# Grade 12: Contemporary Physics

## Curriculum Connections

## Physics–University Preparation

IP = Initiating and Planning, PR = Performing and Recording, AI = Analysing and Interpreting, C = Communicating

**Physics Curriculum Connections (SPH4U)**

**Activity 1: Next Stop, Mars!**

***Scientific Investigation Skills and Career Exploration***

- **A1.2** select appropriate instruments (e.g., pendulums, springs, ripple tanks, lasers) and materials (e.g., sliding blocks, inclined planes), and identify appropriate methods, techniques, and procedures, for each inquiry [IP]
- **A1.4** apply knowledge and understanding of safe laboratory practices and procedures when planning investigations by correctly interpreting Workplace Hazardous Materials Information System (WHMIS) symbols; by using appropriate techniques for handling and storing laboratory equipment and materials and disposing of laboratory materials; and by using appropriate personal protection [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.6** compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.12** use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., vector diagrams, free-body diagrams, vector components, and algebraic equations) [C]

***Dynamics***

- **B1.1** analyse a technological device that applies the principles of linear or circular motion (e.g., a slingshot, a rocket launcher, a race car, a trebuchet) [AI, C]
- **B2.1** use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction,* and *kinetic friction* [C]
- **B2.2** solve problems related to motion, including projectile and relative motion, by adding and subtracting two-dimensional vector quantities, using vector diagrams, vector components, and algebraic methods [PR, AI, C]
- **B3.1** distinguish between reference systems (inertial and non-inertial) with respect to the real and apparent forces acting within such systems (e.g., apparent force in a rotating frame, apparent gravitational force in a vertically accelerating frame, real force pulling on the elastic of a ball-and-paddle toy)

***Energy and Momentum***

- **C1.1** analyse, with reference to the principles of energy and momentum, and propose practical ways to improve, a technology or procedure that applies these principles (e.g., fireworks, rocket propulsion, protective equipment, forensic analysis of vehicle crashes, demolition of buildings) [AI, C]
- **C1.2** assess the impact on society and the environment of technologies or procedures that apply the principles of energy and momentum (e.g., crumple zones, safety restraints, strategic building implosion) [AI, C]
- **C2.1** use appropriate terminology related to energy and momentum, including, but not limited to: *work, work-energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum-impulse theorem, elastic collision*, and *inelastic collision* [C]
- **C2.2** analyse, in qualitative and quantitative terms, the relationship between work and energy, using the work-energy theorem and the law of conservation of energy, and solve related problems in one and two dimensions [PR, AI]
- **C2.5** analyse, in qualitative and quantitative terms, the relationships between mass, velocity, kinetic energy, momentum, and impulse for a system of objects moving in one and two dimensions (e.g., an off-centre collision of two masses on an air table, two carts recoiling from opposite ends of a released spring), and solve problems involving these concepts [PR, AI]

***Gravitational, Electric, and Magnetic Fields***

- **D2.1** use appropriate terminology related to fields, including, but not limited to: *forces, potential energies, potential,* and *exchange particles* [C]
- **D2.2** analyse, and solve problems relating to, Newton's law of universal gravitation and circular motion (e.g., with respect to satellite orbits, black holes, dark matter) [AI]

## Physics Curriculum Connections (SPH4U)

### Activity 2: Detector Physics

***Scientific Investigation Skills and Career Exploration***

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.6** compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams [PR]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.12** use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., vector diagrams, free-body diagrams, vector components, and algebraic equations) [C]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., laser optics researcher, geoscientist, photonics researcher, aerospace engineer) and the education and training necessary for these careers
- **A2.2** describe the contributions of scientists, including Canadians (e.g., Elizabeth MacGill, Pierre Coulombe, Allan Carswell, Gerhard Herzberg), to the fields under study

***Dynamics***

- **B1.1** analyse a technological device that applies the principles of linear or circular motion (e.g., a slingshot, a rocket launcher, a race car, a trebuchet) [AI, C]
- **B2.1** use appropriate terminology related to dynamics, including, but not limited to*: inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction*, and *kinetic friction* [C]
- **B2.6** analyse, in qualitative and quantitative terms, the forces acting on and the acceleration experienced by an object in uniform circular motion in horizontal and vertical planes, and use free-body diagrams and algebraic equations to solve related problems [AI, C]

***Energy and Momentum***

- **C1.1** analyse, with reference to the principles of energy and momentum, and propose practical ways to improve, a technology or procedure that applies these principles (e.g., fireworks, rocket propulsion, protective equipment, forensic analysis of vehicle crashes, demolition of buildings) [AI, C]
- **C2.1** use appropriate terminology related to energy and momentum, including, but not limited to: work, *work-energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum-impulse theorem, elastic collision*, and *inelastic collision* [C]
- **C2.3** use an inquiry process to analyse, in qualitative and quantitative terms, situations involving work, gravitational potential energy, kinetic energy, thermal energy, and elastic potential energy, in one and two dimensions (e.g., a block sliding along an inclined plane with friction; a cart rising and falling on a roller coaster track; an object, such as a mass attached to a spring pendulum, that undergoes simple harmonic motion), and use the law of conservation of energy to solve related problems [PR, AI]
- **C3.5** explain how the laws of conservation of energy and conservation of momentum were used to predict the existence and properties of the neutrino

***Gravitational, Electric, and Magnetic Fields***

- **D1.1** analyse the operation of a technological system that uses gravitational, electric, or magnetic fields (e.g., a home entertainment system, a computer, magnetic strips on credit cards) [AI, C]
- **D1.2** assess the impact on society and the environment of technologies that use gravitational, electric, or magnetic fields (e.g., satellites used in surveillance or storm tracking, particle accelerators that provide high-energy particles for medical imaging) [AI, C]
- **D2.1** use appropriate terminology related to fields, including, but not limited to: *forces, potential energies, potential,* and *exchange particles* [C]
- **D2.4** analyse, and solve problems involving, the force on charges moving in a uniform magnetic field (e.g., the force on a current-carrying conductor or a free electron) [AI]

***Revolutions in Modern Physics: Quantum Mechanics and Special Relativity***

- **F1.2** assess the importance of relativity and quantum mechanics to the development of various technologies (e.g., nuclear power; light sensors; diagnostic tools such as magnetic resonance imaging [MRI], computerized axial tomography [CAT], positron emission tomography [PET]) [AI, C]
- **F2.1** use appropriate terminology related to quantum mechanics and special relativity, including, but not limited to: *quantum theory, photoelectric effect, matter waves, time dilation,* and *mass–energy transformation* [C]
- **F3.4** describe the standard model of elementary particles in terms of the characteristics of quarks, hadrons, and field particles

**Physics Curriculum Connections (SPH4U)**

**Activity 3: Heisenberg's Uncertainty Principle**

***Scientific Investigation Skills and Career Exploration***

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., laser optics researcher, geoscientist, photonics researcher, aerospace engineer) and the education and training necessary for these careers
- **A2.2** describe the contributions of scientists, including Canadians (e.g., Elizabeth MacGill, Pierre Coulombe, Allan Carswell, Gerhard Herzberg), to the fields under study

***Dynamics***

- **B2.1** use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference*, *components*, *centripetal*, *period*, *frequency*, *static friction*, and *kinetic friction* [C]
- **B2.2** solve problems related to motion, including projectile and relative motion, by adding and subtracting two-dimensional vector quantities, using vector diagrams, vector components, and algebraic methods [PR, AI, C]

***The Wave Nature of Light***

- **E2.1** use appropriate terminology related to the wave nature of light, including, but not limited to: *diffraction, dispersion, wave interference, nodal line, phase, oscillate, polarization,* and *electromagnetic radiation* [C]
- **E2.3** conduct inquiries involving the diffraction, refraction, polarization, and interference of light waves (e.g., shine lasers through single, double, and multiple slits; observe a computer simulation of Young's double-slit experiment; measure the index of refraction of different materials; observe the effect of crossed polarizing filters on transmitted light) [PR]

***Revolutions in Modern Physics: Quantum Mechanics and Special Relativity***

- **F1.2** assess the importance of relativity and quantum mechanics to the development of various technologies (e.g., nuclear power; light sensors; diagnostic tools such as magnetic resonance imaging [MRI], computerized axial tomography [CAT], positron emission tomography [PET]) [AI, C]
- **F2.1** use appropriate terminology related to quantum mechanics and special relativity, including, but not limited to: *quantum theory, photoelectric effect, matter waves, time dilation*, and *mass–energy transformation* [C]
- **F2.4** conduct a laboratory inquiry or computer simulation to analyse data (e.g., on emission spectra, the photoelectric effect, relativistic momentum in accelerators) that support a scientific theory related to relativity or quantum mechanics [PR, AI]

**Physics Curriculum Connections (SPH4U)**

**Activity 4: How Does Motion Affect Time?**

***Scientific Investigation Skills and Career Exploration***

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.3** identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.6** compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams [PR]
- **A1.7** select, organize, and record relevant information on research topics from a variety of appropriate sources, including electronic, print, and/or human sources, using suitable formats and an accepted form of academic documentation [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.12** use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., vector diagrams, free-body diagrams, vector components, and algebraic equations) [C]
- **A1.13** express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures [C]

***Dynamics***

- **B2.1** use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction,* and *kinetic friction* [C]
- **B2.2** solve problems related to motion, including projectile and relative motion, by adding and subtracting two-dimensional vector quantities, using vector diagrams, vector components, and algebraic methods [PR, AI, C]

***Revolutions in Modern Physics: Quantum Mechanics and Special Relativity***

- **F1.1** analyse the development of the two major revolutions in modern physics (e.g., the impact of the discovery of the photoelectric effect on the development of quantum mechanics; the impact of thought experiments on the development of the theory of relativity), and assess how they changed scientific thought [AI, C]
- **F2.1** use appropriate terminology related to quantum mechanics and special relativity, including, but not limited to: *quantum theory, photoelectric effect, matter waves, time dilation,* and *mass–energy transformation* [C]
- **F2.3** solve problems related to Einstein's theory of special relativity in order to calculate the effects of relativistic motion on time, length, and mass (e.g., the half-life of cosmic ray muons, how far into the future a fast space ship would travel, the magnetic field strength necessary to keep protons in the Large Hadron Collider) [PR, AI]
- **F2.4** conduct a laboratory inquiry or computer simulation to analyse data (e.g., on emission spectra, the photoelectric effect, relativistic momentum in accelerators) that support a scientific theory related to relativity or quantum mechanics [PR, AI]
- **F3.3** identify Einstein's two postulates for the theory of special relativity, and describe the evidence supporting the theory (e.g., thought experiments, half lives of elementary particles, relativistic momentum in accelerators, the conversion of matter into energy in a nuclear power plant)

**Physics Curriculum Connections (SPH4U)**

**Activity 5: Electromagnetism and Relativity**

***Scientific Investigation Skills and Career Exploration***

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.5** conduct inquiries, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data [PR]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge [AI]
- **A1.12** use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation (e.g., vector diagrams, free-body diagrams, vector components, and algebraic equations) [C]
- **A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., laser optics researcher, geoscientist, photonics researcher, aerospace engineer) and the education and training necessary for these careers

***Gravitational, Electric, and Magnetic Fields***

- **D2.1** use appropriate terminology related to fields, including, but not limited to*: forces, potential energies, potential*, and *exchange particles* [C]
- **D2.4** analyse, and solve problems involving, the force on charges moving in a uniform magnetic field (e.g., the force on a current-carrying conductor or a free electron) [AI]
- **D3.2** compare and contrast the corresponding properties of gravitational, electric, and magnetic fields (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

***Revolutions in Modern Physics: Quantum Mechanics and Special Relativity***

- **F1.1** analyse the development of the two major revolutions in modern physics (e.g., the impact of the discovery of the photoelectric effect on the development of quantum mechanics; the impact of thought experiments on the development of the theory of relativity), and assess how they changed scientific thought [AI, C]
- **F1.2** assess the importance of relativity and quantum mechanics to the development of various technologies (e.g., nuclear power; light sensors; diagnostic tools such as magnetic resonance imaging [MRI], computerized axial tomography [CAT], positron emission tomography [PET]) [AI, C]
- **F2.1** use appropriate terminology related to quantum mechanics and special relativity, including, but not limited to: *quantum theory, photoelectric effect, matter waves, time dilation,* and *mass–energy transformation* [C]
- **F2.3** solve problems related to Einstein's theory of special relativity in order to calculate the effects of relativistic motion on time, length, and mass (e.g., the half-life of cosmic ray muons, how far into the future a fast space ship would travel, the magnetic field strength necessary to keep protons in the Large Hadron Collider) [PR, AI]
- **F3.3** identify Einstein's two postulates for the theory of special relativity, and describe the evidence supporting the theory (e.g., thought experiments, half lives of elementary particles, relativistic momentum in accelerators, the conversion of matter into energy in a nuclear power plant)

**Physics Curriculum Connections (SPH4U)**

**Activity 6: The Hydrogen Atom**

***Scientific Investigation Skills and Career Exploration***

- **A1.1** formulate relevant scientific questions about observed relationships, ideas, problems, or issues, make informed predictions, and/or formulate educated hypotheses to focus inquiries or research [IP]
- **A1.3** identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately [IP]
- **A1.8** synthesize, analyse, interpret, and evaluate qualitative and quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error [AI]
- **A2.2** describe the contributions of scientists, including Canadians (e.g., Elizabeth MacGill, Pierre Coulombe, Allan Carswell, Gerhard Herzberg), to the fields under study

***Dynamics***

- **B2.1** use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction,* and *kinetic friction* [C]
- **B2.6** analyse, in qualitative and quantitative terms, the forces acting on and the acceleration experienced by an object in uniform circular motion in horizontal and vertical planes, and use free-body diagrams and algebraic equations to solve related problems [AI, C]

***Gravitational, Electric, and Magnetic Fields***

- **D2.1** use appropriate terminology related to fields, including, but not limited to*: forces, potential energies, potential*, and *exchange particles* [C]
- **D2.2** analyse, and solve problems relating to, Newton's law of universal gravitation and circular motion (e.g., with respect to satellite orbits, black holes, dark matter) [AI]
- **D3.2** compare and contrast the corresponding properties of gravitational, electric, and magnetic fields (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

***Revolutions in Modern Physics: Quantum Mechanics and Special Relativity***

- **F1.1** analyse the development of the two major revolutions in modern physics (e.g., the impact of the discovery of the photoelectric effect on the development of quantum mechanics; the impact of thought experiments on the development of the theory of relativity), and assess how they changed scientific thought [AI, C]
- **F2.1** use appropriate terminology related to quantum mechanics and special relativity, including, but not limited to: *quantum theory, photoelectric effect, matter waves, time dilation,* and *mass–energy transformation* [C]
- **F2.2** solve problems related to the photoelectric effect, the Compton effect, and de Broglie's matter waves [PR, AI]
- **F3.2** describe the experimental evidence that supports a wave model of matter (e.g., electron diffraction)