new applications, mainly in fusion plasma diagnostics. The aim is to gain knowledge of the hot fusion plasma
properties with these new tools. We are also studying basic atomic and molecular processes with use of synchrotron radiation as excitation source.

**Programme structure**

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**Compulsory and recommended courses**

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**Theoretical Physics**

**Description of the specialisation**

**Current research**

**Condensed Matter Theory**

Development and application of basic condensed matter theories, especially towards the border area with modern statistical physics, including the study of phase transitions, critical phenomena and strongly correlated systems. The research aims to provide a basic understanding of complex phenomena. Idealized models are studied partly using advanced mathematical analysis, and computer simulations. Connection to experimental and possible technological applications are important.

**Mathematical Physics**

Theoretical research on the smallest subatomic particles and their interactions. Mathematical problems related to the design of quantum mechanics and quantum field theory models for the above purpose. Research in this area is closely linked to current research in mathematics, especially differential geometry, topology and group theory.

**Statistical Physics**
Within statistical physics basic theoretical methods and computer simulation methods are developed and used in a very wide field of research ranging from fundamental problems to various applications and interdisciplinary collaborations. The research carried out in close collaboration with experiments. Problem areas include classical and quantum phase transitions, exotic quantum fluids, complex systems, nanosystems, disordered systems, soft matter and biological systems.

**Theoretical Biological Physics**

Theoretical Biological Physics is the application of methods in theoretical physics to describe biological processes at the molecular level. In particular, emphasis is place on statistical mechanics. The research involves analysis of research questions and development of mathematical models in molecular and cell biology. Theoretical Biological Physics is an interdisciplinary research area where a physical, chemical and biological basis is used when seeking to understand the processes that form the basis of all life.

**Theoretical Particle Physics**

Research in theoretical particle physics aims to find a consistent description of the inner structure. Both phenomenological methods and advanced field-theory calculations are used to describe particles of the different properties and types of interactions, with which one hopes to be able to unite in a unified theory in the future. Recently, this research has been brought closer to astrophysics and cosmology.

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**Material and Nano Physics**

**Description of the specialisation**

**Current research**

**Functional Materials**
Research is conducted within development, production and characterization of nanomaterials and composites in terms of how to influence material properties by controlling the dimensions at the nanometer level. Applications include fields such as energy, biomedicine, optics and photonics.

**Semi conductor Materials**

The research in semiconductor materials includes the design of advanced photonic materials, their characterization, process development and component. Photonic crystals, nanostructured surfaces, nanowires, quantum dots, methods for characterizing nanostructures, monolithic integrated photonic components on indium phosphide, hetero-epitaxial III-V semiconductors on silicon for large-scale integration, and silicon photonics are some of the main activities with applications in communications, sensors and energy.

**Material Physics**

Research is primarily conducted in four areas: (1) Nanostructures and their applications, where mainly nanostructures in silicon are studied in terms of both fundamental aspects as well as applications in areas such as biosensors and imaging detectors. (2) Strongly correlated systems, where basic research in mainly conducted within high temperature superconductors, heavy fermion systems, and topological insulators. (3) Spintronics, where research is focused on spinelectronic components and especially spin torsion oscillators. (4) Finally, surface physics, with emphasis on surface reconstructions and surface reactions. The research has relevance to the development of so-called Gretzel solar cells.

**Nanostructure Physics**

Mainly electronic transport properties of nanostructures. Mesoscopic phenomena and quantum phenomena that occur in structures no larger than atoms, but smaller than those of so-called bulk materials. E-beam lithography and low-temperature equipment is used in the manufacture and characterization of structures. The production and experimental study of nanostructures, and modeling of the measurement results.

**Programme structure**

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Optics and Photonics

Description of the specialisation

Current research

Photonics

The research includes three main areas: (1) Technology and component structures within integrated photonics and nanophotonics, with generic applications towards telecommunications, optical interconnect, sensors, lighting, energy and medicine. (2) Optical high-capacity transmission and (3) optical networks, where the first area is a base for the latter two. The research involves a mixture of applied and comparatively basic fundamental research, the former represented by, e.g., optical networks, and the latter by, e.g., the photonic properties of nanoparticles.

Quantum Electronics and Quantum Optics

Basic research on the fundamental properties of light, interaction between light and matter, and quantum mechanical information transfer (such as quantum cryptography) and quantum information processing. Generation and detection of single photon pulses and the application of these. Research on photons entanglement and its applications.

Laser Physics

Fundamental research on the interaction between light and matter, in the form of atoms, molecules and solids. The laser used in nonlinear spectroscopy and the study of time-dependent quantum phenomena. Principles of laser physics and quantum effects when the laser acts as oscillator and amplifier. The long-term goal is that part of the research results generated will have a practical impact, i.e., to develop the technology and materials for more efficient and better light sources.

Optics

Research is primarily conducted in two areas: (1) Electromagnetic optics and (2) spectroscopy in semiconductors. In both these areas the emphasis is on near-field optics and includes research on diffractive optics, micro-lasers, Raman lasers, plasmonics, ultrafast processes in semiconductors and their nanostructures.

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**Biological and Biomedical Physics**

**Description of the specialisation**

**Current research**

**Computational Biological Physics**

The area includes the study of biological problems with the analytical and computational methods from physics, as well as the physical problems of immediate or potential biological interest. The research area differs from bioinformatics as emphasis is placed in the physical issues and/or dynamic models.

**Biomedical and X-Ray Physics**

Mainly experimental research in applied physics is carried out, aimed towards the development of relevant biomedical instrumentation. Development of new types of X-ray sources and X-ray optics and their use for microscopy, medical imaging, bio-analysis as well as materials physics. New optical and acoustic methods for biomedical applications, such as ultrasound-tweezers for cell biology and visual optics for improved peripheral vision.

**Medical imaging**

Research on technical and physical methods in healthcare and medical research in close collaboration between physicians, physicists and engineers. This subject is highly multidisciplinary and results from almost all physical and technical disciplines used. For successful research, a good understanding of the human biology and physiology, the physicians techniques and methods, and physical principles is required.

**Biomolecular Physics**

Research into the use and development of biophysical methods to study the function of biomolecules based on their occurrence, structure, dynamics and interactions. The focus is on development of fluorescence-based methods for single molecule- and fluctuation-spectroscopy and its applications for fundamental biomolecular studies, where the possibility of being able to study single molecules can be utilized, as well as for applications in ultra-sensitive medical diagnostic and screening procedures.

**Cell Physics**
Experimental and theoretical studies on the functions of biological cells, at the boundary between biology and physics. In particular technology development of microscopic methods and techniques, with a focus on studies of individual proteins and their integrated impact on the cell's interaction with the environment. Main themes of research are cellular transport mechanisms and signaling pathways.

**Theoretical Biological Physics**

Theoretical Biological Physics is the application of theoretical methods from physics to describe biological processes at the molecular level, with emphasis especially from statistical mechanics. The research involves analysis of scientific problems and the development of mathematical models within molecular and cell biology.

**Programme structure**

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**Nuclear Engineering**

**Description of the specialisation**

**Current research**

**Nuclear Safety**

The research activity includes studies of severe accident phenomena in nuclear power plants; advanced multi-physics and multi-scale simulation methods for coupled neutron-kinetic and thermal-hydraulic analysis of transients and accidents in nuclear reactors; experiments and analyses to support safety design of advanced nuclear energy systems, and basic research in boiling heat transfer.

**Reactor Physics**

Research on reactor physics focuses on the transmutation of nuclear waste, mainly in design and safety analysis of fourth-generation lead-cooled reactors. In our uranium laboratory, we are developing advanced
nitride fuels with high thermal conductivity. We also use multi-scale modeling to study nuclear fuel characteristics during operation, as well as the radiation damage in different steel models.

**Reactor Technology**

Reactor Technology includes engineering principles for design, analysis and understanding of processes and systems in nuclear power plants with or in connection with thermal hydraulics, reactor physics and structural integrity. The research is largely focused on two-phase flows with applications to nuclear fuel. Both experimental and theoretical research is performed within the group. The experimental part mainly focuses on heat transfer in the reactor core, while the theoretical part covers the methodology and modeling of nuclear systems from micro-scale to system-level with particular focus on the connection between the reactor physics, structural dynamics and thermo-hydraulic processes.

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**Thesis**

The aim of the education during the thesis-part is for the student to develop an ability to make independent contributions to research, as well as a capability for scientific collaboration, within as well as outside their own subject of study. The thesis should include new research results which the student has prepared independently or in collaboration with others. The main scientific results should meet the quality requirements for publication in internationally recognized journals with peer review. The thesis is typically written as a collection of scientific articles with a specific written summary, a so-called compilation thesis. During the thesis work the student should therefore strive for international publication of the achieved research results. A licentiate thesis should include scientific results corresponding to at least two for the research area representative articles publishable in internationally recognized journals with peer review, and include research results that have been presented at at least one international conference. A doctorate thesis should include scientific results corresponding to at least four for the research area representative articles publishable in internationally recognized journals with peer review, and include research results that have been presented at at least two international conferences. The doctoral thesis and licentiate thesis should be written in English.

This thesis work is a mandatory part of the doctoral education to be defended at a public defense in accordance with internal regulations and guidelines that are specified for doctoral and licentiate degrees at KTH.

**Entry requirements and selection**

**General and special admission requirements and prior knowledge**

The general entry requirements follow the regulations specified by the Higher Education Ordinance, and local rules and regulations at KTH.

For special entry requirements to third level education within the Doctoral Program in Physics, the applicant must have:

1. fulfilled the general entry requirements within the area of Physics, or
2. otherwise acquired largely equivalent knowledge, either in or outside Sweden, within areas appropriate for the research area.
Doctoral students are expected to be able to read and write scientific English and to be able to speak English without difficulty. Higher eligibility requirements may apply, depending on the type of research and specialization, and will be outlined in the announcement of the vacant position.

Selection rules and procedures

Selection of applicants is based on the skills profile that is being sought for in the specific projects described in the announcement of the vacant position. Of great interest in the assessment are previous results from advanced courses at second-level, or independently conducted scientific work. Besides general and special eligibility, it is the degree of maturity and ability of independent judgment and critical analysis that provided the basis for the selection. The final choice is based on the student's assessed ability and capability to carry out and assimilate the whole third-level education.

For final admission to the Doctoral Program in Physics it is also required that:

- a supervisor is available and can be appointed to the student,
- there is funding for the student,
- an opening can be prepared within a research group, and
- equipment and infrastructure required for the completion education is available.

The programme’s degrees and examinations

Degree of Licentiate and Degree of Doctor (PhD)

The courses at the doctoral level should include an oral examination or written knowledge test. The design of the examination should in special cases be such that the examiner can be satisfied that the student meets the learning outcomes. Decisions regarding accreditation of courses taken prior to admission to doctoral level education are made in accordance with internal regulations and guidelines that are specified for doctorate and licentiate degree at KTH.

The programme’s examinations