Physics

Physics is a scientific subject that has its origins in the need of human beings to understand and explain the world around them. Physics covers everything from the interaction of the smallest particles of matter to the origins and structure of the universe. On the basis of systematic observations and experiments, physics strives to discover basic principles that can be expressed mathematically in models and theories.

Aim of the subject

Teaching in the subject of physics should aim at helping students develop knowledge of the concepts, theories, models and working methods of physics. It should contribute to students developing knowledge about different applications of physics in areas such as technology, medicine and sustainable development, thereby enhancing understanding of the importance of physics in society. Teaching should give students the opportunity to develop a scientific approach to the surrounding world. Teaching should take advantage of current research and students' experiences, curiosity and creativity. Teaching should also help students participate in public debates and discuss ethical issues and views from a scientific perspective.

Physics is constantly being developed in interaction between theory and experiment, where hypotheses, theories and models are tested, re-assessed and modified. Teaching should thus cover the development, limitations and areas of applicability of theories and models. It should contribute to students developing the ability to work theoretically and experimentally, and to communicate using scientific language. Teaching should also help students develop the ability to critically assess and distinguish between statements based on scientific and non-scientific foundations.

Teaching should cover scientific working methods such as formulating and searching for answers, planning and carrying out observations and experiments, and processing, interpreting and critically assessing results and information. Students should be given the opportunity to analyse and solve problems through reasoning based on concepts and models, both with and without the use of mathematics. Teaching should give students the opportunity to discuss and present analyses and conclusions. They should also be given the opportunity to use computerised equipment for collecting, simulating, calculating, processing and presenting data.

Teaching in the subject of physics should give students the opportunities to develop the following:

1) Knowledge of the concepts, models, theories and working methods of physics, and also understanding their development.

2) The ability to analyse and find answers to subject-related questions, and to identify, formulate and solve problems. The ability to reflect on and assess chosen strategies, methods and results.
3) The ability to plan, carry out, interpret and report experiments and observations, and also the ability to handle materials and equipment.
4) Knowledge of the importance of physics for the individual and society.
5) The ability to use a knowledge of physics to communicate, and also to examine and use information.

Courses in the subject

- Physics 1a, 150 credits, which builds on knowledge from the compulsory school or equivalent. Grades in the course cannot be included in the student's diploma together with grades in the courses, physics 1b1, or, physics 1b2.
- Physics 1b1, 100 credits, which builds on knowledge from the compulsory school or equivalent. Grades in the course cannot be included in the student's diploma together with grades in the course, physics 1a.
- Physics 1b2, 50 credits, which builds on the course, physics 1b1. Grades in the course cannot be included in the student's diploma together with grades in the course, physics 1a.
- Physics 2, 100 credits, which builds on the course, physics 1a, or the course, physics 1b2.
- Physics 3, 100 credits, which builds on the course, physics 2.

Physics 1a

The course, physics 1a, covers points 1–5 under the heading Aim of the subject.

Core content

Teaching in the course should cover the following core content:

Motion and force

- Speed, momentum and acceleration to describe motion.
- Force as a cause of change in velocity and momentum.
- Equilibrium and linear motion in homogenous gravitational fields and electrical fields.
- Pressure, pressure variations and Archimedes' principle.
- Orientation to Einstein's description of motion at high speeds: Einstein's postulates, time dilation and relative energy.
- Orientation to current models for describing the smallest components of matter, and fundamental forces, and also how the models have been developed.

Energy and energy resources

- Work, force, potential energy and kinetic energy to describe different forms of energy: mechanical, thermal, electrical and chemical energy, and also radiation and nuclear energy.
- The energy principles, entropy and efficiency to describe energy transformation, energy quality and energy storage.
- Thermal energy: internal energy, heat capacity, heat transfer, temperature and phase transformation.
- Electrical energy: Electrical charging, field strength, potential, voltage, current and resistance.
- Nuclear energy: the structure of an atom and nuclear binding energy, strong forces, mass energy equivalence, nuclear reactions, fission and fusion.
- Energy resources and use of energy for a sustainable society.

Radiation in medicine and technology

- Radioactive disintegration, ionising radiation, particle radiation, half life and activity.
- Orientation to electromagnetic radiation and the particle properties of light.
- The interaction between different types of radiation and biological systems, absorbed and equivalent doses. Radiation safety.
- Applications in medicine and technology.

Climate and weather forecasts

- The ideal gas law as a model for describing the physics of the atmosphere.
- Orientation to how physical models and methods of measurement are used to forecast climate and weather.
- Reliability and limitations of forecasts.

The nature, working methods, and mathematical methods of physics.

- The characteristics of a scientific problem.
- How models and theories provide simplifications of reality, and can be changed over time.
- The importance of experimental work in testing, re-assessing and revising hypotheses, theories and models.
- Identifying and studying problems using reasoning from physics and mathematical modelling covering linear equations, power and exponential equations, functions and graphs, and trigonometry and vectors.
- Planning and implementation of experimental investigations and observations, and formulating and testing hypotheses in connection with this.
- Processing and assessing data on results using graphs, unit analysis, and estimates of size.
- Assessing results and conclusions by analysing choice of methods, work processes and sources of error.
- Views on societal questions based on explanatory models of physics, e.g. questions about sustainable development.

Knowledge requirements

Grade E

Students give an account **in basic terms** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in basic terms** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **simple** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with some certainty** their own issues. Students plan and carry out **in consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, evaluate their methods in **simple** assessments and give the reasons for their conclusions with **simple** reasoning.

Students discuss **in basic terms** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **simple** arguments and give an account **in basic terms** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to some extent** their communication to purpose and context. In addition, students use different types of sources and make **simple** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade D

Grade D means that the knowledge requirements for grade E and most of C are satisfied.

Grade C

Students give an account **in detail** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **complex** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses, and formulate **with some certainty** their own issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **simple** assessments and give the reasons for their conclusions with **well grounded** reasoning.

Students discuss **in detail** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded** arguments, and give an account **in detail** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. In addition, students use different types of sources and make **well grounded** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade B

Grade B means that the knowledge requirements for grade C and most of A are satisfied.

Grade A

Students give an account **in detail and in a balanced way** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with certainty** to look for answers to issues, and to describe and **generalise about** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail and in a balanced way** of how the models and theories of physics have been developed. Students evaluate also the validity and limitations of models in **balanced** assessments.

Students identify, analyse and solve **complex** problems in **familiar and new situations** with **good** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with certainty complex** issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **balanced** assessments and give reasons for their conclusions with **well grounded and balanced** reasoning. **Where necessary, students also propose changes**.

Students discuss **in detail and in a balanced way complex** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded and balanced** arguments and give an account **in detail and in a balanced way** of the consequences of **several** possible viewpoints. **Students also propose new issues for discussion**.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. Students use different types of sources and make **well grounded and balanced** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with certainty** their own ability and the requirements of the situation.

Physics 1b1

The course, physics 1b1, covers points 1–5 under the heading Aim of the subject.

Core content

Teaching in the course should cover the following core content:

Motion and force

- Speed, momentum and acceleration to describe motion.
- Force as a cause of change in velocity and momentum.
- Equilibrium and linear motion in homogenous gravitational fields and electrical fields.
- Pressure, pressure variations and Archimedes' principle.
- Orientation to Einstein's description of motion at high speeds: Einstein's postulates, time dilation and relative energy.

Energy and energy resources

- Work, force, potential energy and kinetic energy to describe different forms of energy: mechanical, thermal, electrical and chemical energy, and also radiation and nuclear energy.
- The energy principles, entropy and efficiency to describe energy transformation, energy quality and energy storage.
- Thermal energy: internal energy, heat capacity, heat transfer, temperature and phase transformation.
- Electrical energy: Electrical charging, field strength, potential, voltage, current and resistance.
- Energy resources and use of energy for a sustainable society.

The nature, working methods, and mathematical methods of physics.

- The characteristics of a scientific problem.
- How models and theories provide simplifications of reality, and can be changed over time.
- The importance of experimental work in testing, re-assessing and revising hypotheses, theories and models.
- Identifying and studying problems using reasoning from physics and mathematical modelling covering linear equations, exponential equations, functions and graphs, and trigonometry and vectors.
- Planning and implementation of experimental investigations and observations, and formulating and testing hypotheses in connection with this.

- Processing and assessing data on results using graphs, unit analysis, and estimates of size.
- Assessing results and conclusions by analysing choice of methods, work processes and sources of error.
- Views on societal questions based on the explanatory models of physics, e.g. questions about sustainable development.

Knowledge requirements

Grade E

Students give an account **in basic terms** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in basic terms** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **simple** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with some certainty** their own issues. Students plan and carry out **in consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, evaluate their methods in **simple** assessments and give the reasons for their conclusions with **simple** reasoning.

Students discuss **in basic terms** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **simple** arguments and give an account **in basic terms** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to some extent** their communication to purpose and context. In addition, students use different types of sources and make **simple** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade D

Grade D means that the knowledge requirements for grade E and most of C are satisfied.

Grade C

Students give an account **in detail** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **complex** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses, and formulate **with some certainty** their own issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **simple** assessments and give the reasons for their conclusions with **well grounded** reasoning.

Students discuss **in detail** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded** arguments, and give an account **in detail** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. In addition, students use different types of sources and make **well grounded** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade B

Grade B means that the knowledge requirements for grade C and most of A are satisfied.

Grade A

Students give an account **in detail and in a balanced way** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with certainty** to look for answers to issues, and to describe and **generalise about** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail and in a balanced way** of how the models and theories of physics have been developed. Students evaluate also the validity and limitations of models in **balanced** assessments.

Students identify, analyse and solve **complex** problems in **familiar and new situations** with **good** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with certainty complex** issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **balanced** assessments and give reasons for their conclusions with **well grounded and balanced** reasoning. **Where necessary, students also propose changes**.

Students discuss **in detail and in a balanced way complex** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded and balanced** arguments and give an account **in detail and in a balanced way** of the consequences of **several** possible viewpoints. **Students also propose new issues for discussion**.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. Students use different types of sources and make **well**

grounded and balanced assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with certainty** their own ability and the requirements of the situation.

Physics 1b2

The course, physics 1b2, covers points 1–5 under the heading Aim of the subject.

Core content

Teaching in the course should cover the following core content:

Motion and force

- Orientation to current models for describing the smallest components of matter, and fundamental forces, and also how the models have been developed.

Energy and energy resources

- Nuclear energy: the structure of an atom and nuclear binding energy, strong forces, mass energy equivalence, nuclear reactions, fission and fusion.

Radiation in medicine and technology

- Radioactive disintegration, ionising radiation, particle radiation, half life and activity.
- Orientation to electromagnetic radiation and the particle properties of light.
- The interaction between different types of radiation and biological systems, absorbed and equivalent doses. Radiation safety.
- Applications in medicine and technology.

Climate and weather forecasts

- The ideal gas law as a model for describing the physics of the atmosphere.
- Orientation to how physical models and methods of measurement are used to forecast climate and weather.
- Reliability and limitations of forecasts.

The nature, working methods, and mathematical methods of physics.

- The characteristics of a scientific problem.
- How models and theories provide simplifications of reality, and can be changed over time.
- The importance of experimental work in testing, re-assessing and revising hypotheses, theories and models.
- Identifying and studying problems using reasoning from physics and mathematical modelling covering linear equations, power and exponential equations, functions and graphs.
- Planning and implementation of experimental investigations and observations, and formulating and testing hypotheses in connection with this.

- Processing and assessing data on results using graphs, unit analysis, and estimates of size.
- Assessing results and conclusions by analysing choice of methods, work processes and sources of error.
- Views on societal questions based on the explanatory models of physics, e.g. questions about sustainable development.

Knowledge requirements

Grade E

Students give an account **in basic terms** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in basic terms** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **simple** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with some certainty** their own issues. Students plan and carry out **in consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, evaluate their methods in **simple** assessments and give the reasons for their conclusions with **simple** reasoning.

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Students use **with some certainty** the language of science and adapt **to some extent** their communication to purpose and context. In addition, students use different types of sources and make **simple** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade D

Grade D means that the knowledge requirements for grade E and most of C are satisfied.

Grade C

Students give an account **in detail** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **complex** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses, and formulate **with some certainty** their own issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **simple** assessments and give the reasons for their conclusions with **well grounded** reasoning.

Students discuss **in detail** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded** arguments, and give an account **in detail** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. In addition, students use different types of sources and make **well grounded** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade B

Grade B means that the knowledge requirements for grade C and most of A are satisfied.

Grade A

Students give an account **in detail and in a balanced way** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with certainty** to look for answers to issues, and to describe and **generalise about** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail and in a balanced way** of how the models and theories of physics have been developed. Students evaluate also the validity and limitations of models in **balanced** assessments.

Students identify, analyse and solve **complex** problems in **familiar and new situations** with **good** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with certainty complex** issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **balanced** assessments and give reasons for their conclusions with **well grounded and balanced** reasoning. **Where necessary, students also propose changes**.

Students discuss **in detail and in a balanced way complex** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded and balanced** arguments and give an account **in detail and in a balanced way** of the consequences of **several** possible viewpoints. **Students also propose new issues for discussion**.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. Students use different types of sources and make **well**

grounded and balanced assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with certainty** their own ability and the requirements of the situation.

Physics 2

The course, physics 2, covers points 1–5 under the heading Aim of the subject.

Core content

Teaching in the course should cover the following core content:

Motion and force

- Two-dimensional motion in gravitational fields and electrical fields.
- Central motion.
- Torque to describe states of equilibrium.
- Simulating two-dimensional motion using simple numerical methods.

Waves, electromagnetism and signals

- Harmonic oscillation as a model for describing phenomena in everyday life and technology.
- Reflection, refraction and interference of light, sound and other wave motion.
- Harmonic oscillation and resonance with applications in everyday life and technology.
- Orientation to volume and Doppler effects.
- Relationships between electrical and magnetic fields: magnetic fields around current carrying conductors, motion of electric charges in magnetic fields, induction and some applications e.g. alternating current generators and transformers.
- Wave and particle descriptions of electromagnetic radiation. Orientation to propagation of electromagnetic waves. Photoelectric effects and the concept of photons.
- Wave properties of matter. de Broglie's hypotheses and wave-particle duality.
- Physics principles underlying technical applications for communication and detection.

The development and structure of the universe

- Orientation to current models and theories for describing the universe's large-scale development and formation of galaxies, stars and planets.
- The electron structure of atoms, and absorption and emission spectra.
- Methods for studying the universe. Electromagnetic radiation from stars and interstellar space.
- Methods for identifying and studying exoplanets. Conditions for life on other planets.

The nature, working methods, and mathematical methods of physics.

- Models and theories as simplifications of reality. Models and their areas of applicability and how they can be developed, generalised or replaced by other models and theories over time.
- The importance of experimental work in testing, re-assessing and revising hypotheses, theories and models.
- Identifying and studying problems using reasoning from physics and mathematical modelling covering linear and non-linear functions, equations and graphs, and derivatives and vectors.
- Planning and implementation of experimental investigations and observations, and formulating and testing hypotheses in connection with this.
- Processing and assessing data and results using regression analysis, analysis of graphs, unit analysis, and estimates of size.
- Assessing results and conclusions by analysing choice of methods, work processes, sources of error and measuring uncertainty.
- Relations and links between physics and ethical, philosophical and religious issues.

Knowledge requirements

Grade E

Students give an account **in basic terms** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in basic terms** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **simple** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with some certainty** their own issues. Students plan and carry out **in consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, evaluate their methods in **simple** assessments and give the reasons for their conclusions with **simple** reasoning.

Students discuss **in basic terms** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **simple** arguments and give an account **in basic terms** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to some extent** their communication to purpose and context. In addition, students use different types of sources and make **simple** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade D

Grade D means that the knowledge requirements for grade E and most of C are satisfied.

Grade C

Students give an account **in detail** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **complex** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses, and formulate **with some certainty** their own issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **simple** assessments and give the reasons for their conclusions with **well grounded** reasoning.

Students discuss **in detail** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded** arguments, and give an account **in detail** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. In addition, students use different types of sources and make **well grounded** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade B

Grade B means that the knowledge requirements for grade C and most of A are satisfied.

Grade A

Students give an account **in detail and in a balanced way** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with certainty** to look for answers to issues, and to describe and **generalise about** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail and in a balanced way** of how the models and theories of physics have been developed. Students evaluate also the validity and limitations of models in **balanced** assessments.

Students identify, analyse and solve **complex** problems in **familiar and new situations** with **good** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with certainty complex** issues. Students plan and carry out **after consultation** with the supervisor experiments and observations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **balanced** assessments and give reasons for their conclusions with **well grounded and balanced** reasoning. **Where necessary, students also propose changes**.

Students discuss **in detail and in a balanced way complex** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded and balanced** arguments and give an account **in detail and in a balanced way** of the consequences of **several** possible viewpoints. **Students also propose new issues for discussion**.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. Students use different types of sources and make **well grounded and balanced** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with certainty** their own ability and the requirements of the situation.

Physics 3

The course, physics 3, covers points 1–5 under the heading Aim of the subject.

Core content

Teaching in the course should cover the following core content:

Motion and force

- In-depth treatment of force and motion e.g. motion with air and fluid resistance, impact in two dimensions, angular momentum and rotational motion.
- In-depth treatment of harmonic oscillation with applications in e.g. damped oscillation, electrical AC circuits or radio communications.
- In-depth treatment of wave motion with application in e.g. acoustics, movement in the Earth's crust, waterways and electromagnetic waves.
- The special theory of relativity and introduction to general relativity theory.

Matter and materials

- Further processing of wave particle duality, e.g. particles in a box, tunnelling effects, Heisenberg's uncertainty principle, one-dimensional time independent Schrödinger equations, quantum numbers and the Pauli exclusion principle.
- Optical and electrical properties of solid materials, as a consequence of the energy structure of electrons.
- Applications of quantum physics and solid-state physics e.g. in lasers, semi-conductor electronics and modern material technologies.
- Particle model of ideal gases and relationships between their microscopic and macroscopic properties.

Modelling and simulation

- Studying smaller projects where computer-based numerical simulation is used to deepen and apply knowledge in an optional area for a problem related to physics.

Working methods and mathematical models in physics.

- The importance of experimental work, mathematics and simulations for testing, re-assessing and revising hypotheses, theories and models.
- Identifying and studying problems using the reasoning of physics and mathematical modelling.
- Planning and implementation of experimental and numerical studies, and also formulating and testing hypotheses in connection with this.
- Processing and assessing data and results.

- Assessing results and conclusions by analysing choice of methods, work processes and sources of error.

Knowledge requirements

Grade E

Students give an account **in basic terms** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in basic terms** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **simple** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with some certainty** their own issues. Students plan and carry out **in consultation** with the supervisor experiments, observations and numerical simulations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, evaluate their methods in **simple** assessments and give the reasons for their conclusions with **simple** reasoning.

Students discuss **in basic terms** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **simple** arguments and give an account **in basic terms** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to some extent** their communication to purpose and context. In addition, students use different types of sources and make **simple** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade D

Grade D means that the knowledge requirements for grade E and most of C are satisfied.

Grade C

Students give an account **in detail** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with some certainty** to look for answers to issues, and to describe and **exemplify** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail** of how the models and theories of physics have been developed. Students also evaluate the validity and limitations of models in **simple** assessments.

Students identify, analyse and solve **complex** problems in **familiar situations** with **satisfactory** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses, and formulate **with some certainty** their own issues. Students plan and carry out **after consultation** with the supervisor experiments, observations and numerical simulations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **simple** assessments and give the reasons for their conclusions with **well grounded** reasoning.

Students discuss **in detail** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded** arguments, and give an account **in detail** of the consequences of **some** possible viewpoints.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. In addition, students use different types of sources and make **well grounded** assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with some certainty** their own ability and the requirements of the situation.

Grade B

Grade B means that the knowledge requirements for grade C and most of A are satisfied.

Grade A

Students give an account **in detail and in a balanced way** of the meaning of concepts, models, theories and working methods from each of the course's different areas. Students use these **with certainty** to look for answers to issues, and to describe and **generalise about** the phenomena and relationships of physics. Based on **some** examples, students give an account **in detail and in a balanced way** of how the models and theories of physics have been developed. Students evaluate also the validity and limitations of models in **balanced** assessments.

Students identify, analyse and solve **complex** problems in **familiar and new situations** with **good** results. This applies to both theoretical and practical work. In their work, students formulate relevant hypotheses and formulate **with certainty complex** issues. Students plan and carry out **after consultation** with the supervisor experiments, observations and numerical simulations in a satisfactory way. In addition, students handle materials and equipment safely. Furthermore, students interpret their results, assess their methods in **balanced** assessments and give reasons for their conclusions with **well grounded and balanced** reasoning. **Where necessary, students also propose changes**.

Students discuss **in detail and in a balanced way complex** issues concerning the importance of physics for the individual and society. In their discussions, students put forward **well grounded and balanced** arguments and give an account **in detail and in a balanced way** of the consequences of **several** possible viewpoints. **Students also propose new issues for discussion**.

Students use **with some certainty** the language of science and adapt **to a great extent** their communication to purpose and context. Students use different types of sources and make **well**

grounded and balanced assessments of the credibility and relevance of their sources and information.

In consultation with the supervisor, students assess **with certainty** their own ability and the requirements of the situation.