Contemporary Physics

Curriculum Connections

ALBERTA, NORTHWEST TERRITORIES, NUNAVUT—Physics 20 and Physics 30

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics Curriculum Connections (Physics 20 and Physics 30)
(2007, updated 2014)

Activity 1: Next Stop, Mars!

PHYSICS 20—UNIT A: KINEMATICS

Specific Learning Outcomes

20–A1.1k define, qualitatively and quantitatively, displacement, velocity and acceleration

20–A1.4k interpret, quantitatively, the motion of one object relative to another, using displacement and velocity vectors

20–A1.5k explain, quantitatively, two-dimensional motion in a horizontal or vertical plane, using vector components

20–A1.3sts explain that the process for technological development includes testing and evaluating designs and prototypes on the basis of established criteria **(ST5d) [ICT C6–4.5]**

Specific Outcomes for Skills (Nature of Science Emphasis)

Planning

20–A1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- identify, define and delimit questions to investigate

Performing and Recording

20–A1.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- perform an experiment to demonstrate the relationships among displacement, velocity, acceleration and time, using available technologies

Analyzing and Interpreting

20–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- solve, quantitatively, projectile motion problems near Earth's surface, ignoring air resistance **(AI–NS3) [ICT C6–4.1]**

Communication and Teamwork

20–A1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

PHYSICS 30—UNIT A: MOMENTUM AND IMPULSE

Specific Learning Outcomes

30–A1.2k explain, quantitatively, the concepts of impulse and change in momentum, using Newton's laws of motion

30–A1.3k explain, qualitatively, that momentum is conserved in an isolated system

30–A1.4k explain, quantitatively, that momentum is conserved in one- and two-dimensional interactions in an isolated system

Specific Outcomes for Skills (Science and Technology Emphasis)

Analyzing and Interpreting

30–A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze, quantitatively, one- and two-dimensional interactions, using given data or by manipulating objects or computer simulations **(AI–NS3) [ICT C6–4.2, C7–4.2]**

Activity 2: Detector Physics

PHYSICS 30—UNIT B: FORCES AND FIELDS

Specific Learning Outcomes

30–B2.2k compare forces and fields

30–B2.6k explain, quantitatively, electric fields in terms of intensity (strength) and direction, relative to the source of the field and to the effect on an electric charge

30–B2.8k describe, quantitatively, the motion of an electric charge in a uniform electric field

30–B2.9k explain, quantitatively, electrical interactions using the law of conservation of energy

30–B3.5k explain, qualitatively and quantitatively, how a uniform magnetic field affects a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular

PHYSICS 30—UNIT D: ATOMIC PHYSICS

Specific Learning Outcomes

30-D3.6k relate, qualitatively and quantitatively, the mass defect of the nucleus to the energy released in nuclear reactions, using Einstein's concept of mass-energy equivalence

30-D4.1k explain how the analysis of particle tracks contributed to the discovery and identification of the characteristics of subatomic particles

Specific Outcomes for Skills (Science and Technology Emphasis)

Initiating and Planning

30-D4.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- predict the characteristics of elementary particles, from images of their tracks in a bubble chamber, within an external magnetic field **(IP-NS3)**

Analyzing and Interpreting

30–B2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze, quantitatively, the motion of an electric charge following a straight or curved path in a uniform electric field, using Newton's second law, vector addition and conservation of energy **(AI–NS3)**

30–B3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze, quantitatively, the motion of an electric charge following a straight or curved path in a uniform magnetic field, using Newton's second law and vector addition **(AI–NS3) [ICT C7–4.2]**

30–D4.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze, quantitatively, particle tracks for subatomic particles other than protons, electrons and neutrons **(AI-NS1) [ITC C7-4.2]**

Communication and Teamwork

30–B2.4s and **30–B3.4s** work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assigning results

Activity 3: Heisenberg's Uncertainty Principle

PHYSICS 30—UNIT A: MOMENTUM AND IMPULSE

Specific Learning Outcomes

30–A1.4k explain, quantitatively, that momentum is conserved in one- and two-dimensional interactions in an isolated system

PHYSICS 30—UNIT C: ELECTROMAGNETIC RADIATION

Specific Learning Outcomes

30–C1.8k describe, qualitatively, diffraction, interference and polarization

30–C2.1k define the photon as a quantum of EMR and calculate its energy

30–C2.6k explain, qualitatively and quantitatively, the Compton effect as another example of wave-particle duality, applying the laws of mechanics and of conservation of momentum and energy to photons

Specific Outcomes for Skills (Science and Technology Emphasis)

Performing and Recording

30–C2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Analyzing and Interpreting

30–C2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

Communication and Teamwork

30–C2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assigning results

Activity 4: How Does Motion Affect Time?

n/a

Activity 5: Electromagnetism and Relativity

PHYSICS 30—UNIT B: FORCES AND FIELDS

Specific Learning Outcomes

30–B2.1k define vector fields

30–B2.2k compare forces and fields

30–B2.6k explain, quantitatively, electric fields in terms of intensity (strength) and direction, relative to the source of the field and to the effect on an electric charge

30–B3.2k compare gravitational, electric and magnetic fields (caused by permanent magnets and moving charges) in terms of their sources and directions

30–B3.3k describe how the discoveries of Oersted and Faraday form the foundation of the theory relating electricity to magnetism

30–B3.4k describe, qualitatively, a moving charge as the source of a magnetic field and predict the orientation of the magnetic field from the direction of motion

30–B3.5k explain, qualitatively and quantitatively, how a uniform magnetic field affects a moving electric charge, using the relationships among charge, motion, field direction and strength, when motion and field directions are mutually perpendicular

30–B3.7k describe and explain, qualitatively, the interaction between a magnetic field and a moving charge and between a magnetic field and a current-carrying conductor

Specific Outcomes for Skills (Science and Technology Emphasis)

Analyzing and Interpreting

30–B3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze, quantitatively, the motion of an electric charge following a straight path in uniform and mutually perpendicular electric and magnetic fields, using Newton's second law and vector addition **(AI–NS3) [ICT C7–4.2]**
- use free-body diagrams to describe forces acting on an electric charge in electric and magnetic fields **(AI–NS1)**

Communication and Teamwork

30–B3.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assigning results

Activity 6: The Hydrogen Atom

PHYSICS 20—UNIT C: CIRCULAR MOTION, WORK AND ENERGY

Specific Learning Outcomes

20–C1.2k explain, qualitatively and quantitatively, that the acceleration in uniform circular motion is directed toward the centre of a circle

20–C1.3k explain, quantitatively, the relationships among speed, frequency, period and radius for circular motion

20–C1.4k explain, qualitatively, uniform circular motion in terms of Newton's laws of motion

PHYSICS 30—UNIT B: FORCES AND FIELDS

Specific Learning Outcomes

30–B1.2k explain electrical interactions in terms of the repulsion and attraction of charges

30–B1.6k apply Coulomb's law, quantitatively, to analyze the interaction of two point charges

30–B1.1sts explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**

PHYSICS 30—UNIT D: ATOMIC PHYSICS

Specific Learning Outcomes

30-D2.5k calculate the energy difference between states, using the law of conservation of energy and the observed characteristics of an emitted photon

Specific Outcomes for Skills (Science and Technology Emphasis)

Analyzing and Interpreting

30–B1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assigning results

Contemporary Physics

Curriculum Connections

BRITISH COLUMBIA AND YUKON—Physics 11 and 12

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

* Elaborations are not included in this chart.

Physics 11 and 12 Curriculum Connections
(2018)

Activity 1: Next Stop, Mars!

Curriculum Competencies

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Analyze cause-and-effect relationships

Evaluating

- Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions
- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Co-operatively design projects with local and/or global connections and applications
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations

Physics 11—Content

- **vector and scalar quantities**
- **projectile motion**
- **graphical methods** in physics

Physics 12—Content

- frames of reference
- relative motion within a stationary reference frame
- **gravitational field** and Newton's law of universal gravitation

- gravitational potential energy
- **gravitational dynamics and energy relationships**
- **impulse** and momentum

Activity 2: Detector Physics

Curriculum Competencies

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Consider the changes in knowledge over time as tools and technologies have developed
- Connect scientific explorations to careers in science

Physics 11—Content

- balanced and unbalanced **forces in systems**

Physics 12—Content

- electric potential energy, electric potential, and electric potential difference
- **magnetic field** and **magnetic force**

Activity 3: Heisenberg's Uncertainty Principle

Curriculum Competencies

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Analyze cause-and-effect relationships

Evaluating

- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Physics 11—Content

- **vector and scalar quantities**
- balanced and unbalanced **forces in systems**
- **properties and behaviours** of waves

Activity 4: How Does Motion Affect Time?

Curriculum Competencies

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies

- Construct, analyze, and interpret graphs, models, and/or diagrams
- Analyze cause-and-effect relationships

Evaluating

- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Physics 12—Content

- postulates of special relativity
- **relativistic effects** within a moving reference frame
- **graphical methods** in physics

Activity 5: Electromagnetism and Relativity

Curriculum Competencies

Processing and analyzing data and information

- Construct, analyze, and interpret graphs, models, and/or diagrams
- Analyze cause-and-effect relationships

Evaluating

- Connect scientific explorations to careers in science

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Co-operatively design projects with local and/or global connections and applications
- Contribute to finding solutions to problems at a local and/or global level through inquiry
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Physics 12—Content

- frames of reference
- postulates of special relativity
- **relativistic effects** within a moving reference frame
- **electromagnetic induction**

Activity 6: The Hydrogen Atom

Curriculum Competencies

Processing and analyzing data and information

- Construct, analyze, and interpret graphs, models, and/or diagrams

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science

Physics 11—Content

- conservation of energy; principle of work and energy
- **properties and behaviours** of waves

Physics 12—Content

- **electric field** and Coulomb's law

Contemporary Physics

Curriculum Connections

MANITOBA—Senior 3 Physics and Senior 4 Physics (40S)

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Senior 3 and 4 Physics Curriculum Connections
(2003 and 2005)

Activity 1: Next Stop, Mars!

Senior 3 Physics

Skills and Attitudes Outcomes

Inquiry Skills

S3P-0-2a Select and use appropriate visual, numeric, graphical, and symbolic modes of representation to identify and represent relationships.

S3P-0-2b Propose problems, state hypotheses, and plan, implement, adapt, or extend procedures to carry out an investigation where required.

S3P-0-2c Estimate and measure accurately, using Système International (SI) units.

S3P-0-2f Record, organize, and display data, using an appropriate formula. Include: labelled diagrams, tables, graphs.

S3P-0-2h Analyze problems, using vectors. Include: adding and subtracting vectors in straight lines and at right angles, vector components.

Attitudes

S3P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

S3P-0-4c Demonstrate confidence in carrying out scientific investigations and in addressing STSE issues.

Topic 4.1: Gravitational Fields

S3P-4-01: Define the gravitational field qualitatively as the region of space around a mass where another point mass experiences a force.

Senior 4 Physics

Topic 1.1: Kinematics

S4P-1-1 Derive the special equations for constant accelerations.
Include: $\vec{a} = \frac{\Delta\vec{v}}{\Delta t}; \Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2; v_2^2 = v_1^2 + 2a\Delta d; \Delta\vec{d} = \left(\frac{\vec{v}_1+\vec{v}_2}{2}\right)\Delta t$

S4P-1-2 Solve problems for objects moving in a straight line with a constant acceleration.
Include: $\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t;\ \Delta\vec{d} = \vec{v}_1\Delta t + \frac{1}{2}\vec{a}\Delta t^2; v_2^2 = v_1^2 + 2a\Delta d; \Delta\vec{d} = \left(\frac{\vec{v}_1+\vec{v}_2}{2}\right)\Delta t$

S4P-1-3 Solve relative motion problems for constant velocities using vectors.

Topic 1.3: Momentum

S4P-1-13 Solve problems using the impulse-momentum equation and the Law of Conservation of Momentum.

S4P-1-14 Relate the impulse-momentum equation to real-life situations.

Topic 1.6: Work and Energy

S4P-1-33 Solve problems related to the conservation of energy. Include: gravitational and spring potential, and kinetic energy.

Topic 2.1: Exploration of Space

S4P-2-5 Solve problems for the escape velocity of a spacecraft. Include Law of Conservation of Energy, binding energy.

Topic 2.2: Low Earth Orbit

S4P-2-12Describe qualitatively some of the technological challenges to exploring deep space.

Activity 2: Detector Physics

Senior 4 Physics

Skills and Attitudes Outcomes

Nature of Science

S4P-0-1c Relate the historical development of scientific ideas and technology to the form and function of scientific knowledge today.

S4P-0-1d Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

Science, Technology, Society, and the Environment (STSE)

S4P-03b Describe examples of how technology has evolved in response to scientific advances and how scientific knowledge has evolved as the result of new innovations in technology.

Topic 2.3: Electric and Magnetic Fields

S4P-2-21 Use hand rules to describe the directional relationships between electric and magnetic fields and moving charges.

S4P-2-22 Describe qualitatively various technologies that use electric and magnetic fields.

Activity 3: Heisenberg's Uncertainty Principle

Senior 3 Physics: Skills and Attitudes Outcomes

Nature of Science

S3P-01a Explain the roles of theory, evidence, and models in the development of scientific knowledge.

Inquiry Skills

S3P-0-2h Analyze problems, using vectors. Include: adding and subtracting vectors in straight lines and at right angles, vector components.

Attitudes

S3P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 2.2: Particle and Wave Models of Light

S3P-2-10 Describe phenomena that are discrepant to the particle model of light. Include: diffraction, partial reflection and refraction of light.

S3P-2-11 Summarize the evidence for the wave model of light. Include: Propagation, reflection, refraction, partial reflection/refraction, diffraction, dispersion.

S3P-2-17 Evaluate the particle and wave models of light and outline the currently accepted view. Include: the principle of complementarity.

Activity 4: How Does Motion Affect Time?

Senior 4 Physics

Topic 1.1: Kinematics

S4P-1-3 Solve relative motion problems for constant velocities using vectors.

Activity 5: Electromagnetism and Relativity

Senior 3 Physics:

Skills and Attitudes Outcomes

Nature of Science

S3P-01a Explain the roles of theory, evidence, and models in the development of scientific knowledge.

Attitudes

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 4.2: Electric Fields

S3P-4-14: Define the electric field qualitatively as the region of space around a charge where a positive test charge experiences a force.

S3P-4-15: Diagram electric fields using lines of force with respect to a positive test charge. Include: single point charges (positive and negative), near two like charges, near two unlike charges, between a single charge and a charged plate, between two oppositely charged parallel plates.

Topic 4.4: Electromagnetism

S3P-4-26: Diagram and describe qualitatively the magnetic field around a current-carrying wire. Include: direction and intensity of the field.

Senior 4 Physics

Skills and Attitudes Outcomes

Nature of Science

S4P-0-1b Describe the importance of peer review in the evaluation and acceptance of scientific theories, evidence, and knowledge claims.

S4P-0-1d Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

Attitudes

S4P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solution, and carry out investigations.

Topic 2.3: Electric and Magnetic Fields

S4P-2-21 Use hand rules to describe the directional relationships between electric and magnetic fields and moving charges.

Topic 3.2: Electromagnetic Induction

S4P-3-8 Demonstrate how a change in magnetic flux induces voltage.

Activity 6: The Hydrogen Atom

Senior 4 Physics

Skills and Attitudes Outcomes

Nature of Science

S4P-0-1b Describe the importance of peer review in the evaluation and acceptance of scientific theories, evidence, and knowledge claims.

Topic 2.3 Electric and Magnetic Fields

S4P-2-14 State Coulomb's Law and solve problems for more than one electric force acting on a charge. Include one and two dimensions.

Contemporary Physics

Curriculum Connections

NEW BRUNSWICK—Physics 11 and Physics 12

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Physics 11 and 12 Curriculum Connections
(2003)

Activity 1: Next Stop, Mars!

STSE

Relationships Between Science and Technology

116-6 describe and evaluate the design of technological solutions and the way they function, using scientific principles

Nature of Science and Technology

115-5 distinguish between scientific questions and technological problems

Skills

Initiating and Planning

212-3 design an experiment identifying and controlling major variables

212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making

Performing and Recording

213-2 carry out procedures controlling the major variables and adapting or extending procedures where required

213-3 use instruments effectively and accurately for collecting data

Analysing and Interpreting

214-5 interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

214-16 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves

Physics 11—Kinematics

Knowledge

325-7 identify the frame of reference for a given motion

325-5 use vectors to represent force, velocity, and acceleration

Physics 11—Work and Energy

Knowledge

326-1 analyse quantitatively the relationships among mass, height, speed, and heat energy using the law of conservation of energy

326-5 describe quantitatively mechanical energy as the sum of kinetic and potential energies

Physics 12—Dynamics Extension

Knowledge

ACP-1 use vector analysis in two dimensions for systems involving two or more masses, relative motion, static equilibrium, and static torques

326-3 apply quantitatively the laws of conservation of momentum to one- and two-dimensional collisions and explosions

Physics 12—Projectiles, Circular Motion and Universal Gravitation

Knowledge

325-6 analyse quantitatively the horizontal and vertical motion of a projectile

Physics 12—Fields

Knowledge

328-1 describe gravitational, electric, and magnetic fields as regions of space that affect mass and charge

Activity 2: Detector Physics

STSE

Nature of Science and Technology

115-4 describe the historical development of a technology

Relationships Between Science and Technology

116-7 analyse natural and technological systems to interpret and explain their structure and dynamics

Physics 12—Fields

Knowledge

328-1 describe gravitational, electric, and magnetic fields as regions of space that affect mass and charge

328-3 describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles

Activity 3: Heisenberg's Uncertainty Principle

Physics 11—Waves

Knowledge

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect

Activity 4: How Does Motion Affect Time?
n/a
Activity 5: Electromagnetism and Relativity
Skills   ***Initiating and Planning***   212-4 state a prediction and a hypothesis based on available evidence and background information   ***Physics 12—Fields***   ***Knowledge***   328-7 analyse, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor   328-5 analyse, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field   328-6 describe the magnetic field produced by current in both a solenoid ad a long, straight conductor
Activity 6: The Hydrogen Atom
Physics 12—Projectiles, Circular Motion and Universal Gravitation   ***Knowledge***   325-12 describe uniform circular motion, using algebraic and vector analysis   325-13 explain quantitatively circular motion, using Newton's laws   ***Physics 12—Fields***   ***Knowledge***   328-1 describe gravitational, electric, and magnetic fields as regions of space that affect mass and charge   328-1 describe gravitational, electric, and magnetic fields by illustrating the source and directions of the lines of force   328-1 compare Newton's universal law of gravitation and Coulomb's law, and apply both laws quantitatively

Contemporary Physics

Curriculum Connections

NEWFOUNDLAND AND LABRADOR—Physics 2204 and Physics 3204

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Physics 2204 and Physics 3204 Curriculum Connections
(2018 and 2019)

Activity 1: Next Stop, Mars!

Physics 2204—Kinematics

Skills

2.0 design an experiment identifying and controlling major variables

7.0 use instruments effectively and accurately for collecting data

Knowledge

27.0 use vectors to represent displacement, velocity, and acceleration

28.0 analyze quantitatively the horizontal or vertical motion of an object

29.0 identify the frame of reference for a given motion

Attitudes

- Work collaborativey in planning and carrying out investigations, as well as in generating and evaluating ideas

Physics 2204—Dynamics

Skills

18.0 construct and test a prototype of a device or system and troubleshoot problems as they arise

19.0 propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan

Knowledge

38.0 apply quantitatively the laws of conservation of momentum to one-dimensional collisions and explosions

Attitudes

- Show concern for safety and accept the need for rules and regulations

Physics 2204—Work and Energy

Knowledge

45.0 analyze quantitatively the relationships among gravitational potential energy, kinetic energy, and heat energy using the law of conservation of energy

Activity 2: Detector Physics

Physics 3204—Fields

STSE

38.0 analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

47.0 analyze technological systems to interpret and explain their structure and dynamics

Skills

6.0 develop appropriate sampling procedures

Knowledge

37.0 describe electric fields as regions of space the affect charge

41.0 describe magnetic fields as regions of space that affect mass and charge

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- value the contributions to scientific and technological development made by individuals from many societies and cultural backgrounds
- show a continuing and more informed curiosity and interest in science and science-related issues

Activity 3: Heisenberg's Uncertainty Principle

Physics 3204—Introduction to Quantum Physics

STSE

34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge

Skills

4.0 formulate operation definitions of major variables

Knowledge

59.0 summarize the evidence for the wave and particle models of light

Attitudes

- value the role and contribution of science and technology to our understanding of phenomena that are directly observable and those that are not

Activity 4: How Does Motion Affect Time?

n/a

Activity 5: Electromagnetism and Relativity

Physics 3204—Fields

STSE

34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge

Skills

18.0 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others

Knowledge

41.0 describe magnetic fields as regions of space that affect mass and charge

42.0 describe the magnetic field produced by current in both a solenoid and a long, straight conductor

43.0 analyze, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field

Attitudes

- show a continuing and more informed curiosity and interest in science and science-related issues

Activity 6: The Hydrogen Atom

Physics 2204—Work and Energy

Knowledge

45.0 analyze quantitatively the relationships among gravitational potential energy, kinetic energy, and heat energy using the law of conservation of energy

Physics 2204—Waves

Knowledge

68.0 explain qualitatively and quantitatively the phenomena of wave interference, reflection, and diffraction

Attitudes

- value processes for drawing conclusions

Physics 3204—Forces

Skills

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

Knowledge

28.0 describe uniform circular motion, using algebraic and vector analysis

29.0 explain quantitatively circular motion using Newton's laws

Physics 3204—Fields

Skills

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

15.0 explain how data support or refute the hypothesis or prediction

Physics 3204—Fields

Knowledge

39.0 apply Coulomb's law quantitatively

Physics 3204—Introduction to Quantum Physics

STSE

34.0 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge

50.0 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced

Knowledge

56.0 explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts

57.0 explain the relationship between the energy levels in Bohr's model, the energy difference between the levels, and the energy of the emitted photons

Contemporary Physics

Curriculum Connections

NOVA SCOTIA—Physics 11 and 12

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Physics 11 and 12 Curriculum Connections
(2002)

Activity 1: Next Stop, Mars!

Physics 11—Kinematics

- identify the frame of reference for a given motion and to distinguish fixed and moving frames (325-7)
- use vectors to represent position, displacement, velocity, and acceleration (325-5)

Physics 11—Dynamics

- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- design an experiment identifying and controlling major variables (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- carry out procedures controlling the major variables and adapting or extending procedures where required (213-2)
- use instruments effectively and accurately for collecting data (213-3)
- interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables (214-5)
- describe the functioning of technology devices based on principles of momentum (116-5)

Physics 11—Momentum and Energy

- analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept (326-6)

Physics 12—Force, Motion, Work, and Energy

- use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques (ACP-1)
- determine in which real-life situations involving elastic and inelastic interactions the laws of conservation of momentum and energy are best used (326-4)
- analyse quantitatively the horizontal and vertical motion of a projectile (325-6)

Attitudes

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

Safety in Science

449 show concern for safety and accept the need for rules and regulations

Activity 2: Detector Physics

Physics 11—Dynamics

- analyse and describe examples where knowledge of the dynamics of bodies was enhanced or revised as a result of the invention of a technology (116-2)
- describe the functioning of technology devices based on principles of momentum (116-5)

Physics 11—Momentum and Energy

- analyse and describe examples where technological solutions were developed based on scientific understanding (116-4)

Physics 12—Fields

- describe magnetic, electric, and gravitational fields as regions of space that affect mass and charge (328-1)
- describe magnetic, electric, and gravitational fields by illustrating the source and direction of the lines of force (328-2)
- describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles (328-3)

Activity 3: Heisenberg's Uncertainty Principle

Physics 11—Waves

- explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler-Fizeau effect (327-8)

Physics 12—Waves and Modern Physics

- explain how a photon momentum revolutionized thinking in the scientific community (115-3)
- apply and assess alternative theoretical models for interpreting knowledge in a given field (214-6)
- summarize the evidence for the wave and particle models of light (327-11)

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

Activity 4: How Does Motion Affect Time?

n/a

Activity 5: Electromagnetism and Relativity

Physics 11—Dynamics

- use vectors to represent forces (325-5)
- explain how a major scientific milestone revolutionized thinking in dynamics (115-3)

Physics 11—Fields

- explain the roles of evidence, theories and paradigms, and peer review in the development of the scientific knowledge associated with a major scientific milestone (114-2, 114-5, 115-3)
- communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others (215-1)
- describe magnetic, electric, and gravitational fields as regions of space that affect mass and charge (328-1)

Physics 12—Fields

- describe the magnetic field produced by a current in a long, straight conductor, and in a solenoid (328-6)
- analyse qualitatively the forces acting on a moving charge in a uniform magnetic field (328-5)
- analyse qualitatively electromagnetic induction by both a changing magnetic flux and a moving conductor (328-7)

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Scientific Inquiry

444 value the processes for drawing conclusions

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 6: The Hydrogen Atom

Physics 11—Dynamics

- use vectors to represent forces (325-5)

Physics 11—Momentum and Energy

- describe quantitatively mechanical energy as the sum of kinetic and potential energies (326-5)
- analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept (326-6)
- analyse common energy transformation situations using the closed system work-energy theorem (326-7)

Physics 11—Waves

- explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler-Fizeau effect (327-8)
- analyse and describe examples where scientific understanding was enhanced as a result of the invention of a technological device (116-2)

Physics 12—Force, Motion, Work, and Energy

- describe uniform circular motion using algebraic and vector analysis (325-12)

Physics 12—Fields

- describe magnetic, electric, and gravitational fields by illustrating the source and direction of the lines of force (328-2)

- describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles (328-3)
- compare Newton's law of universal gravitation with Coulomb's law, and apply both laws quantitatively (328-4)

Physics 12—Waves and Modern Physics

- explain quantitatively the Compton effect and the de Broglie hypothesis, using the laws of mechanics, the conservation of momentum, and the nature of light (329-1)
- explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts (329-2)
- explain the relationship among the energy levels in Bohr's model, the energy difference between levels, and the energy of the emitted photons (329-3)

Attitudes

Collaboration

- 445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Grade 12: Contemporary Physics

Curriculum Connections

ONTARIO - 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)

Contemporary Physics

Curriculum Connections

PRINCE EDWARD ISLAND—Physics 521A and Physics 621A

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 521A and 621A Curriculum Connections
(2009 and 2010)

Activity 1: Next Stop, Mars!

PHYSICS 521A—KINEMATICS

Skills

Performing and Recording

213-2 carry out a procedure, controlling the major variables and adapting the procedure where required

Analysing and Interpreting

214-5 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

Communication and Teamwork

215-6 work co-operatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

Knowledge

325-7 identify the frame of reference for a given motion

325-5 use vectors to represent position, displacement, velocity, acceleration, and force

PHYSICS 521A—MOMENTUM AND ENERGY

STSE

Relationships Between Science and Technology

116-6 describe and evaluate the design of technological solutions and the way they function, using principles of energy and momentum

Skills

Initiating and Planning

212-3 design an experiment, identifying and controlling major variables

Performing and Recording

213-2 carry out a procedure, controlling the major variables and adapting the procedure where required

213-3 use instruments effectively and accurately for collecting data

Analysing and Interpreting

214-5 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

214-11 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion

Knowledge

326-11 analyse quantitatively the relationships among mass, height, speed, and heat energy using the law of conservation of energy

326-5 describe quantitatively mechanical energy as the sum of kinetic and potential energies

326-4 determine which laws of conservation of energy or momentum are best used to solve particular real-life situations involving elastic and inelastic collisions

PHYSICS 621A—APPLICATION OF VECTORS

Skills

Analysing and Interpreting

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

214-16 evaluate a personally designed and constructed device on the basis of criteria they have developed themselves

Knowledge

ACP-1 use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques

325-6 analyse quantitatively the horizontal and vertical motion of a projectile

Activity 2: Detector Physics

PHYSICS 621A—CIRCULAR AND PLANETARY MOTION

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationship between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Knowledge

325-13 explain quantitatively circular motion, using Newton's laws

PHYSICS 621A—ELECTRICITY AND MAGNETISM

Skills

Performing and Recording

213-4 estimate quantities

Knowledge

328-1 describe gravitational, electric, and magnetic fields as regions of space that affect mass and charge

328-3 describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles

Activity 3: Heisenberg's Uncertainty Principle

Physics 521A—Waves

Knowledge

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

Activity 4: How Does Motion Affect Time?

n/a

Activity 5: Electromagnetism and Relativity

PHYSICS 621A—ELECTRICITY AND MAGNETISM

STSE

Nature of Science and Technology

114-2 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge

115-3 explain how a major scientific milestone revolutionized thinking in the scientific communities

Knowledge

328-7 analyse, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor

328-5 analyse, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field

328-6 describe the magnetic field produced by current in both a solenoid and a long, straight conductor

Activity 6: The Hydrogen Atom

PHYSICS 521A—MOMENTUM AND ENERGY

Knowledge

326-5 describe quantitatively mechanical energy as the sum of kinetic and potential energies

PHYSICS 621A—ELECTRICITY AND MAGNETISM

Knowledge

328-1 describe gravitational, electric, and magnetic fields as regions of space that affect mass and charge

328-3 describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles

Contemporary Physics

Curriculum Connections

SASKATCHEWAN—Physics 30

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 30 Curriculum Connections
(2016, updated April 2017)

Activity 1: Next Stop, Mars!

Forces and Motion

PH30-FM-1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motions. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

c. Solve problems involving different types of motion in one- and two-dimensions, including relative motion, using graphical methods, vector analysis and kinematics equations
(e.g., $\vec{v} = \frac{\Delta\vec{d}}{t}$, $\vec{v}_\mathrm{f} = \vec{v}_\mathrm{i} + \vec{a}\Delta t$, $\vec{v}_\mathrm{f}^2 = \vec{v}_\mathrm{i}^2 + 2\vec{a}\Delta\vec{d}$, $\Delta\vec{d} = \vec{v}_\mathrm{i}\Delta t + \frac{1}{2}\vec{a}\Delta t^2$ and $\Delta\vec{d} = \frac{1}{2}(\vec{v}_\mathrm{i} + \vec{v}_\mathrm{f})\Delta t$). (S)

g. Design and perform an experiment that includes collecting, analyzing and interpreting data from objects that undergo projectile motion or uniform circular motion. (STSE)

j. Predict the path an object (e.g., shot put, discus, hammer throw, bolo, particles in a synchrotron and rocket undergoing gravity assisted space travel) will follow once released from uniform circular motion. (K, S, STSE)

Conservation Laws

PH30-CO1 Investigate the nature of mechanical energy and efficiency in mechanical systems in relation to the law of conservation of energy. [SI]

e. Explain the law of conservation of energy in terms of isolated and non-isolated systems and conservation of mechanical energy. (STSE, K)

f. Solve problems related to kinetic, potential and total mechanical energy using relevant equations (e.g., $W = \vec{F}\cdot\vec{d}\cos\theta$, $W = \Delta E$, $E_\mathrm{k} = \frac{m\vec{v}^2}{2}$, $E_\mathrm{p} = m\vec{g}\vec{h}$, and $TME = E_\mathrm{k} + E_\mathrm{p}$). (K, S)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

i. Solve problems involving gravitational field strength using $g = \frac{Gm}{r^2}$ and Newton's law of universal gravitation ($F = \frac{Gm_1m_2}{r^2}$). (K, S)

Activity 2: Detector Physics

Modern Physics

PH30-MP2 Assess the effects of radioactivity and applications of nuclear technology on society and the environment. [CP, DM, SI]

m. Discuss the importance of mass defect and $e = mc^2$ and why this particular equation has gained such prominence in society. (STSE, A)

Fields

PH30-FI2 Investigate electric and magnetic fields and their interactions with matter. [SI, TPS]

f. Recognize how our understanding of the interrelationships between magnetic and electric fields has led to the development of technologies such as generators and electromagnets (e.g., moving charged particles create a magnetic field, interaction of electric and magnetic fields). (K, STSE)

j. Analyze the direction of positive, negative and neutral charges moving in natural (e.g., solar flares and aurorae) and man-made (e.g., particle accelerators and MRI's) magnetic fields. (K, STSE)

l. Analyze ways in which natural and technological sources of electric and magnetic fields can influence society and the environment (e.g., changes in animal migration, health concerns and increased communication). (K, STSE, A)

Activity 3: Heisenberg's Uncertainty Principle

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

g. Discuss the implications of conducting observations while investigating wave-particle phenomena and objects at a quantum-scale. (K)

Conservation Laws

PH30-CO2 Analyze the motion of objects and interactions between objects using momentum concepts, including the law of conservation of momentum. [SI]

d. Provide examples that show how momentum is or is not conserved in everyday situations. (K)

f. Solve problems using the law of conservation of momentum in one- and two-dimensional interactions (e.g., head-on collisions, glancing collisions, rocket launches and explosions). (K, S)

Activity 4: How Does Motion Affect Time?

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

c. Distinguish between the theories of general and special relativity with respect to space and time (e.g., curvature of space-time, time dilation, length contraction and relativistic mass). (K, STSE)

d. Consider the implications of inconsistent time with respect to a frame of reference (e.g., time travel and the twin paradox). (S)

e. Explore the impact of scientific understanding of relativity on the development of technologies such as the Global Positioning System, atomic clocks and communication systems. (K, S, STSE)

Forces and Motion

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Activity 5: Electromagnetism and Relativity

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

c. Distinguish between the theories of general and special relativity with respect to space and time (e.g., curvature of space-time, time dilation, length contraction and relativistic mass). (K, STSE)

Fields

PH30-FI2 Investigate electric and magnetic fields and their interactions with matter. [SI, TPS]

f. Recognize how our understanding of the interrelationships between magnetic and electric fields has led to the development of technologies such as generators and electromagnets (e.g., moving charged particles create a magnetic field, interaction of electric and magnetic fields). (K, STSE)

h. Represent the direction of the magnetic field around current- induced conductors, including linear wires and wire coils, using the right hand and/or left-hand rules. (K, S)

Activity 6: The Hydrogen Atom

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

a. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

Contemporary Physics

Curriculum Connections

Next Generation Science Standards (NGSS): Grades 9–12

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Physics Curriculum Connections **(April 2013)**
Activity 1: Next Stop, Mars!
Energy **HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.** [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or t he energies in gravitational, magnetic, or electric fields.] **HS-PS3-5. Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.** [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to systems containing two objects.] ***Forces and Interactions*** **HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.** [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]
Activity 2: Detector Physics
n/a

Activity 3: Heisenberg's Uncertainty Principle
Waves and Electromagnetic Radiation **HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other.** [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.]
Activity 4: How Does Motion Affect Time?
n/a
Activity 5: Electromagnetism and Relativity
n/a
Activity 6: The Hydrogen Atom
Forces and Interactions **HS-PS2-4. Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects.** [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]