Description of the Physics Programs and Curriculum

France

In 2010–2011 and 2012, a new curriculum was gradually implemented for upper-secondary school (Grades 10, 11, and 12) with more emphasis on skills. The Grade 11 and Grade 12 scientific curricula allow students to aim at careers in science, technology, engineering, and mathematics (STEM). The physics and chemistry curriculum is meant to develop students' scientific and critical thinking and strengthen their interest in and affinity for scientific reasoning and research. Together with introducing new science knowledge and content, the curriculum targets developing the following skills:

- Appropriating a subject (e.g., students are trained to extract relevant information)
- Analyzing (e.g., students are trained to organize knowledge and information or modeling)
- Realizing (e.g., students are trained to experiment or to execute calculation techniques)
- Validating (e.g., students are trained to validate results of experience)
- Communicating (e.g., students are trained to use appropriate scientific vocabulary)

With a variety of information supports (scientific texts, data structure tables/charts, experimental videos, etc.) students have to solve problems using scientific reasoning. They are expected to identify the appropriate physical quantity to measure and to identify trends in data using various digital tools for data processing and graphing.

The curricula for 11th and 12th grades are both structured around three aspects of the scientific process: to observe, to understand, and to act, with a focus on modern inputs. The Grade 12 physics topics in each content area are listed below.

Scientific Processes	Content Areas	Topics
To Observe: Waves and Matter	Waves and particles; Properties and characteristics of a wave; and Spectral analysis	Electromagnetic radiation in the universe, including the electromagnetic spectrum, emission and detection of various types of waves and particles (radio, infrared, visible light, UV), interference, diffraction and Doppler Effect Mechanical waves, including the emission and detection of various types of mechanical waves (acoustic waves, seismic waves, swell), magnitude of an earthquake, sound intensity level), the relationship among speed, frequency, and wavelength, and interference, diffraction and Doppler Effect Spectral analysis, including visible and UV spectroscopy, infrared spectroscopy, nuclear magnetic resonance spectroscopy

Scientific Processes	Content Areas	Topics
To Understand: Laws and Models	Time, motion and evolution; Structure of matter and matter transformation processes; and Energy, matter, and radiation	Motion (displacement, velocity and acceleration), Newton's Laws of Motion, the principle of the conservation of linear momentum, circular motion principles for satellites, Kepler's three laws, work, potential energy, mechanical energy in the absence and in the presence of friction, time, special relativity (Einstein's postulate that the speed of light is constant in a vacuum and is the same for all observers, proper times, time dilation) Internal energy, specific heat capacity, modes of heat transfer (conduction, convection, radiation), quantum emission and absorption, stimulated emission and optical amplification (LASER quantum principle), electron vibrations, molecular vibrations, wave and particle duality, De Broglie's formula, probabilistic effect
To Act: 21st Century Challenges	Sustainable development, respect for the environment; and the storage and transmission of information	Energy, matter and radiation, including energy chains (the economy of energy) Systems for information transmission, digital images, analog-to-digital converters, physical processes of data transmission (cable, optical fiber, radio transmission), digital storage on optical disc

Some topics from Grade 11 are also included in TIMSS Advanced 2015 Frameworks:

- Wien's law
- Particle model and quantum theory of light, energy levels
- Radioactivity, fusion and fission reactions, law of conservation of matter and energy
- Ohm's law, Joule-Lenz's law
- Difference between electric power and electric energy

Italy

Students assessed in TIMSS Advanced 2015 followed the National Guidelines of 2010 for the upper secondary schools (*Licei, Istituti Tecnici, Istituti Professionali*). The five-year curriculum is divided into three parts by grade. The topics taught at each grade are listed below.

Grade	Topics
Grades 9 and 10	Scalar quantity and vector quantity, unit of measurement
	Geometrical optics: reflection and refraction, optical instruments
	Thermic phenomena (macroscopic viewpoint): temperature, definition of heat, calorimetry, thermal equilibrium, changes in states of matter
	Forces and equilibrium: machines and mechanical advantage
	Equilibrium of fluids: density and pressure, Pascal's principle, Archimedes' principle and buoyant force
	Kinematics: one-dimensional motion, displacement, velocity, acceleration
	Forces and Newton's laws of motion
	Work and energy: potential energy, kinetic energy, conservation of energy, power
Grades 11 and 12	Two-dimensional motion
	Forces and Newton's laws of motion (study in depth): inertial and not inertial reference frame, Galilean principle of relativity; Conservation of energy (study in depth)
	Fluid Dynamics: volume flow rate and equation of continuity, Bernoulli's equation
	Linear momentum, conservation of momentum, and elastic collisions
	Center of mass, torque, angular velocity and angular momentum, conservation of angular momentum
	Gravitation: from Kepler to Newton
	Ideal gas, ideal gas law
	Molecular theory of gases
	Laws of thermodynamics, entropy
	Oscillatory motion: harmonic motion
	Mechanical waves: amplitude, period, frequency and wavelength of periodic waves
	Wave propagation: absorption, reflection, interference, refraction, diffraction, polarization, dispersion
	Acoustic waves
	Light waves
	Coulomb's Law, Electric field
	Electric potential energy, electric potential and voltage
	Capacitors and capacitance, dielectrics in capacitors, energy of a capacitor

Grade	Topics
Grades 11 and 12 (Continued)	Circuits and Ohm's law, resistors in series and in parallel, resistivity and conductivity, voltmeters and ammeters, electrolytic conductivity, R-C circuits
	Magnets and magnetic force: magnetic force on a charge, magnetic force on a current carrying wire
	Magnetic field created by a current carrying wire, magnetic force between two currents going in the same and in opposite direction
	Electric motors
Grade 13	Electromagnetic induction
	Applications of induction
	R-L circuits
	Maxwell's Equations
	Electromagnetic radiation and electromagnetic spectrum
	Relativity, mass-energy equivalence
	The photoelectric effect and the nature of light
	Planck's theory of blackbody radiation
	Atomic spectra and quantum theory
	Structure of the nucleus, radioactivity
	Recommended insights: astrophysics and cosmology
	Elementary particles
	Nano- and micro-technologies, new materials
	Solid state physics: semiconductors
	Renewable energy

Lebanon

The rapid expansion of science and technology in the present century necessitates the renovation of its teaching from both the conceptual and methodological points of view. From this perspective, the new international and global tendencies towards science teaching were the main inspirations for preparing the science curriculum. The science curriculum presents the main concepts in a global approach based on the understanding of scientific principles in relation to everyday life in the domains of health, environment, technology, and ethics. The adopted pedagogical innovation focuses on mastery of the scientific method, communication techniques, and the transfer of knowledge. The curriculum defines conceptual objectives, both technical and methodological, that permit the establishment of a relationship between teaching and evaluation. Several teaching approaches are favored in the proposed curriculum, in particular putting learners in research situations to support students' construction of personal knowledge.

Science plays an important role in our everyday life. It manifests itself in all aspects of human activity. Consequently, it is important that students become life-long learners of science, starting with science at school, and continuing to learn science beyond their school years. To achieve the above, science teaching aims to realize the general objectives listed in the table below.

General Objectives
Develop learners' intellectual and practical scientific skills
Deepen learners' awareness of the ability of humans to understand, invent, and create
Understand the nature of science and technology, their development across history, and their impact on human thought
Insure that learners have acquired the facts, concepts, and principles necessary to understand natural phenomena
Motivate students to apply basic scientific principles in all sciences
Explain the scientific concepts and principles behind commonly used machines and devices
Acquire knowledge about health, environment, and safety practices and behave accordingly
Realize that some natural resources can be depleted and make the learner aware of the role of science in sustaining these resources
Encourage learners to use scientific knowledge and skills in novel situations, especially in everyday life
Emphasize the role of scientists in the advancement of human kind
Encourage learners to be open to the ideas of scientists from different cultures and to their contribution to the advancement of science
Encourage learners to abide by scientific values such as honesty and objectivity
Develop learners' scientific curiosity and orientation toward scientific research
Encourage learners to work independently and cooperatively when solving scientific problems
Make learners aware of career possibilities in different science-related areas

Reference document: Educational Center for Research and Development, *General objectives of the curricula and their details*. 1997, Beirut, Lebanon.

Norway

TIMSS 2003 and PISA 2003 showed a decrease in Norwegian students' performance in mathematics and science in compulsory school compared with TIMSS 1995 and PISA 2000. This resulted in a broad discussion about how to improve the learning outcomes in Norway. A big effort was made to change the curriculum for all subjects in all 13 grades. There was an agreement nationally that something had to be done, and the new curriculum received support across all political parties in the parliament. It was called the Knowledge Promotion Reform, and was implemented in the autumn of 2006. The last cohort using the previous curriculum was in Grade 13 in the 2007–2008 school year, which means that these students were assessed in TIMSS Advanced 2008. Students assessed in TIMSS Advanced 2015 have been taught according to the 2006 curriculum.

In the present curriculum, two features stand out. First, the learning goals are formulated as competencies. Second, there are five basic skills (literacies) which are supposed to be used and developed in all subjects and at all levels: the ability to express oneself orally, the ability to read, the ability to express oneself in writing, the ability to use digital tools, and numeracy. Digital devices are supposed to be widely used in teaching, learning, and testing.

The following table indicates topics taught in the courses Physics 1 and Physics 2, normally taken in Grades 12 and 13, respectively.

Content Area	Topics
Classical Physics (Physics 1 and 2)	Force vectors and Newton's Three Laws of Motion; the concepts of energy, work and effect, conservation of mechanical energy; friction, air resistance, calculations in situations with constant friction; qualitative understanding of the first and second laws of thermodynamics; current, voltage and resistance, conservation of charge, simple and branched direct current circuits; frequency, period, wavelength and wave speed, bending and interference; electric fields, Coulomb's law; Newton's law of gravitation; magnetic fields around permanent magnets and electric currents, magnetic flux, magnetic flux density around a straight conductor, force on a conductor in a magnetic field, Faraday's induction law; application of Newton's laws in vector form for motion in homogeneous magnetic fields and in a homogeneous gravitational fields; acceleration and forces in circular motion, and on objects at the top and bottom of a vertical circular path; conservation of momentum for one-dimensional collisions
Modern Physics (Physics 1 and 2)	Bohr's atom model, frequencies and wavelengths of spectral lines in emission and absorption spectra; fission and fusion processes; Stefan-Boltzmann's law and Wien's displacement law; HR diagrams; the life-cycle of a star, how elements are produced in stars; the standard model for the evolution of the universe; the basis for the special theory of relativity, qualitative discussion of some consequences of this theory for time, momentum and energy, qualitative description of the general theory of relativity; Einstein's explanation of photoelectric effect, qualitative discussion of experiments with the photoelectric effect, Compton scattering and the wave nature of particles; conservation laws that apply in processes with elementary particles, the interaction between elementary particles; Heisenberg's uncertainty relations, "entangled photons"

Content Area	Topics
Explaining Nature Through Mathematics (Physics 1 and 2)	Parameter presentation of rectilinear movement of a particle; creation of mathematical models for relations between physical quantities found experimentally; the use of mathematical models as sources for qualitative and quantitative information; the use of differential and integral calculus to find position, velocity and acceleration; the use of calculus to find work and change in potential energy in central fields and for a spring that stretches
The Young Researcher (Physics 1 and 2)	Key features of scientific method in physics; examples of explanation models that are inconsistent with physics and scientific methodology; how a researcher's approach, expectations and experiences can affect research; planning and implementation of experiments; collecting and processing data, presentation and evaluation of results; simulation programs; examples of scientific experiments, uncertainty in data and results, assessing the limitations of methods
Physics and Technology (Physics 1 and 2)	The difference between conductors, semi-conductors and insulators based on the atom model, doping of semi-conductors; the construction and use of a diode and a transistor; light detectors in digital photography; how modern sensors are characterized, and how the sensors' characteristics set limits for measurements; technological applications of induction; physical principles behind medical examinations such as X-rays, ultrasonography and magnetic resonance imaging; sampling and digital processing of sound

The previous curriculum for physics involved a more quantitative approach to the subject than the present one in certain subject areas. For instance, thermodynamics (including the ideal gas law) is only discussed qualitatively in the present curriculum. In the previous curriculum, students were required to perform simple calculations concerning heating and cooling of physical objects and similar processes. In the present curriculum, there is instead a greater emphasis on a qualitative knowledge of a broader range of physical topics, including the theory of relativity, quantum theory, and technological applications of physics. Also, discussions on a meta-level (such as can be found under the heading "the young researcher") are more emphasized in the present curriculum. There have only been minor adjustments made to the curriculum after 2006.

Not all students have to take a national written exam in physics. For Physics 1 there is no national written exam, since Physics 1 is defined as an "oral-practical" subject. For Physics 2, about 60 percent of the students are sampled for a written exam. For the local oral exam about 7 percent and 20 percent of the students in the respective courses are sampled for testing. Both the new and the previous curriculum emphasize the use of digital tools in physics. Under previous curricula, a liberal policy was developed to encourage and allow an extensive use of aids in all teaching and testing. Written notes and advanced calculators were normally allowed in local tests as well as in national written examinations. This has changed in the present curriculum. The written exam in Physics 2 is now divided into two parts. The first part is solved by pen and paper only; no aids are allowed. The second part allows the use of all aids which cannot communicate.

There is no national certification of teaching materials, such as textbooks, in Norway. The authors and publishers are free to decide the content of a textbook; the responsibility for covering the national curriculum rests on the school and the teacher.

Generally, one may say that the present curriculum emphasizes qualitative aspects of physics more, and quantitative aspects less, than the previous curriculum did. There are fewer and simpler calculations made in physics now than before.

Portugal

Physics is offered as an optional subject in the Grade 12 Science and Technology upper secondary academic track and some professional/vocational tracks. Its main objective is to promote and develop students' basic knowledge of concepts, laws and theories of physics, as well as their applications in explaining natural phenomena and technological devices. The curriculum is organized into units under three main areas: Mechanics, Electricity and Magnetism, and Modern Physics. The topics included in each unit are listed below.

Content Area	Units	Topics
Mechanics	Particle Mechanics	Particle kinematics and dynamics in more than one dimension: reference frames, position, vector, trajectory equations, displacement, average velocity, instantaneous velocity, average acceleration and instantaneous acceleration vectors, motion equations, tangential and radial acceleration, Newton's Second Law, circular motion Motion under the action of a constant force: importance of motion initial conditions, motion equations, projectile motion Applying Newton's Laws: objects connected by a cord, car in a banked circular turn, vertical circular loop, static frictional force and kinetic frictional force
	Oscillations	Hooke's Law, simple harmonic motion (period, frequency and angular frequency, displacement from equilibrium and amplitude), velocity and acceleration in SHM, energy of a simple harmonic oscillator, and damped oscillations
	Linear Momentum	Center of mass (extended object and system of particles), velocity and acceleration of the CM, linear momentum (particle and system of particles), momentum and Newton's second Law, conservation of linear momentum, elastic and inelastic collisions
	Fluids	Hydrostatic: density, pressure, variation of pressure with depth, Pascal's Law, buoyant force, Archimedes' Principle, floating objects equilibrium Fluid dynamics: steady flow, equation of continuity, Bernoulli's equation, viscosity
	Gravitation	Kepler's Laws, Newton's law of gravitation, gravitational constant and Cavendish experiment, gravitational field, gravitational force and weight, gravitational potential energy, orbital speed, escape speed
Electricity and Magnetism	Electricity and Magnetism	Coulomb's law and electric fields: charge conservation, conductors and insulators, charging objects by induction and by contact, polarization, Coulomb's law and its similarity to Newton's laws, electric field, properties of conductors in electrostatic equilibrium Electrical potential: electric potential energy, electric potential, equipotential surfaces, capacitors

Content Area	Units	Topics
Electricity and Magnetism (Continued)	Electric Circuits	Electric current: microscopic model of current, current and potential difference, resistance and resistivity, Ohm's law Energy in electrical circuits: Joule's law, electromotive force and total power output of a battery, internal resistance of a battery and power delivered to the external load resistance, terminal voltage of a battery, electromotive force of a motor, internal resistance of a motor, terminal voltage of a motor Electric circuits equations: resistors in series and parallel, applying Ohm's law to circuits with batteries, motors and resistors, R-C circuits
	Magnetic Fields	Sources of magnetic fields, magnetic field lines, magnetic force acting on a charge moving in a magnetic field, motion of charged particles in crossed electric and magnetic fields, Thomson's experiment, mass spectrometer, cyclotrons, magnetic force on a current-carrying wire, and Earth's magnetic field
Modern Physics	Relativity	Relative motion: inertial frames and accelerated frames, the principle of Galilean relativity, Galilean transformation equations Einstein's relativity: postulates of special theory of relativity, relativity of simultaneity, time dilation and length contraction, rest energy of a particle, general theory of relativity (curvature of space-time, principle of equivalence
	Introduction to Quantum Physics	Planck's energy quantization, Einstein theory of light, wave-matter duality for light, ionizing and non-ionizing radiations, photoelectric effect, Compton scattering, X-rays, wave-matter duality for matter, De Broglie wavelength, and Heisenberg's principle
	Nuclear Physics and Radioactivity	Nuclear binding energy and nuclear stability, natural radioactivity, alpha, beta and gamma emission, law of radioactive decay, half-life and mean life, activity, biological effects of radioactive emissions, absorbed dose and dose equivalent, ionizing radiation detectors, applications of ionizing radiations, and nuclear reactions (nuclear fusion and nuclear fission)

Russian Federation

The physics curriculum (program) for the Russian students assessed in TIMSS Advanced 2015 followed the 2004 Federal Education Standards for Upper Secondary Education (Grades 10-11) of 2004. The content of this program are presented at two levels: Basic and Profile. These levels are distinguished by the amount of the material being studied and the amount of instructional time. The Basic level program is designed for those students who plan to learn a profession that is not related to physics. The Profile level program includes at least 4 lessons (3 hours) per week and provides sufficient depth of physics study to make it possible for students to enter a profession where physics is actively used. It includes a large amount of content and has higher requirements for its mastery. The mastery of this content makes it possible for students to continue to university-level studies in physics disciplines.

The Profile level curriculum includes an explanation of the main goals of the program and provides for the organization and planning of physics courses, including:

- General characteristics of the Profile course
- Compulsory content and learning outcomes
- The number of lessons per week and per year
- General learning skills and activities

The goals of studying physics at the Profile level of secondary general education are:

- To develop knowledge of scientific methods, a contemporary physical picture of the world, properties of matter and energy, dynamic and statistical laws of nature, elementary particles and fundamental interactions, the structure and evolution of the universe, and the basics of fundamental physical theories
- To master skills to observe, plan, and carry out experiments; process measurement results; hypothesize; and build models and establish the boundaries of their application
- To apply knowledge to explain natural phenomena, properties of matter, and principles of technical devices; to solve physical problems; and to evaluate the reliability of new information
- To develop cognitive interests, intellectual and creative abilities in problem solving in physics, and independent acquisition of new knowledge; and abilities to execute experimental studies and prepare reports, essays and other creative works
- To develop respect for opposing opinions and work cooperatively; the ability to evaluate scientific achievements morally and ethically; and respect for the creators of science and technology
- To use acquired knowledge and skills to solve practical problems, manage and protect the environment, and promote the safety of human life and society

The compulsory learning content lists the topics to be taught in secondary school physics courses. A list of requirements for graduates of secondary school includes the learning outcomes related to the topics taught. These requirements are generally described in terms of what students should know and what they should be able to do. In addition, students should be able to use the knowledge and skills that they acquire in everyday life. These program has been in place since 2004 and was updated by the Ministry of Education and Science in 2012. The content and topics of the Profile physics course are listed below.

Content Area	Topics
Physics as a Science and the Nature of Science	Scientific methods; the role of experiment and theory in the study of nature; modelling of natural phenomena and objects; scientific hypotheses; the role of mathematics in physics; physical laws and theories and the limits of their applicability; the physical picture of the world
Mechanics	Motion; equations of uniformly accelerated rectilinear motion; circular motion with constant velocity; centripetal acceleration; the principle of superposition of forces; the laws of dynamics; inertial reference frames; Galileo's principle of relativity; forces in mechanics: gravity, elasticity, friction; Newton's Law of Universal Gravitation; weight and weightlessness; the laws of conservation of momentum and mechanical energy; moment of force; equilibrium of a solid body; mechanical vibrations; amplitude, period, and frequency of oscillation; the equation of harmonic oscillations; free and forced vibrations; resonance; mechanical waves; wavelength
Molecular Physics	The atomic hypothesis of the structure of matter and its experimental evidence; the model of the ideal gas, absolute temperature scale; temperature as a measure of the average kinetic energy of the thermal motion of particles; the relationship between the pressure of an ideal gas and the average kinetic energy of thermal motion of its molecules; the equation of state of an ideal gas; gas processes; model of the structure of liquids; saturated and unsaturated vapor; humidity in air; model of the structure of solids; changes in aggregate states of matter; the first law of thermodynamics; adiabatic processes; the second law of thermodynamics; principles of thermal machines; efficiency of a heat engine; problems of energy and environmental protection
Electrodynamics	Elementary electric charge; the law of conservation of electric charge; Coulomb's Law; the principle of superposition of electric fields; the potential of an electric field; conductors and dielectrics in an electric field; energy of an electric field; electrical current; series and parallel circuits; electromotive force (EMF); Ohm's law for a complete circuit; electric current in metals, liquids, gases and vacuum; plasma; semiconductors; conductivity of semiconductors; semiconductor diodes; semiconductors; induced magnetic fields. Ampere's force law; Lorentz force; magnetic flux; Faraday's law of induction; Lenz's law; self-inductance; inductance; energy of a magnetic field; magnetic properties of matter; oscillating circuits; free electromagnetic oscillations; forced electromagnetic waves; alternating current; production, transmission and consumption of electrical energy; electromagnetic fields; speed of electromagnetic waves; properties of electromagnetic radiation; light as an electromagnetic wave; the speed of light; interference of light; diffraction of light; diffraction grating; the laws of reflection and refraction of light; total internal reflection dispersion of light; various types of electromagnetic radiation and their practical application; the formula of thin lens;. optical instruments

Content Area	Topics
Quantum Physics	Max Planck's quantum hypothesis; the photoelectric effect; Stoletov experiments; Einstein's equation for the photoelectric effect; photons; the planetary model of the atom; Bohr's quantum postulates and line spectra; de Broglie's hypothesis and wave-particle duality; electron diffraction; lasers; models of nuclear structure; nuclear forces; nucleon models; nuclear binding energy; nuclear spectra; nuclear reactions; chain reactions in nuclear fission; radioactivity; radioactive decay
Structure of the Universe	The solar system; stars and their sources of energy; modern ideas about the origin and evolution of the Sun and stars; our galaxy; other galaxies; the spatial scale of the observable universe; the applicability of the laws of physics to explain the nature of space objects; redshift in the spectra of galaxies; modern views on the structure and evolution of the universe

Textbooks are written specifically in accordance with the approved program and teachers develop classroom materials based on the curricular documents. It is up to both textbook authors and classroom teachers to decide additional topics to include beyond what is specified in the physics program. Teachers are given the autonomy to develop their own approaches to teaching the course content in terms of sequencing the topics and can adapt their teaching to the need of their students in terms of knowledge and development.

Slovenia

The published physics curriculum used for the student population assessed in TIMSS Advanced 2015 Physics describes the goals, contents, competences, expected results, cross-curricular connections, and didactic recommendations for teaching Physics in Grades 10 to 13 as well as requirements for grading students.

Physics is taught as a fundamental natural science to develop students' ability to study natural phenomena and emphasis is placed on understanding and evaluating achievements of modern science and technology. Physics education in secondary school builds on knowledge of physics and mathematics from primary school and gives appropriate basis for study of science.

Students develop basic competences in science in technology, in mathematics, in digital literacy, in communicating science in their mother language as well as in foreign languages, in learning to learn, and in entrepreneurship.

The curriculum puts emphasis on cross-curricular links at the levels of content, process skills and conceptual level. Interdisciplinary cooperation creates the possibility of transferability of knowledge, thereby creating conditions for a better understanding, greater usability of knowledge and hence greater creativity in all subject areas.

Teachers have autonomy to decide how best to implement their teaching, methods and forms of assignments and the order of reading material. In each year from Grade 10 to 12, all *gymnasia* students have 70 45-minutes classes (52.5 hours) of compulsory physics lessons. These hours of lessons comprise 80 percent prescribed compulsory content and 20 percent elective content, specified by teachers. The prescribed topics in each compulsory and elective content are listed below.

Compulsory Content Areas	Topics
Measurement, Physical Quantities and Units	Use and measurement of physical quantities, conversion of units, calculating error (absolute and relative)
Motion	Displacement, average and instantaneous velocity, acceleration, circular motion (frequency, period, angular velocity and radial acceleration)
Force and Moments of Force	Composing and decomposing forces (graphically), equilibrium of forces, Newton's Third Law, frictional force, resistance force, moments of force, pressure and pressure in fluids
Newton's Laws of Motion and Law of Gravitation	Applying Newton's law in motion and circular motion, Newton's law of gravitation, Kepler's Laws
Work and Energy	Work, kinetic energy, potential energy, mechanical energy and law of conservation of mechanical energy
Structure of Matter and Temperature	Calculate the number of particles (molecules or atoms) in a given mass of a pure substance and the mass of one of the components; Kelvin temperature scale, thermal expansion of solids, liquids and gases, linear and spatial extensibility, law of ideal gases
Internal Energy and Heat	Apply the first law of thermodynamics, specific heat capacity, phase transition, heat flux, Stefan's law, thermal conductivity, heat engine, reversible and irreversible processes, second law of thermodynamics

Compulsory Content Areas	Topics
The Electric Charge and Electric Fields	Conductors and insulators, electroscope, Coulomb's law, capacitors, electric fields
Electric Current	Electric current, voltage, Ohm's law, resistance and resistivity, series and parallel electric circuits, equations for resistors in series and parallel circuits, electric power, Kirchhoff's circuit laws
Magnetic Field	Permanent magnet, magnetic fields around electrical conductors, magnetic field lines, magnetic force acting on a charge moving in a magnetic field, magnetic torque, density of the magnetic field, mass spectrometer, Hall effect sensor (working principle)
Induction	Induction in a moving conductor in a magnetic field, changes of the magnetic field in a coil and in a transformer, Faraday's and Lenz' laws of induction, L-C circuit
Oscillations	Simple harmonic motion (period, frequency, displacement from equilibrium and amplitude, velocity, acceleration and energy), damped oscillation and resonance
Waves	Transverse and longitudinal waves, sinusoidal waves (amplitude, wavelength), absorption, reflection, refraction, interference, polarization and Doppler Effect
Light	Electromagnetic spectrum, specular reflection, Snell's law, optical physics and geometric optics
Atoms	Structure of atoms, photoelectric effect, energy levels of atoms
Atomic Nuclei	Structure of atomic nuclei, mass and atomic number, radioactive isotopes and their half-lives, radioactive decay, fission and fusion, nuclear reactions (conservation law, energy)
Astronomy	Solar system, nuclear processes on the Sun, stars, the galaxy

Elective Content Areas	Topics
Linear Momentum	Linear momentum (theorem), conversion of linear momentum, elastic and inelastic collisions
Angular Momentum	Angular momentum (theorem, conversion)
Fluids	Volumetric and mass flow rate, Bernoulli's equation, surface tension
Semiconductors	Difference between metals, insulators and semiconductors; semiconductor diode, photodiode and solar cell (characteristics)
Theory of Relativity	Speed of light, speed of light in vacuum, time dilation and length contraction, relativistic particles (linear momentum and kinetic energy)

In Grade 13, physics is a compulsory subject only for students who choose physics as one of their five *matura* examination subjects. Physics in Grade 13 has 140 45-minutes lessons. Half of these, 70 lessons (52.5 hours), is intended to deepen and enhance the physics knowledge acquired in Grades 10 to 12 as well as learning some special contents. Teachers decide which two or three themes from Mechanics, Heat, Electrics with Magnetism, Waves and Optics, and Modern Physics will be in focus of the course. The course includes 20 lessons (15 hours) of laboratory work and 50 lessons (37.5 hours) for lecture and assessment.

The physics curriculum prescribes the standards of knowledge that students should acquire by the end of Grade 12 and includes a separate list of standards for the *matura* examination at the end

of Grade 13. The standards for the *matura* examination, listed below, are more detailed descriptions of topics from the standards for Grade 12.

Grade 12 Standards
Fundamental physical quantities and units of the international measurement system
The scientific method of studying natural phenomena
Description of linear motion and the main features of curvilinear motion and its graphic representations
Vector quantities and mathematical operations with vectors
Newton's laws and law of gravity
Work, power, and energy
Microscopic view and description of the structure of matter
Temperature, heat, and internal energy
Laws of thermodynamics
Conservation laws for mass, energy, and electric charge
Electric charge and electric field
Simple electrical circuits
Magnetic fields
Induction
The fundamental laws of oscillation and waves, especially electromagnetic radiation
The visible spectrum of electromagnetic radiation
Sound
Wave nature of light
Light as a form of energy and basic optical equipment
Basic structures and characteristics of atoms
The basic structure of the atomic nucleus and the charges and masses of the nucleons
Qualitatively explain the mass defect in terms of energy
Radioactive decay
Fission and fusion of nuclei
The operation of a nuclear reactor
The structure of our solar system and the fundamental processes taking place on the Sun
Characteristics of the most important objects in the universe

Didactic recommendations in the curriculum relate to the implementation of the curriculum, laboratory work, project and term papers, the use of ICT, and about active forms of teaching. In physics, in addition to content knowledge, it is also important for students to acquire procedural knowledge and skills, so teachers incorporate independent work and group work, problem solving, project work, modern laboratory work, and field work into their classroom practice. Increasingly, traditional experimental work is gradually being replaced with more modern laboratory approaches, the objectives of which include the development of observation skills, thinking, reasoning, and research skills. The physics curriculum recommends that teachers should enhance their physics lessons with the use of computer technology. It recommends also interactive forms of lessons to promote the active participation of all students.

Sweden

Two consecutive physics courses, Physics 1 and 2, comprise the physics curriculum covered by Swedish students participating in TIMSS Advanced 2015 Physics. Both courses are defined by a national curriculum that includes the goal of the subject, core content, and assessment criteria. These curricula describe learning objectives in short texts and teachers are expected to interpret the brief descriptions.

The curriculum dictates that physics courses should give students opportunity to develop

- Knowledge of the concepts, models, theories, and methods of physics, and how they have developed
- The ability to analyze and find answers to subject-related questions, and to identify, formulate, and solve problems as well as the ability to reflect on and evaluate strategies, methods and results
- The ability to plan, carry out, interpret and report experiments and observations, and to handle materials and equipment
- Knowledge of the importance of physics for the individual and society
- The ability to use knowledge in physics to communicate, and to evaluate and use information

In Physics 1, motion and force content deals with speed, momentum, acceleration and force. Students learn about equilibrium and linear motion in homogenous gravitational and electrical fields, and also pressure, pressure variations, and Archimedes' principle. In addition, the core content touches on relativistic and nuclear physics. In Physics 2, content related to motion and force is added by including two-dimensional motion in gravitational and electrical fields. Students learn about central motion and torque and about simulating two-dimensional motion using simple numerical methods.

Energy and energy resources are covered as content in Physics 1. Work, force, potential energy and kinetic energy are used to describe different forms of energy. Students learn about the principle of conservation of energy, entropy, and efficiency to describe energy transformation, energy quality, and energy storage, as well as thermal energy (internal energy, heat capacity, heat transfer, temperature, and phase transformation). Students also learn about electrical energy (electrical charges, field strength, potential, voltage, current, and resistance) and nuclear energy (the structure of an atom and nuclear binding energy, strong forces, mass-energy equivalence, nuclear reactions, fission, and fusion). The core content also includes a resource perspective on energy and the use of energy for a sustainable society. Radiation in medicine and technology in Physics 1 covers radioactive disintegration, ionizing radiation, particle radiation, half-life and activity. Students are introduced to electromagnetic radiation and the particle properties of light and learn about

the interaction between different types of radiation and biological systems. Radiation content is further covered in Physics 2 under the heading of waves, electromagnetism, and signals. Students learn about harmonic oscillation and resonance with applications in everyday life and technology. Students also learn about reflection, refraction and interference of light, sound, and other waves. The Doppler Effect is covered briefly. The core content includes relationships between electric and magnetic fields (magnetic fields around conductors, the motion of electric charges in magnetic fields, and induction). Students are introduced to wave and particle descriptions of electromagnetic radiation, the propagation of electromagnetic waves, photoelectric effects, and photons. Students also learn about wave properties of matter, de Broglie's hypotheses, and wave-particle duality.

In Physics 1, under the heading of climate and weather forecasts, students learn about the ideal gas law as a model for describing the physics of the atmosphere. They are given a brief introduction to how physical models and methods of measurement are used to forecast climate and weather, as well as reliability and limitations of forecasts. In Physics 2, students work with content related to the development and structure of the universe. The core content specifies the electron structure of atoms and absorption and emission spectra. Students are introduced to methods for studying the universe, including electromagnetic radiation from stars and interstellar space.

A substantial amount of the core content descriptions in Physics 1 and 2 is given to a domain described as the nature, working methods, and mathematical methods of physics. This large content area deals with the characteristics of scientific problems, method, and theory. It also covers the identification and study of problems using reasoning from physics and mathematical modelling covering linear and non-linear functions, equations, graphs, trigonometry, and vectors. Views on societal questions based on explanatory models of physics are also covered, e.g., questions about sustainable development. This wider perspective is further developed in Physics 2 by relations and links between physics and ethical, philosophical, and religious issues.

United States

The United States does not have a uniform curriculum for physics. For TIMSS Advanced 2015, students were sampled from courses identified as second-year physics using the definitions from the School Codes for the Exchange of Data (SCED) course classification system. The SCED courses included five College Board Advanced Placement (AP) courses (Physics B, Physics 1, Physics 2, Physics C: mechanics, and Physics C: electricity and magnetism), two International Baccalaureate (IB) Diploma Programme courses (IB Physics Standard Level and IB Physics High Level), and other courses implemented at the state, district, or school level. Descriptions of courses and their content in school catalogues were reviewed to determine course eligibility. As a result, the students assessed in TIMSS Advanced 2015 participated in varying curricula. The AP and IB courses have specific curricula that are taught to all students regardless of the state, district, or school in which they take them.

AP Physics B is a second-year algebra-based physics course. The curriculum is divided into five main topic areas: Newtonian Mechanics; Fluid and Thermal Physics; Electricity and Magnetism; Waves and Optics; Atomic and Nuclear Physics. Under Newtonian Mechanics, the curriculum covers kinematics; Newton's laws of motion; work, energy, power; systems of particles, linear momentum; circular motion and rotation; oscillations and gravitation. Under Fluid Mechanics and Thermal Physics, the curriculum covers fluid mechanics; temperature and heat; kinetic theory and thermodynamics. Under Electricity and Magnetism, the curriculum covers electrostatics; conductors, capacitors, dielectrics; electric circuits; magnetic fields; electromagnetism. Under Waves and Optics, the curriculum covers wave motion; physical optics; geometric optics. Under Atomic and Nuclear Physics, the curriculum covers atomic physics and quantum effects; nuclear physics.

In 2014, AP Physics B was revised by the College Board and replaced by the two-year series of AP Physics 1 and AP Physics 2. Thus, in the 2014-15 school year, schools stopped teaching AP Physics B and instead began teaching a two-year sequence of algebra-based physics: AP Physics 1 and Physics 2.These two courses collectively cover similar content as AP Physics B but in more depth. AP Physics 1 focuses on Newtonian mechanics (including rotational motion); work, energy, and power; mechanical waves and sound; electrostatics and electric circuits. AP Physics 2 focuses on more advanced topics including principles of fluids; thermodynamics; electromagnetism; optics; and topics in modern physics, including quantum, atomic and nuclear physics. Both Physics B and the Physics 1 and 2 courses are included in the TIMSS Advanced 2015 sample, as the specific courses offered during students' junior and senior year may vary across states and school districts during the transition year.

AP Physics C: Mechanics covers all of the same content under Newtonian Mechanics as AP Physics B, but in greater depth. AP Physics C: Electricity and Magnetism covers all of the same content under Electricity and Magnetism as AP Physics B, but in greater depth. Both AP Physics C courses are calculus-based.

IB Physics Standard Level (SL) has a core curriculum which covers physics and physical measurement, mechanics, thermal physics, oscillations and waves, electric currents, fields and forces, atomic and nuclear physics, energy, power, and climate change. The curriculum also includes 30 hours of instruction on two of the following topics: light and wave phenomena, quantum physics and nuclear physics, digital technology, relativity and particle physics, astrophysics, communication, and electromagnetic waves. Finally, the curriculum includes 40 hours of practical work, composed of investigations and a project.

IB Physics Higher Level (HL) has the same core curriculum as IB Physics SL, but includes six additional required topics: motion in fields, thermal physics, wave phenomena, electromagnetic induction, quantum physics and nuclear physics, and digital technology. The curriculum also contains 45 hours of instruction on two of the following additional topics: astrophysics, communications, electromagnetic waves, relativity, medical physics, and particle physics. The curriculum includes 60 hours of practical work, composed of investigations and a project.

Students were also sampled from other second year physics courses, with course curriculums varying by state, district, or school.