

# Physics, Grade 11

## University Preparation

SPH3U

This course develops students' understanding of the basic concepts of physics. Students will explore kinematics, with an emphasis on linear motion; different kinds of forces; energy transformations; the properties of mechanical waves and sound; and electricity and magnetism. They will enhance their scientific investigation skills as they test laws of physics. In addition, they will analyse the interrelationships between physics and technology, and consider the impact of technological applications of physics on society and the environment.

**Prerequisite:** Science, Grade 10, Academic

### Big Ideas

#### *Kinematics*

- Motion involves a change in the position of an object over time.
- Motion can be described using mathematical relationships.
- Many technologies that apply concepts related to kinematics have societal and environmental implications.

#### *Forces*

- Forces can change the motion of an object.
- Applications of Newton's laws of motion have led to technological developments that affect society and the environment.

#### *Energy and Society*

- Energy can be transformed from one type to another.
- Energy transformation systems often involve thermal energy losses and are never 100% efficient.
- Although technological applications that involve energy transformations can affect society and the environment in positive ways, they can also have negative effects, and therefore must be used responsibly.

#### *Waves and Sound*

- Mechanical waves have specific characteristics and predictable properties.
- Sound is a mechanical wave.
- Mechanical waves can affect structures, society, and the environment in positive and negative ways.

#### *Electricity and Magnetism*

- Relationships between electricity and magnetism are predictable.
- Electricity and magnetism have many technological applications.
- Technological applications that involve electromagnetism and energy transformations can affect society and the environment in positive and negative ways.

## Fundamental Concepts Covered in This Course (see also page 5)

Fundamental Concepts	Kinematics	Forces	Energy and Society	Waves and Sound	Electricity and Magnetism
Matter					
Energy					
Systems and Interactions					
Structure and Function					
Sustainability and Stewardship					
Change and Continuity					

# A. SCIENTIFIC INVESTIGATION SKILLS AND CAREER EXPLORATION

## OVERALL EXPECTATIONS

Throughout this course, students will:

- A1.** demonstrate scientific investigation skills (related to both inquiry and research) in the four areas of skills (initiating and planning, performing and recording, analysing and interpreting, and communicating);
- A2.** identify and describe careers related to the fields of science under study, and describe the contributions of scientists, including Canadians, to those fields.

## SPECIFIC EXPECTATIONS

### A1. Scientific Investigation Skills

Throughout this course, students will:

#### Initiating and Planning [IP]\*

- 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
- A1.2** select appropriate instruments (e.g., probeware, calorimeters, pendulums, solenoids) and materials (e.g., drag sleds, electric bells, balls, ramps), and identify appropriate methods, techniques, and procedures, for each inquiry
- A1.3** identify and locate a variety of print and electronic sources that enable them to address research topics fully and appropriately
- 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

#### Performing and Recording [PR]\*

- 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
- 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
- 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

#### Analysing and Interpreting [AI]\*

- A1.8** synthesize, analyse, interpret, and evaluate qualitative and/or 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
- A1.9** analyse the information gathered from research sources for logic, accuracy, reliability, adequacy, and bias

\* The abbreviation(s) for the broad area(s) of investigation skills – IP, PR, AI, and/or C – are provided in square brackets at the end of the expectations in strands B–F to which the particular area(s) relate (see pp. 20–22 for information on scientific investigation skills).

**A1.10** draw conclusions based on inquiry results and research findings, and justify their conclusions with reference to scientific knowledge

**Communicating [C]\***

**A1.11** communicate ideas, plans, procedures, results, and conclusions orally, in writing, and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

**A1.12** use appropriate numeric (e.g., SI and imperial units), symbolic, and graphic modes of representation for qualitative and quantitative data (e.g., vector diagrams, free-body diagrams, algebraic equations)

**A1.13** express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

## A2. Career Exploration

Throughout this course, students will:

**A2.1** identify and describe a variety of careers related to the fields of science under study (e.g., theoretical physicist; communications, networks, and control systems professional; engineer; metallurgist) and the education and training necessary for these careers

**A2.2** describe the contributions of scientists, including Canadians (e.g., Richard E. Taylor, Leonard T. Bruton, Willard S. Boyle, Martha Salcudean, Harriet Brooks, Louis Slotin), to the fields under study

## B. KINEMATICS

### OVERALL EXPECTATIONS

By the end of this course, students will:

- B1.** analyse technologies that apply concepts related to kinematics, and assess the technologies' social and environmental impact;
- B2.** investigate, in qualitative and quantitative terms, uniform and non-uniform linear motion, and solve related problems;
- B3.** demonstrate an understanding of uniform and non-uniform linear motion, in one and two dimensions.

### SPECIFIC EXPECTATIONS

#### B1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- B1.1** analyse, on the basis of research, a technology that applies concepts related to kinematics (e.g., devices used to measure speed in sports; rocket accelerators; motion-detecting sensors for security systems; speedometers in automobiles) [IP, PR, AI, C]

*Sample questions:* How does a speed gun measure the motion of a ball thrown by a baseball pitcher? How are accelerometers used to study the motion of animals in wilderness settings? How are accelerometers used in video game consoles? What type of device is used to monitor false starts in a sprint? How does it work?

- B1.2** assess the impact on society and the environment of a technology that applies concepts related to kinematics (e.g., photo radar helps prevent vehicular accidents and reduces fuel consumption associated with excessive speeding) [AI, C]

*Sample issue:* The use of the global positioning system (GPS) increases accuracy in mapping, surveying, navigation, monitoring earthquakes, and tracking the movement of oil spills and forest fires, among other benefits. However, its extensive use raises concerns about privacy and human rights.

*Sample questions:* How are satellites used to track animal species in remote areas? How can scientists and environmentalists use this information to help protect vulnerable species? What is the impact of the use of speed limiters and tracking devices in the trucking industry? What effect do lower truck speeds have on highway safety and vehicle emissions?

#### B2. Developing Skills of Investigation and Communication

By the end of this course, students will:

- B2.1** use appropriate terminology related to kinematics, including, but not limited to: *time, distance, position, displacement, speed, velocity, and acceleration* [C]
- B2.2** analyse and interpret position–time, velocity–time, and acceleration–time graphs of motion in one dimension (e.g., use tangent slopes to create velocity–time graphs from position–time graphs and acceleration–time graphs from velocity–time graphs; use the area under the curve to create position–time graphs from velocity–time graphs and velocity–time graphs from acceleration–time graphs) [AI, C]
- B2.3** use a velocity–time graph for constant acceleration to derive the equation for average velocity [e.g.,  $v_{av} = (v_1 + v_2)/2$ ] and the equations for displacement [e.g.,  $\Delta d = ((v_1 + v_2)/2) \Delta t$ ,  $\Delta d = v_1 \Delta t + \frac{1}{2} a (\Delta t^2)$ ], and solve simple problems in one dimension using these equations [AI]

**B2.4** conduct an inquiry into the uniform and non-uniform linear motion of an object (e.g., use probeware to record the motion of a cart moving at a constant velocity or a constant acceleration; view a computer simulation of an object attaining terminal velocity; observe a video of a bouncing ball or a skydiver; observe the motion of a balloon with a small mass suspended from it) [PR]

**B2.5** solve problems involving distance, position, and displacement (e.g., find total displacement using a scale vector diagram and vector components, and compare it to total distance travelled) [AI, C]

**B2.6** plan and conduct an inquiry into the motion of objects in one dimension, using vector diagrams and uniform acceleration equations [IP, PR, C]

**B2.7** solve problems involving uniform and non-uniform linear motion in one and two dimensions, using graphical analysis and algebraic equations [AI, C]

**B2.8** use kinematic equations to solve problems related to the horizontal and vertical components of the motion of a projectile (e.g., a cannon ball

shot horizontally off a cliff, a ball rolling off a table, a golf ball launched at a  $45^\circ$  angle to the horizontal) [AI, C]

**B2.9** conduct an inquiry into the projectile motion of an object, and analyse, in qualitative and quantitative terms, the relationship between the horizontal and vertical components (e.g., airborne time, range, maximum height, horizontal velocity, vertical velocity) [PR, AI]

### B3. Understanding Basic Concepts

By the end of this course, students will:

**B3.1** distinguish between the terms *constant*, *instantaneous*, and *average* with reference to speed, velocity, and acceleration, and provide examples to illustrate each term

**B3.2** distinguish between, and provide examples of, scalar and vector quantities as they relate to the description of uniform and non-uniform linear motion (e.g., time, distance, position, velocity, acceleration)

**B3.3** describe the characteristics and give examples of a projectile's motion in vertical and horizontal planes

# C. FORCES

## OVERALL EXPECTATIONS

By the end of this course, students will:

- C1.** analyse and propose improvements to technologies that apply concepts related to dynamics and Newton's laws, and assess the technologies' social and environmental impact;
- C2.** investigate, in qualitative and quantitative terms, net force, acceleration, and mass, and solve related problems;
- C3.** demonstrate an understanding of the relationship between changes in velocity and unbalanced forces in one dimension.

## SPECIFIC EXPECTATIONS

### C1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- C1.1** analyse, with reference to Newton's laws, a technology that applies these laws (e.g., extremely low friction bearings, near frictionless carbon, different types of athletic shoes, roller coasters), and propose ways to improve its performance [AI, C]

*Sample questions:* What factors are taken into consideration in the design of golf clubs? What element(s) could be changed to improve a club's performance? How do anti-lock brakes work, and what limitations do they have? What impact does the condition of the road (wet, dry, smooth, grooved) have on the forces acting on the braking of a skidding car? What are the benefits and limitations of electronic stability controls (ESC) on automobiles?

- C1.2** evaluate the impact on society and the environment of technologies that use the principles of force (e.g., prosthetics, plastic car bodies) [AI, C]

*Sample issue:* Before the 1960s, when car bodies were strong and rigid, passengers tended to be severely injured during collisions. The introduction of technologies that absorb or dissipate force, such as crumple zones, seat belts, and air bags, has reduced serious automobile injuries and the social costs associated with them.

*Sample questions:* How do snow tires reduce the risk of traffic accidents in the winter? How does society benefit from this risk reduction? What are the advantages and disadvantages for the environment of various methods of using the natural forces from tidal currents to generate energy?

### C2. Developing Skills of Investigation and Communication

By the end of this course, students will:

- C2.1** use appropriate terminology related to forces, including, but not limited to: *mass, time, speed, velocity, acceleration, friction, gravity, normal force, and free-body diagrams* [C]
- C2.2** conduct an inquiry that applies Newton's laws to analyse, in qualitative and quantitative terms, the forces acting on an object, and use free-body diagrams to determine the net force and the acceleration of the object [PR, AI, C]
- C2.3** conduct an inquiry into the relationship between the acceleration of an object and its net force and mass (e.g., view a computer simulation of an object attaining terminal velocity; observe the motion of an object subject to friction; use electronic probes to observe the motion of an object being pulled across the floor), and analyse the resulting data [PR, AI]

**C2.4** analyse the relationships between acceleration and applied forces such as the force of gravity, normal force, force of friction, coefficient of static friction, and coefficient of kinetic friction, and solve related problems involving forces in one dimension, using free-body diagrams and algebraic equations (e.g., use a drag sled to find the coefficient of friction between two surfaces) [AI, C]

**C2.5** plan and conduct an inquiry to analyse the effect of forces acting on objects in one dimension, using vector diagrams, free-body diagrams, and Newton's laws [IP, PR, AI, C]

**C2.6** analyse and solve problems involving the relationship between the force of gravity and acceleration for objects in free fall [AI]

### C3. Understanding Basic Concepts

By the end of this course, students will:

**C3.1** distinguish between, and provide examples of, different forces (e.g., friction, gravity, normal force), and describe the effect of each type of force on the velocity of an object

**C3.2** explain how the theories and discoveries of Galileo and Newton advanced knowledge of the effects of forces on the motion of objects

**C3.3** state Newton's laws, and apply them, in qualitative terms, to explain the effect of forces acting on objects

**C3.4** describe, in qualitative and quantitative terms, the relationships between mass, gravitational field strength, and force of gravity



# D. ENERGY AND SOCIETY

## OVERALL EXPECTATIONS

By the end of this course, students will:

- D1.** analyse technologies that apply principles of and concepts related to energy transformations, and assess the technologies' social and environmental impact;
- D2.** investigate energy transformations and the law of conservation of energy, and solve related problems;
- D3.** demonstrate an understanding of work, efficiency, power, gravitational potential energy, kinetic energy, nuclear energy, and thermal energy and its transfer (heat).

## SPECIFIC EXPECTATIONS

### D1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- D1.1** analyse, using the principles of energy transformations, a technology that involves the transfer and transformation of thermal energy (e.g., a power station, an air conditioner, a fuel cell, a laser printer) [AI, C]

**Sample questions:** How do vertical or rooftop gardens help insulate structures? In what ways have refrigeration technologies changed since their initial development? When they are designed efficiently, how do homes with solar-powered cells use the energy from the sun? How do ground-source heat pumps reduce the need for traditional heating and cooling systems?

- D1.2** assess, on the basis of research, how technologies related to nuclear, thermal, or geothermal energy affect society and the environment (e.g., thermal regulating units, radiopharmaceuticals, dry-steam power plants, ground-source heat pumps) [IP, PR, AI, C]

**Sample issue:** With the rising economic and environmental costs of heating homes using conventional methods, geothermal technologies are an increasingly popular alternative. However, tapping geothermal heat sources involves placing kilometres of tubing containing antifreeze in the ground, which constitutes a potential environmental hazard.

**Sample questions:** How is the nuclear technology known as receptor binding assay used to monitor the toxicity of shellfish? How does this technology benefit consumers? How can nuclear

technology be used to sterilize insects? If used widely, what impact would such a pest-control technique have on society and the environment? What is the benefit of using fast-freeze technologies in cold chain shipping for highly perishable goods?

### D2. Developing Skills of Investigation and Communication

By the end of this course, students will:

- D2.1** use appropriate terminology related to energy transformations, including, but not limited to: *mechanical energy, gravitational potential energy, kinetic energy, work, power, fission, fusion, heat, heat capacity, temperature, and latent heat* [C]
- D2.2** solve problems relating to work, force, and displacement along the line of force [AI]
- D2.3** use the law of conservation of energy to solve problems in simple situations involving work, gravitational potential energy, kinetic energy, and thermal energy and its transfer (heat) [AI]
- D2.4** plan and conduct inquiries involving transformations between gravitational potential energy and kinetic energy (e.g., using a pendulum, a falling ball, an object rolling down a ramp) to test the law of conservation of energy [IP, PR]
- D2.5** solve problems involving the relationship between power, energy, and time [AI]
- D2.6** conduct inquiries and solve problems involving the relationship between power and work (e.g., the power of a student using different types of fitness equipment) [PR, AI]

**D2.7** compare and contrast the input energy, useful output energy, and per cent efficiency of selected energy generation methods (e.g., hydroelectric, thermal, geothermal, nuclear fission, nuclear fusion, wind, solar) [AI, C]

**D2.8** investigate the relationship between the concepts of conservation of mass and conservation of energy, and solve problems using the mass-energy equivalence [PR, AI]

**D2.9** conduct an inquiry to determine the specific heat capacity of a single substance (e.g., aluminum, iron, brass) and of two substances when they are mixed together (e.g., the heat lost by a sample of hot water and the heat gained by a sample of cold water when the two samples are mixed together) [PR]

**D2.10** solve problems involving changes in temperature and changes of state, using algebraic equations (e.g.,  $Q = mc\Delta T$ ,  $Q = mL_v$ ,  $Q = mL_f$ ) [AI, C]

**D2.11** draw and analyse heating and cooling curves that show temperature changes and changes of state for various substances [AI, C]

### D3. Understanding Basic Concepts

By the end of this course, students will:

**D3.1** describe a variety of energy transfers and transformations, and explain them using the law of conservation of energy

**D3.2** explain the concepts of and interrelationships between energy, work, and power, and identify and describe their related units

**D3.3** explain the following concepts, giving examples of each, and identify their related

units: *thermal energy, kinetic energy, gravitational potential energy, heat, specific heat capacity, specific latent heat, power, and efficiency*

**D3.4** identify, qualitatively, the relationship between efficiency and thermal energy transfer

**D3.5** describe, with reference to force and displacement along the line of force, the conditions that are required for work to be done

**D3.6** describe and compare nuclear fission and nuclear fusion

**D3.7** explain, using the kinetic molecular theory, the energy transfer that occurs during changes of state

**D3.8** distinguish between and provide examples of conduction, convection, and radiation

**D3.9** identify and describe the structure of common nuclear isotopes (e.g., hydrogen, deuterium, tritium)

**D3.10** compare the characteristics of (e.g., mass, charge, speed, penetrating power, ionizing ability) and safety precautions related to alpha particles, beta particles, and gamma rays

**D3.11** explain radioactive half-life for a given radioisotope, and describe its applications and their consequences

**D3.12** explain the energy transformations that occur within a nuclear power plant, with reference to the laws of thermodynamics (e.g., nuclear fission results in the liberation of energy, which is converted into thermal energy; the thermal energy is converted into electrical energy and waste heat, using a steam turbine)

# E. WAVES AND SOUND

## OVERALL EXPECTATIONS

By the end of this course, students will:

- E1.** analyse how mechanical waves and sound affect technology, structures, society, and the environment, and assess ways of reducing their negative effects;
- E2.** investigate, in qualitative and quantitative terms, the properties of mechanical waves and sound, and solve related problems;
- E3.** demonstrate an understanding of the properties of mechanical waves and sound and of the principles underlying their production, transmission, interaction, and reception.

## SPECIFIC EXPECTATIONS

### E1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- E1.1** analyse how properties of mechanical waves and sound influence the design of structures and technological devices (e.g., the acoustical design of a concert hall; the design of headphones, hearing aids, musical instruments, wave pools) [AI, C]

*Sample issue:* Waves cause vibrations when they oscillate at different frequencies.

Oscillating waves caused by wind or earthquakes can threaten the structure of bridges if they are not properly designed. Engineers have developed different designs of bridges, depending on local conditions, but no single design can take all possible wave frequencies into account.

*Sample questions:* How do energy-conversion buoys use the properties of waves to generate electricity? Why do different musical instruments produce different sounds? What features need to be incorporated into the acoustic design of an outdoor concert venue in order for it to provide optimal sound quality for the audience but limited noise in the surrounding area?

- E1.2** analyse the negative impact that mechanical waves and/or sound can have on society and the environment, and assess the effectiveness of a technology intended to reduce this impact [AI, C]

*Sample issue:* Noise pollution from industrial, transportation, entertainment, and other sources can increase stress, lead to hearing loss, disrupt ecosystems, and alter animal behaviour. Noise pollution can be reduced by using mufflers, sound barriers, baffles, and earplugs, and by turning down the volume on devices such as cellphones and headsets.

*Sample questions:* What impact can tsunamis have on coastal regions? How effective is tsunami-monitoring equipment in reducing death tolls and property destruction? How do the noise levels produced by different types of jet engines compare with each other? How effective are the sound baffles erected on the sides of highways that run through residential areas?

### E2. Developing Skills of Investigation and Communication

By the end of this course, students will:

- E2.1** use appropriate terminology related to mechanical waves and sound, including, but not limited to: *longitudinal wave, transverse wave, frequency, period, cycle, amplitude, phase, wavelength, velocity, superposition, constructive interference, destructive interference, standing waves, and resonance* [C]
- E2.2** conduct laboratory inquiries or computer simulations involving mechanical waves and their interference (e.g., using a mass oscillating on a spring, a mass oscillating on a pendulum, the oscillation in a string instrument) [PR]

- E2.3** plan and conduct inquiries to determine the speed of waves in a medium (e.g., a vibrating air column, an oscillating string of a musical instrument), compare theoretical and empirical values, and account for discrepancies [IP, PR, AI, C]
- E2.4** investigate the relationship between the wavelength, frequency, and speed of a wave, and solve related problems [PR, AI]
- E2.5** analyse the relationship between a moving source of sound and the change in frequency perceived by a stationary observer (i.e., the Doppler effect) [AI]
- E2.6** predict the conditions needed to produce resonance in vibrating objects or air columns (e.g., in a wind instrument, a string instrument, a tuning fork), and test their predictions through inquiry [IP, PR, AI]
- E2.7** analyse the conditions required to produce resonance in vibrating objects and/or in air columns (e.g., in a string instrument, a tuning fork, a wind instrument), and explain how resonance is used in a variety of situations (e.g., to produce different notes in musical instruments; to limit undesirable vibrations in suspension bridges; to design buildings so that they do not resonate at the frequencies produced by earthquakes) [AI, C]

### E3. Understanding Basic Concepts

By the end of this course, students will:

- E3.1** distinguish between longitudinal and transverse waves in different media, and provide examples of both types of waves
- E3.2** explain the components of resonance, and identify the conditions required for resonance to occur in vibrating objects and in various media (e.g., with reference to a musical instrument, a child on a swing, the Tacoma Narrows Bridge)
- E3.3** explain and graphically illustrate the principle of superposition with respect to standing waves and beat frequencies
- E3.4** identify the properties of standing waves, and, for both mechanical and sound waves, explain the conditions required for standing waves to occur
- E3.5** explain the relationship between the speed of sound in various media and the particle nature of the media (e.g., the speed of sound in solids, liquids, and gases; the speed of sound in warm and cold air)
- E3.6** explain selected natural phenomena (e.g., echo location, or organisms that produce or receive infrasonic, audible, or ultrasonic sound) with reference to the characteristics and properties of waves

# F. ELECTRICITY AND MAGNETISM

## OVERALL EXPECTATIONS

By the end of this course, students will:

- F1.** analyse the social, economic, and environmental impact of electrical energy production and technologies related to electromagnetism, and propose ways to improve the sustainability of electrical energy production;
- F2.** investigate, in qualitative and quantitative terms, magnetic fields and electric circuits, and solve related problems;
- F3.** demonstrate an understanding of the properties of magnetic fields, the principles of current and electron flow, and the operation of selected technologies that use these properties and principles to produce and transmit electrical energy.

## SPECIFIC EXPECTATIONS

### F1. Relating Science to Technology, Society, and the Environment

By the end of this course, students will:

- F1.1** analyse the social and economic impact of technologies related to electromagnetism (e.g., particle accelerators, mass spectrometers, magnetic levitation [maglev] trains, magnetic resonance imaging [MRI], electromagnetic pulses after nuclear explosions) [AI, C]

**Sample issue:** The use of red-light camera technology at busy intersections has decreased the number of accidents and pedestrian fatalities. However, some people view the use of this technology as an unnecessary intrusion by “Big Brother”.

**Sample questions:** What are the benefits of electromagnetic medical technologies? What impact does the cost of acquiring these technologies, and the need for specialized technicians to operate them, have on equitable access to health care in all regions of Canada? What harmful effects do solar flares have on our atmosphere, satellites orbiting the earth, and electrical systems?

- F1.2** analyse the efficiency and the environmental impact of one type of electrical energy production (e.g., from hydroelectric, fossil fuel-burning, wind, solar, geothermal, or nuclear sources), and propose ways to improve the sustainability of electrical energy production [AI, C]

**Sample issue:** Compared to oil, coal is relatively inexpensive and plentiful, and, globally, the number of coal-burning electrical plants is expanding. Yet, coal power is inefficient, and the mining and burning of coal produce a great deal of pollution. Although technology is available to make coal cleaner, it is costly and has been implemented to only a limited extent.

**Sample questions:** How efficient are the small- and large-scale solar-power systems used in individual homes and industrial settings? What is the environmental impact of the generation of solar power? What technologies are being used to improve the efficiency of energy sources such as coal and biofuel? What impact does the increasing use of biofuels have on air quality, land use, and agricultural practices?

### F2. Developing Skills of Investigation and Communication

By the end of this course, students will:

- F2.1** use appropriate terminology related to electricity and magnetism, including, but not limited to: *direct current, alternating current, conventional current, electron flow, electrical potential difference, electrical resistance, power, energy, step-up transformer, and step-down transformer* [C]
- F2.2** analyse diagrams of series, parallel, and mixed circuits with reference to Ohm’s law ( $V = IR$ ) and Kirchhoff’s laws [AI]

- F2.3** design and build real or computer-simulated mixed direct current (DC) circuits, and explain the circuits with reference to direct current, potential difference, and resistance [PR, C]
- F2.4** conduct an inquiry to identify the characteristics and properties of magnetic fields (e.g., using magnetic compasses, iron filings, and electric and magnetic field sensors) [PR]
- F2.5** investigate, through laboratory inquiry or computer simulation, the magnetic fields produced by an electric current flowing through a long straight conductor and a solenoid (e.g., use sensors to map the magnetic field around a solenoid) [PR]
- F2.6** solve problems involving energy, power, potential difference, current, and the number of turns in the primary and secondary coils of a transformer [AI]
- F2.7** investigate electromagnetic induction, and, using Lenz's law, the law of conservation of energy, and the right-hand rule, explain and illustrate the direction of the electric current induced by a changing magnetic field [PR, AI, C]
- F2.8** construct a prototype of a device that uses the principles of electromagnetism (e.g., an electric bell, loudspeaker, ammeter, electric motor, electric generator), and test and refine their device [PR, AI]
- F3.1** describe the properties of magnetic fields in permanent magnets and electromagnets (e.g., the three-dimensional nature of fields, continuous field lines, fields around current-carrying conductors and coils)
- F3.2** explain, by applying the right-hand rule, the direction of the magnetic field produced when electric current flows through a long straight conductor and through a solenoid
- F3.3** distinguish between conventional current and electron flow in relation to the left- and right-hand rules
- F3.4** explain Ohm's law, Kirchhoff's laws, Oersted's principle, the motor principle, Faraday's law, and Lenz's law in relation to electricity and magnetism
- F3.5** describe the production and interaction of magnetic fields, using diagrams and the principles of electromagnetism (e.g., Oersted's principle, the motor principle, Faraday's law, Lenz's law)
- F3.6** explain the operation of an electric motor and a generator, including the roles of their respective components
- F3.7** distinguish between alternating current (AC) and direct current, and explain why alternating current is presently used in the transmission of electrical energy
- F3.8** describe the components of step-up and step-down transformers, and, using concepts and principles related to electric current and magnetic fields, explain the operation of these transformers
- F3.9** describe and explain safety precautions (e.g., "call before you dig", current-limiting outlets in bathrooms) related to electrical circuits and higher transmission voltages (e.g., with reference to transformer substations, buried cables, overhead power lines)

### F3. Understanding Basic Concepts

By the end of this course, students will:

- F3.1** describe the properties of magnetic fields in permanent magnets and electromagnets (e.g., the three-dimensional nature of fields, continuous field lines, fields around current-carrying conductors and coils)