

## Study plan: **PHYSICS - MASTER**

### **Name**

Bokmål: Physics - master

Nynorsk: Physics - master

English: Physics - master

### **Qualification awarded**

Master of Science in Physics.

### **Workload**

120 ECTS credits. With a workload of 30 ECTS credits per semester, the students should be prepared to study a minimum of 40 hours per week on the study program.

### **Learning outcomes**

*Knowledge – The candidate...*

- has a solid basis in natural sciences in general, and in particular in physics
- has advanced knowledge of theory and methods in one of the disciplines offered
- has thorough knowledge about mathematical and statistical methods for analysis of physical problems
- can apply knowledge on new areas of research in one of the disciplines offered
- has good knowledge of scientific method and knows how to conduct a research experiment
- can analyse and assess scientific literature and research in the field of physics

*Skills – The candidate...*

- can use scientific measurement equipment and carry out advanced experiments
- can evaluate and analyse measurement data in a critical manner
- can assess sensors and measurement devices and evaluate and quantify their error sources
- can use programming tools and advanced software for solving physical problems numerically
- can work independently with problem solving following scientific method
- can evaluate and analyse published theories, methods and experiments in the physics literature
- can carry out an independent, limited research or development project under supervision in physics or related areas

*General competences – The candidate...*

- displays good communication skills, oral and written, in the presentation of scientific work for both the general public and for the specialists in the field
- can analyse academic, professional and research ethical problems in the field of physics
- displays good working habits and follows the code of ethics in scientific work
- can continue a career within research, teaching, production, development and technical professions in the society
- can produce a well-structured presentation of an extensive independent scientific work
- can contribute to new thinking and innovation processes in the field of physics

### **Admission requirements**

Admission to the Master's programme in physics requires a Bachelor's degree in physics, or another degree following a programme of study of not less than three years' duration, or similar education approved in accordance with the Norwegian Universities Act section 3-4.

In addition, specialisation in physics worth the equivalent of not less than 80 ECTS credits is required. Normally, an average mark of C or better is required in the Bachelor's degree or similar basis of admission. Students are expected to have skills equivalent to the prerequisites the courses in the study program build upon.

### **Target group**

The Master's programme in physics is aimed at students holding a Bachelor's degree in physics or similar who are interested in pursuing a career in earth observation, electrical engineering, energy and climate, or space physics.

### **Programme description**

The Master's programme in physics offers specialisation in four disciplines:

- Earth Observation
- Electrical Engineering
- Energy and Climate
- Space Physics

#### *Earth Observation*

The Earth Observation discipline teaches techniques for monitoring objects, surface classes, processes and parameters on the Earth with spaceborne and airborne instruments. Earth observation by satellite remote sensing provides large benefits to climate research, environmental monitoring and resource management, particularly in remote and uninhabited areas. The Earth Observation research group in Tromsø specialises in the analysis of satellite images for maritime and cryosphere applications in the High North, but also work with terrestrial applications such as forest monitoring and vegetation mapping.

The central location of Tromsø in the Arctic has led to substantial activity related to earth observation and remote sensing technologies. Today, around 250 people work with remote sensing in the Tromsø area, producing steadily increasing revenues, which makes it a sector of major economic importance. The Earth Observation group at UiT contributes to this development both through fundamental research and application development. The group has strong connections to the local companies, research institutes and users of satellite images, as well as to international research institutes. The cross-disciplinary collaboration with these actors is vital in the design of useful tools for applications such as oil spill detection, ship detection, sea ice charting and glacier monitoring. The Earth Observation group possesses a large archive of satellite data and ground truth data, participates actively in cruises and field campaigns that collect reference data, and has access to powerful computing facilities.

The objective of the Earth Observation discipline is to teach the techniques used in satellite remote sensing of the Earth, with a focus on environmental monitoring. The tools are drawn from various fields such as signal and image processing, pattern recognition, applied statistics and physics. The aim is further to deliver candidates to the earth observation community, providing competent workers to all levels of the value chain, from users of remote sensing data in resource management and decision-making bodies to industry companies, research institutes and academia.

Exercises, assignments, and Master thesis projects given are defined in relation to on-going research activity or current scientific interests within the Earth Observation group.

## *Electrical Engineering*

Electrical engineering provides solutions to the ever-increasing advanced technological demands of modern society. Technology and industry is rapidly developing. Electrical engineering education and competence is at the core of this transition, and will provide a solid foundation for employment in several growth industries. Sensors are essential, for example in medicine and biological research, for new materials, and for oil and gas. This requires knowledge about optics, nanotechnology, transducers, and imaging techniques. In society, there is a virtual explosion of data from websites, images, speech, genes, etc., requiring innovative data analysis based on machine learning, pattern recognition, statistics, and signal- and image analysis implemented in scalable computer programs.

The Electrical Engineering discipline offers specialisation in five different fields of research:

- Optics
- Nanoscopy
- Microwave techniques
- Ultrasound
- Machine learning

In Tromsø, electrical engineering education is based on a strong research group covering all these fields. There are good facilities for laboratory work with modern equipment.

The Electrical Engineering group covers a wide range of application areas, some of which are the oil and gas sector, bio-medical physics and imaging, super-resolution optical microscopy/optical nanoscopy, and health analytics:

- The petroleum oil and gas industry is of key national importance. The majority of the remaining petroleum resources are located offshore northern Norway, leading to new challenges with respect to equipment operating in a cold and harsh climate. The Electrical Engineering group is leading a consortium of research institutions and oil companies performing research on and development of the next generation cold-water subsea sensors. Petroleum activity in the north also poses environmental issues since spills may affect one of Europe's most important breeding areas for fish. The Electrical Engineering group is developing data analysis methods for early detection of errors in the petroleum production line.
- Bio-medical physics and imaging research in the Electrical Engineering group is concentrated on development of new antenna concepts capable of both producing hyperthermia and receiving extremely weak radiated electromagnetic waves containing information on the tissue temperature distribution (microwave radiometry). Hyperthermia is an anti-tumoral therapeutic modality. It consists of selective heating of tumors to temperatures above 42 degrees Celsius, while maintaining healthy tissue nearer to physiological temperatures.
- Optical Nanoscopy research in the Electrical Engineering Group is at the crossroads of Biology and Physics. The group is developing novel fluorescence optical nanoscopy techniques for real-time imaging of sub-cellular organelles (50-100 nm) in living cells. The experimental facilities consist of state-of-the-art commercial high-speed structured illumination microscopy (SIM) and direct stochastic optical reconstruction microscopy (dSTORM) and custom build epi-fluorescence microscopy/nanoscopy based on optical waveguides.
- Health Analytics in the Electrical Engineering group is focused towards machine learning and data mining in electronic health records (where all the data recorded for each patient in the healthcare

system is stored), for personalized medical diagnosis support, for discovering hidden comorbidity patterns, and for decision support for clinicians. Researchers from the Electrical Engineering group have especially been involved in projects using data from the University Hospital of North Norway related to colorectal cancer and gastrointestinal surgery.

### *Energy and Climate*

Climate change has made it critical to search for environmentally friendly and sustainable sources of energy. There is a great need for knowledge that can help us undertake the shift towards sustainable energy production. We need to develop sustainable energy solutions, for instance from fusion energy, wind, and solar sources. In addition, continued monitoring of climate change, its causes and effects, and an understanding of climate dynamics in general will be essential for coming generations in order to make climate predictions. This is the knowledge that the Energy and Climate discipline aims to provide. The education and the master's projects offered are rooted in the research interests at UiT within the field. Current research on sustainable energy concentrates on renewable energy and fusion energy. The research on climate change concerns climate modelling and polar meteorology. Most activities are oriented towards challenges and opportunities in the High North. Students will find work opportunities in the energy and power private sector as well as in major companies that has sustainability and self-sufficiency on their agenda. In addition, students may continue with their work in science at research institutes and the university sector within sustainable energy and climate dynamics.

This discipline offers specialisation in three different fields of research:

- Climate dynamics
- Fusion plasma physics
- Solar energy and hybrid systems

The climate dynamics specialisation provides knowledge on atmosphere and ocean circulation, processes important in the climate system, and climate change due to natural and anthropogenic external forcings. The specialisation includes a solid program in physics and mathematics and provides knowledge within fluid dynamics and climate modelling. Special attention is given to the climate of the Arctic. A master's thesis in this field will test hypotheses concerning processes and couplings in the climate system, for instance related to the coupling between atmospheric circulation and Arctic climate.

Students following the fusion plasma physics specialisation will acquire a high level of knowledge of fluid dynamics, plasma physics, turbulent motions, energy transport, and numerical calculations. Candidates with these skills are highly desired in the scientific research sector and industry nationally and abroad. The Sun and other stars are powered by the energy released from fusion of hydrogen into helium. For more than half a century, there has been a large international research program focused on the development of controlled thermonuclear fusion for production of clean electrical energy on Earth. If successful, this will provide humankind with electrical energy for millennia. The fusion process requires so high temperatures that the matter is in the state of a plasma. In a reactor, this plasma will be confined by strong magnetic fields.

Students following the solar energy and hybrid systems specialisation will acquire in-depth insight into the nature of this source of energy, and how it can be exploited for the benefit of humankind. In particular, candidates will be trained to understand the physics and mathematics behind solar energy conversion. The student will learn how various materials harvest solar energy on a nanoscale all the way to how to design complete solar energy systems and, importantly, how the intermittent nature of the energy source can be dealt with. For solar energy to become widespread, successful and game

changing it is crucial to have renewable energy hybrid systems and good energy storage possibilities. A hybrid system is when for example wind and solar energy as well as an energy storage capacity is working together to create a more self-sufficient and secure energy supply system.

### *Space Physics*

Tromsø is in a unique geographical position to study the Aurora Borealis and the upper Polar atmosphere, and we have long traditions since the early 1900's within this field of research. The Auroral Observatory in Tromsø formed the original basis of the physics studies at UiT The Arctic University of Norway. Today, the activities have been extended to research on the solar corona, the Sun-Earth interaction, and the upper atmosphere. Researchers at the Department of Physics and Technology work with data from the EISCAT (European Incoherent SCATter) radars and other instruments at Ramfjordmoen, Svalbard, and Andøya, with numerical modelling, and with laboratory experiments (Aurolab).

The Northern (and Southern) Lights are manifestations of space weather that has its origin in the variability of the Sun's activity. Most auroras occur as a result of huge solar magnetic explosions (solar mass ejections and solar flares) that enhance the solar wind and solar radiation arriving at the Earth. The scales of the perturbations that follow (geomagnetic storms) vary from the size of the Earth's magnetotail (about 200 Earth radii) to the fine structure of the aurora (tens of meters) at 100-200 km height above the Earth's surface.

As a student on the Master's degree programme in physics, you can choose one-year projects on a range of topics, for example:

- Observations with EISCAT of phenomena in the upper polar atmosphere, e.g. ion instabilities, fine structures in the aurora, and space weather (dynamics).
- Analysis and interpretation of EISCAT and other radar observations.
- Experimental, theoretical and numerical studies of dusty plasmas in the mesosphere with rockets, mesospheric and EISCAT radars.
- Theoretical and numerical analysis of turbulence and transport in space and laboratory plasma.
- Experimental studies of plasma phenomena in laboratory plasmas.

### **Requirements for the independent work**

The Master's thesis corresponds to a workload of 60 ECTS credits and must be submitted within a deadline set in connection with approval of the supervision contract. After handing in the Master's thesis, it is assessed, and normally within 6 weeks an oral presentation and examination is held, that may influence on the final mark. The Master's project must be carried out on an individual basis.

### **Teaching**

The courses in the study programme have varied forms of instruction, typically lectures, exercises, laboratory work, computer work, or combinations of these.

Special curricula, project papers and the Master's thesis are supervised on an individual basis by the department's academic staff, possibly in collaboration with external companies or institutions by agreement.

### **Programme structure**

The study programmes for the four disciplines should mainly consist of courses at the master's level (3000 level). At most 10 ECTS credits are allowed from 2000 level courses in physics. Additional 2000 level courses from other fields of science than Physics and Technology (e.g., courses in mathematics,

statistics or informatics) can be allowed if they are considered as very relevant for the field of work and the topic of the master thesis. Students must send an application to the Department of Physics and Technology for the 2000 level courses they wish to include in their master's degree, and only the accepted courses can be a part of the master's degree.

If the Master's thesis involves work in a laboratory, in the field or on a research cruise, it is mandatory to conduct a course in safety education prior to commencing the thesis.

### *Earth Observation*

Compulsory courses in the Earth Observation discipline:

- FYS-3001 Earth observation
- FYS-3012 Pattern recognition
- FYS-3023 Environmental monitoring from satellite
- FYS-3900 Master's thesis in physics

Generally recommended optional courses in the Earth Observation discipline:

- FYS-3011 Detection theory
- FYS-3810 Individual special curriculum
- STA-2002 Theoretical statistics
- STA-3001 Computer-intensive statistics
- STA-3002 Multivariable statistical analysis
- STA-3003 Nonparametric inference

Optional courses should be determined in collaboration with your supervisor in connection with choice of research topic in the Master's thesis. Other optional courses may be approved on application or if recommended by your supervisor. An individual special curriculum or project paper may also be part of the degree.

### *Electrical Engineering*

Compulsory courses in the Electrical Engineering discipline:

- FYS-3900 Master's thesis in physics

Students are required to choose at least four of the following 3000-level courses:

- FYS-3007 Microwave techniques
- FYS-3009 Photonics
- FYS-3011 Detection theory
- FYS-3012 Pattern recognition
- FYS-3024 Biomedical instrumentation and imaging
- FYS-3029 Optical nanoscopy
- FYS-3810 Individual special curriculum
- STA-3001 Computer-intensive statistics
- STA-3002 Multivariable statistical analysis
- STA-3003 Nonparametric inference

Optional courses in the Electrical Engineering discipline may be chosen from those 3000-level courses listed above, that were not chosen among the four required 3000-level courses.

Additional relevant optional courses for Electrical Engineering are:

- FYS-2006 Signal processing
- FYS-2007 Statistical signal theory
- FYS-2008 Measurement techniques
- FYS-2010 Digital image processing
- FYS-3001 Earth observation from satellites
- FYS-3023 Environmental monitoring from satellite
- \* AUT-2006 Elektronikk
- \* INF-2200 Datamaskinarkitektur og -organisering
- \* INF-2201 Operativsystem
- \* MAT-2100 Kompleks analyse
- MAT-2200 Differential equations
- MAT-2201 Numerical methods
- MAT-2202 Optimization models
- MAT-2300 Algebra 1
- MAT-3113 Nonlinear partial differential equations
- MAT-3114 Algebraic topology
- MAT-3200 Mathematical methods
- STA-2001 Stochastic processes
- STA-2002 Theoretical statistics
- \* STA-2003 Tidsrekker

\* = Currently only offered in Norwegian.

Optional courses should be determined in collaboration with your supervisor in connection with choice of research topic in the Master's thesis. Other optional courses may be approved on application or if recommended by your supervisor. An individual special curriculum or project paper may also be part of the degree.

### *Energy and Climate*

Compulsory courses in the Energy and Climate discipline:

- FYS-3900 Master's thesis in physics

Students are required to choose at least one of the following courses:

- FYS-3026 Fusion plasma physics
- FYS-3028 Solar energy and energy storage
- FYS-3030 Fluid dynamics of atmospheres and oceans
- MAT-3213 Climate dynamics

Students specialising in fusion plasma physics must either choose FYS-2009 Introduction to plasma physics the first Autumn semester, or they must have similar background from their previous education.

Recommended optional courses approved in the climate dynamics specialisation:

- FYS-3001 Earth observation from satellites

- FYS-3030 Fluid dynamics of atmospheres and oceans
- FYS-3810 Individual special curriculum
- MAT-2201 Numerical methods
- MAT-3200 Mathematical methods
- MAT-3202 Nonlinear waves

Recommended optional courses approved in the fusion plasma physics specialisation:

- FYS-3030 Fluid dynamics of atmospheres and oceans
- FYS-3810 Individual special curriculum
- MAT-2201 Numerical methods
- MAT-3200 Mathematical methods
- MAT-3202 Nonlinear waves

Recommended optional courses approved in the solar energy and hybrid systems specialisation:

- FYS-2006 Signal processing
- FYS-2007 Statistical signal theory
- FYS-3009 Photonics
- FYS-3029 Optical nanoscopy
- FYS-3030 Fluid dynamics of atmospheres and oceans
- FYS-3810 Individual special curriculum
- MAT-2201 Numerical methods
- BIO-3111 GIS and remote sensing
- \*AUT-2005 Reguleringsteknikk
- \*AUT-2006 Elektronikk

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Optional courses should be determined in collaboration with your supervisor in connection with choice of research topic in the Master's thesis. Other optional courses may be approved on application or if recommended by your supervisor. An individual special curriculum or project paper may also be part of the degree.

### *Space Physics*

Compulsory courses in the Space Physics discipline:

- FYS-2009 Introduction to plasma physics
- FYS-3003 Cosmic geophysics
- FYS-3900 Master's thesis in physics

Recommended optional courses approved in the Space Physics discipline:

- FYS-3000 Introduction to satellite and rockets techniques and space instrumentations
- FYS-3002 Techniques for investigating the near-earth space environment
- FYS-3017 Experimental methods in laboratory and space plasma



Other optional courses approved for Space Physics:

- FYS-3001 Earth observation from satellites
- FYS-3007 Microwave techniques
- FYS-3011 Detection theory
- FYS-3012 Pattern recognition
- FYS-3023 Environmental monitoring from satellite
- FYS-3026 Fusion plasma physics
- FYS-3030 Fluid dynamics of atmospheres and oceans
- FYS-3810 Individual special curriculum
- MAT-3113 Nonlinear partial differential equations
- MAT-3200 Mathematical methods

Optional courses should be determined in collaboration with your supervisor in connection with choice of research topic in the Master's thesis. Other optional courses may be approved on application or if recommended by your supervisor. An individual special curriculum or project paper may also be part of the degree.

### Study plan table

#### *Earth Observation*

S2	FYS-3900 Master's thesis in physics (30 of 60 ECTS credits)		
A2	FYS-3900 Master's thesis in physics (20 of 60 ECTS credits)		FYS-3023 Environmental monitoring from satellite (10 ECTS credits)
S1	FYS-3900 Master's thesis in physics (10 of 60 ECTS credits)	Optional course (10 ECTS credits)	FYS-3001 Earth observation (10 ECTS credits)
A1	Optional course (10 ECTS credits)	FYS-3012 Pattern recognition (10 ECTS credits)	Optional course (10 ECTS credits)

#### *Electrical Engineering*

S2	FYS-3900 Master's thesis in physics (30 of 60 ECTS credits)		
A2	FYS-3900 Master's thesis in physics (20 of 60 ECTS credits)		Obligatory course (10 ECTS credits)
S1	FYS-3900 Master's thesis in physics (10 of 60 ECTS credits)	Obligatory course (10 ECTS credits)	Optional course (10 ECTS credits)
A1	Obligatory course	Obligatory course	Optional course

	(10 ECTS credits)	(10 ECTS credits)	(10 ECTS credits)
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### *Energy and Climate*

S2	FYS-3900		
A2	Master's thesis in physics (60 ECTS credits)		
S1	Obligatory course (10 ECTS credits)	Optional courses (20 ECTS credits)	
A1	Optional courses (30 ECTS credits)		

### *Space Physics*

S2	FYS-3900		
A2	Master's thesis in physics (60 ECTS credits)		
S1	FYS-3003 Cosmic geophysics (10 ECTS credits)	Optional courses (20 ECTS credits)	
A1	FYS-2009 Introduction to plasma physics (10 ECTS credits)	Optional courses (20 ECTS credits)	

### **Assessment**

Form of assessment varies, but most examinations are portfolio assessments of a take-home exam, project paper or laboratory report, in combination with a final oral or written exam. In some courses, mandatory assignments have to be approved for access to the exam.

### **Language of instruction**

Language of instruction is English and all of the syllabus material is in English. Examination questions will be given in English, but may be answered either in English or in a Scandinavian language.

Also the Master's thesis may be written either in English or in a Scandinavian language.

### **Internationalisation and exchange possibilities**

Exchange studies abroad or at the University Centre in Svalbard can be recognised in the Master's degree if recommended by your supervisor, and only if the external courses are validated prior to departure. The period of time for the exchange studies depends on the individual educational plan, and should be planned in collaboration with the student advisor and the students supervisor.

A link to a list over exchange opportunities is given on the webpage for the study program.

### **Syllabus**

Syllabus and reading list will be prepared for each individual course and presented at the start of studies.

**Other regulations**

The Faculty of Science and Technology has developed supplementary regulations for the Master's programmes.

The study programme is evaluated every year according to the university's quality assurance system. The courses in the study programme are evaluated every third time they are given, as a minimum. Course evaluation consists of both student and teacher reports.