PHYSICS 20–30

PROGRAM RATIONALE AND PHILOSOPHY

Science programs provide opportunities for students to develop the knowledge, skills and attitudes they need to become productive and responsible members of society. The programs also allow students to explore interests and prepare for further education and careers. Students graduating from Alberta schools require the scientific and related technological knowledge and skills that will enable them to understand and interpret their world. They also need to develop attitudes that will motivate them to use their knowledge and skills in a responsible manner.

To become scientifically literate, students need to develop a knowledge of science and its relationship to technologies and society. They also need to develop the broad-based skills required to identify and analyze problems; to explore and test solutions; and to seek, interpret and evaluate information. To ensure relevance to students as well as to societal needs, a science program must present science in a meaningful context—providing opportunities for students to explore the process of science, its applications and implications, and to examine related technological problems and issues. By doing so, students become aware of the role of science in responding to social and cultural change and in meeting needs for a sustainable environment, economy and society.

Program Vision

The secondary science program is guided by the vision that all students, regardless of gender or cultural background, are given the opportunity to develop scientific literacy. The goal of scientific literacy is to develop in students the science-related knowledge, skills and attitudes that they need to solve problems and make decisions and, at the same time, to help students become lifelong learners who maintain their sense of wonder about the world around them.

Diverse learning experiences within the science program provide students with opportunities to explore, analyze and appreciate the interrelationships among science, technology, society and the environment and to develop understandings that will affect their personal lives, their careers and their futures.

Goals

The following goals for Canadian science education, developed in the *Common Framework of Science Learning Outcomes K to 12: Pan-Canadian Protocol for Collaboration on School Curriculum* (1997), are addressed through the Alberta science program. Science education will:

- encourage students at all grade levels to develop a critical sense of wonder and curiosity about scientific and technological endeavours
- enable students to use science and technology to acquire new knowledge and solve problems so that they may improve the quality of their lives and the lives of others
- prepare students to critically address science-related societal, economic, ethical and environmental issues
- provide students with a foundation in science that creates opportunities for them to pursue progressively higher levels of study, prepares them for science-related occupations and engages them in science-related hobbies appropriate to their interests and abilities
- develop in students of varying aptitudes and interests a knowledge of the wide spectrum of careers related to science, technology and the environment.

Aboriginal Perspectives

Courses in the senior high school sciences incorporate Aboriginal perspectives in order to develop, in all students, an appreciation of the cultural diversity and achievements of First Nations, Métis and Inuit (FNMI) peoples. These courses are designed to:

- acknowledge the contributions of Aboriginal peoples to understandings of the natural world
- support relational thinking by integrating learning from various disciplines of science
- develop the concept of humankind's connectivity to the natural world and foster an appreciation for the importance of caring for the environment
- foster the development of positive attitudes by providing experiences that encourage all students to feel confident about their ability to succeed in science.

Information and Communication Technology (ICT)

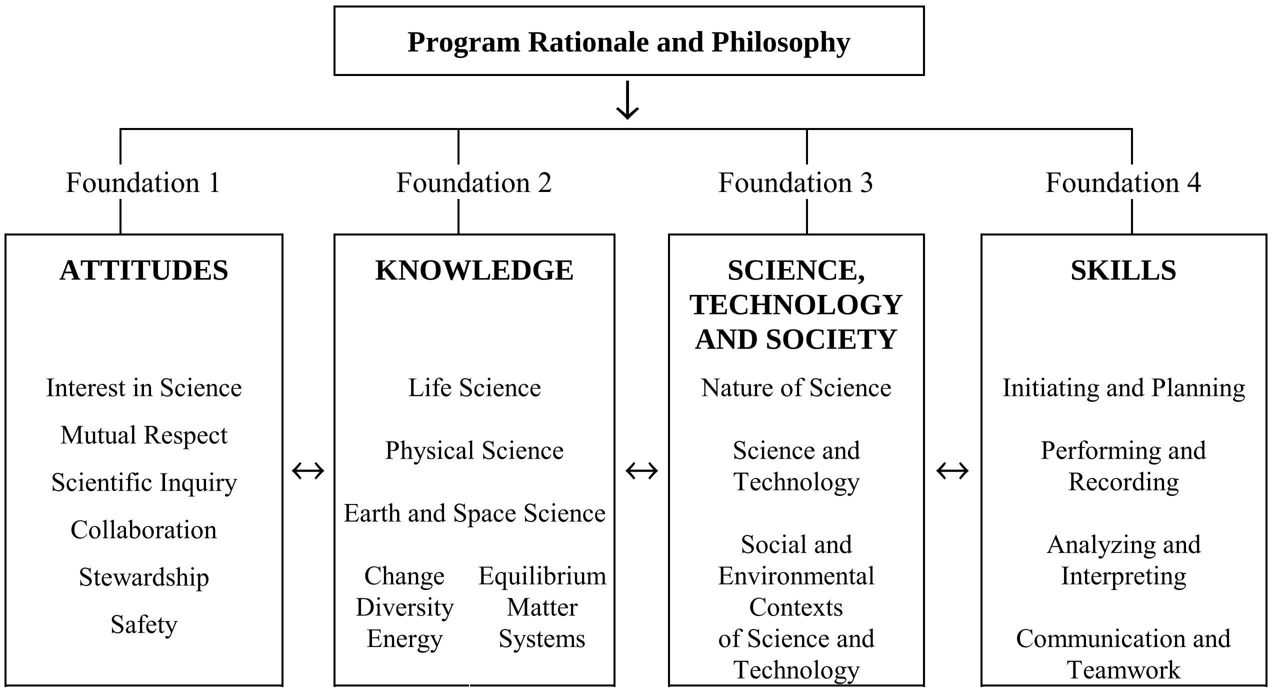
Selected curriculum outcomes from Alberta Education's Information and Communication Technology (ICT) Program of Studies are infused throughout the 20-level and 30-level sciences so that students will develop a broad perspective on the nature of technology, learn how to use and apply a variety of technologies, and consider the impact of ICT on individuals and society. The infusion of ICT outcomes supports and reinforces the understandings and abilities that students are expected to develop within Foundation 3 (Science, Technology and Society) and Foundation 4 (Skills) of these courses. Effective, efficient and ethical application of ICT outcomes contributes to the program vision.

Infusion of ICT outcomes provides learning opportunities for students to:

- understand the nature of technology and apply terminology appropriately
- use equipment carefully and share limited ICT resources
- use technology in an ethical manner, including respecting the ownership of information and digital resources and citing electronic sources
- use technology safely, including applying ergonomic principles and appropriate safety procedures
- use the Internet safely, including protecting personal information and avoiding contact with strangers
- use technology appropriately, including following communication etiquette and respecting the privacy of others.

PROGRAM FOUNDATIONS

To support the development of scientific literacy, a science program must provide learning experiences that address critical aspects of science and its application. These foundations provide a general direction for the program and identify the major components of its structure.



Foundation 1
Attitudes—*Students will be encouraged to* develop attitudes that support the responsible acquisition and application of scientific and technological knowledge to the mutual benefit of self, society and the environment.

Foundation 2
Knowledge—*Students will* construct knowledge and understandings of concepts in life science, physical science and Earth and space science, and apply these understandings to interpret, integrate and extend their knowledge.

Foundation 3
Science, Technology and Society (STS)—*Students will* develop an understanding of the nature of science and technology, the relationships between science and technology, and the social and environmental contexts of science and technology.

Foundation 4
Skills—*Students will* develop the skills required for scientific and technological inquiry, for solving problems, for communicating scientific ideas and results, for working collaboratively and for making informed decisions.

Foundation 1: Attitudes

Foundation 1 is concerned with the generalized aspects of behaviour that are commonly referred to as attitudes. Attitude outcomes are of a different form than outcomes for skills and knowledge: they are exhibited in a different way, and they are rooted more deeply in the experiences that students bring to school. Attitude development is a lifelong process that involves the home, the school, the community and society at large. Attitudes are best shown not by the events of a particular moment but by the pattern of behaviours over time. Development of positive attitudes plays an important role in student growth by interacting with students' intellectual development and by creating a readiness for responsible application of what is learned.

Interest in Science

Students will be encouraged to develop enthusiasm and continuing interest in the study of science.

Mutual Respect

Students will be encouraged to appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds.

Scientific Inquiry

Students will be encouraged to develop attitudes that support active inquiry, problem solving and decision making.

Collaboration

Students will be encouraged to develop attitudes that support collaborative activity.

Stewardship

Students will be encouraged to develop responsibility in the application of science and technology in relation to society and the natural environment.

Safety

Students will be encouraged to demonstrate a concern for safety in science and technology contexts.

Foundation 2: Knowledge

Foundation 2 focuses on the subject matter of science, including the laws, theories, models, concepts and principles that are essential to an understanding of each science area. For organizational purposes, this foundation is framed using widely accepted science disciplines.

Life Science

Life science deals with the growth and interactions of life forms within their environments in ways that reflect their uniqueness, diversity, genetic continuity and changing nature. Life science includes such fields of study as ecosystems, biological diversity, organisms, cells, biochemistry, genetic engineering and biotechnology.

Physical Science

Physical science, which encompasses chemistry and physics, deals with matter, energy and forces. Matter has structure, and there are interactions among its components. Energy links matter to gravitational, electromagnetic and nuclear forces in the universe. Physical science also addresses the conservation laws of mass and energy, momentum and charge.

Earth and Space Science

Earth and space science brings global and universal perspectives to student knowledge. The planet Earth exhibits form, structure and patterns of change, as does the surrounding solar system and the physical universe beyond it. Earth and space science includes such fields of study as geology, meteorology and astronomy.

Themes are the major ideas of science and technology that transcend discipline boundaries and demonstrate unity among the natural sciences. Six themes have been identified for the senior high school sciences program.

Change
Students will develop an understanding of:

How all natural entities are modified over time, how the direction of change might be predicted and, in some instances, how change can be controlled.

Diversity
Students will develop an understanding of:

The array of living and nonliving forms of matter and the procedures used to understand, classify and distinguish these forms of matter on the basis of recurring patterns.

Energy
Students will develop an understanding of:

The capacity for doing work that drives much of what takes place in the universe through its variety of interconvertible forms.

Equilibrium
Students will develop an understanding of:

The state in which opposing forces or processes balance in a static or dynamic way.

Matter
Students will develop an understanding of:

The constituent parts, and the variety of states, of the material in the physical world.

Systems
Students will develop an understanding of:

The interrelated groups of things or events that can be defined by their boundaries and, in some instances, by their inputs and outputs.

Foundation 3: Science, Technology and Society (STS)

Foundation 3 is concerned with understanding the scope and character of science, its connections to technology and the social context in which it is developed. The following is a brief introduction to the major ideas underlying this component of the program.

Nature of Science

Science provides an ordered way of learning about the nature of things, based on observation and evidence. Through science, we explore our environment, gather knowledge and develop ideas that help us interpret and explain what we see. Scientific activity provides a conceptual and theoretical base that is used in predicting, interpreting and explaining natural and technological phenomena. Science is driven by a combination of specific knowledge, theory, observation and experimentation. Science-based ideas are continually being tested, modified and improved as new knowledge and explanations supersede existing knowledge and explanations.

Science and Technology

Technology is concerned with solving practical problems that arise from human needs. Historically, the development of technology has been strongly linked to the development of science, with each making contributions to the other. While there are important relationships and interdependencies, there are also important differences. Whereas the focus of science is on the development and verification of knowledge, the focus of technology is on the development of solutions, involving devices and systems that meet a given need within the constraints of a problem. The test of scientific knowledge is that it helps us explain, interpret and predict; the test of technology is that it works—it enables us to achieve a given purpose.

Social and Environmental Contexts

The history of science shows that scientific development takes place within a social context. Many examples can be used to show that cultural and intellectual traditions have influenced the focus and methodologies of science, and that science in turn has influenced the wider world of ideas.

Today, research is often driven by societal and environmental needs and issues. As technological solutions have emerged from previous research, many of the new technologies have given rise to complex social and environmental issues. Increasingly, these issues are becoming part of the political agenda. The potential of science to inform and empower decision making by individuals, communities and society is central to scientific literacy in a democratic society.

Foundation 4: Skills

Foundation 4 is concerned with the skills that students develop in answering questions, solving problems and making decisions. While these skills are not unique to science, they play an important role in the development of scientific understandings and in the application of science and technology to new situations. Four broad skill areas are outlined in the secondary science program. Each skill area is developed at each level with increasing scope and complexity of application.

Initiating and Planning

These are the skills of questioning, identifying problems and developing preliminary ideas and plans.

Performing and Recording

These are the skills of carrying out a plan of action that include gathering evidence by observation and, in most cases, manipulating materials and equipment.

Analyzing and Interpreting

These are the skills of examining information and evidence; of processing and presenting data so that they can be interpreted; and of interpreting, evaluating and applying the results.

Communication and Teamwork

In science, as in other areas, communication skills are essential at every stage during which ideas are being developed, tested, interpreted, debated and agreed upon. Teamwork skills are also important, as the development and application of science ideas are collaborative processes both in society and in the classroom.

PROGRAM ORGANIZATION

Attitude Outcomes

A listing of Attitude outcomes is included at the beginning of each of the 20-level and 30-level courses in the senior high school sciences program. These specific outcomes are to be developed throughout the particular course in conjunction with the specific outcomes for Knowledge, STS and Skills listed within each unit of study.

Units of Study

In the senior high school sciences program, four units of study are outlined for each course. Each unit in the 20-level and 30-level courses includes the following components.

Themes

Themes are the major ideas of science that transcend topics of study.

Overview

The overview introduces the contents of the unit and suggests an approach to unit development.

Links to Mathematics

This section lists topics from mathematics programs of study that are related to the science content of the unit.

Focusing Questions

These questions frame a context for introducing the unit and suggest a focus for investigative activities and application of ideas by students.

Key Concepts

Key concepts identify major ideas to be developed in the unit. Some of the concepts may be addressed in additional units of the same course, as well as in other courses. The intended scope of treatment of these concepts is indicated by the outcomes.

Outcomes

Two levels of outcomes are provided in each unit:

- General Outcomes: These are the major outcomes in the unit that students are to demonstrate over the course of their learning.
- Specific Outcomes: These are detailed outcomes that delineate the scope of each general outcome and the unit. Specific outcomes for Knowledge; Science, Technology and Society (STS); and Skills are identified.

The outcomes are numbered for the purpose of referencing. This numbering is not intended to imply a fixed instructional sequence.

Examples

Many of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

STS Emphases

The specific outcomes for Science, Technology and Society (STS) and Skills for each general outcome in a unit include one of the following emphases:

- Nature of Science
- Science and Technology
- Social and Environmental Contexts

The STS emphases provide opportunities for students to develop related concepts and skills as outlined on pages 8 to 10.

Additional Links

Links to the STS emphasis frameworks (pages 8 to 10) are shown in **boldface** and (in parentheses) after specific outcomes for STS and after specific outcomes or examples for Skills. Links to the Division 4 ICT curriculum (pages 11 to 13) are shown in **boldface** and [in brackets] after some of the specific outcomes and examples for STS and Skills. The STS and ICT links indicate that the concept or skill from the STS emphasis framework or the Division 4 ICT outcome has been addressed in the specific outcome or example.

Note: The listing of STS and ICT links is not exhaustive; other links may exist.

Framework for Developing a Nature of Science Emphasis (Grades 10–12)

The following concepts and skills are developed through this STS emphasis.

Concepts (focus on how scientific knowledge is developed)

Students will develop an understanding that:

- the goal of science is knowledge about the natural world **(NS1)**
- scientific knowledge and theories develop through hypotheses, the collection of evidence, investigation and the ability to provide explanations **(NS2)**
- scientific knowledge results from peer review and replication of the research of others **(NS3)**
- scientific knowledge is subject to change as new evidence becomes apparent and as laws and theories are tested and subsequently revised, reinforced or rejected **(NS4)**
- the process of scientific investigation includes **(NS5)**:
  - identifying the theoretical basis of the investigation **(NS5a)**
  - defining and delimiting, clearly, research questions or ideas to be tested **(NS5b)**
  - designing the investigation **(NS5c)**
  - evaluating and selecting means to collect and record evidence **(NS5d)**
  - carrying out the investigation **(NS5e)**
  - analyzing the evidence and providing explanations based upon scientific theories and concepts **(NS5f)**
- scientific paradigms are conceptual inventions that help organize, interpret and explain findings **(NS6)**
  - Concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**
  - Conventions of mathematics, nomenclature and notation provide a basis for organizing and communicating scientific theory, relationships and concepts; e.g., chemical symbols **(NS6b)**
  - Scientific language is precise, and specific terms may be used in each field of study **(NS6c)**
- scientific inquiry is limited to certain questions **(NS7)**

Skills (focus on scientific inquiry)

Initiating and Planning **(IP–NS)**
Students will:
- identify, define and delimit questions to investigate **(IP–NS1)**
- design an experiment, identifying and controlling major variables **(IP–NS2)**
- state a prediction and a hypothesis based on available evidence or background information or on a theory **(IP–NS3)**
- evaluate and select appropriate procedures, including appropriate sampling procedures, and instruments for collecting evidence and information **(IP–NS4)**

Performing and Recording **(PR–NS)**
Students will:
- research, integrate and synthesize information from various print and electronic sources regarding a scientific question **(PR–NS1)**
- select and use appropriate instruments for collecting data effectively, safely and accurately **(PR–NS2)**
- carry out procedures, controlling the major variables, and adapt or extend procedures where required **(PR–NS3)**
- compile and organize findings and data by hand or computer, using appropriate formats such as diagrams, flowcharts, tables and graphs **(PR–NS4)**
- apply Workplace Hazardous Materials Information System (WHMIS) standards to handle and dispose of materials **(PR–NS5)**

Analyzing and Interpreting **(AI–NS)**
Students will:
- apply appropriate terminology, classification systems and nomenclature used in the sciences **(AI–NS1)**
- interpret patterns and trends in data and predict the value of a variable by interpolating or extrapolating from graphical data or from a line of best fit **(AI–NS2)**
- estimate and calculate the value of variables, compare theoretical and empirical values, and account for discrepancies **(AI–NS3)**
- identify limitations of data or measurements; explain sources of error; and evaluate the relevance, reliability and adequacy of data and data collection methods **(AI–NS4)**
- identify new questions or problems that arise from what was learned **(AI–NS5)**
- state a conclusion, based on data obtained from investigations, and explain how evidence gathered supports or refutes a hypothesis, prediction or theory **(AI–NS6)**

Communication and Teamwork **(CT–NS)**
Students will:
- work collaboratively to develop and carry out investigations **(CT–NS1)**
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**
- evaluate individual and group processes used in planning and carrying out investigative tasks **(CT–NS3)**

Framework for Developing a Science and Technology Emphasis (Grades 10–12)

The following concepts and skills are developed through this STS emphasis.

Concepts (focus on the interrelationship of science and technology)

Students will develop an understanding that:

- the goal of technology is to provide solutions to practical problems **(ST1)**
- technological development may involve the creation of prototypes, the testing of prototypes and the application of knowledge from related scientific and interdisciplinary fields **(ST2)**
- technological problems often require multiple solutions that involve different designs, materials and processes and that have both intended and unintended consequences **(ST3)**
- scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4)**
- the process for technological development includes **(ST5)**:
  - defining and delimiting, clearly, the problems to be solved and establishing criteria to assess the technological solution **(ST5a)**
  - identifying the constraints, the benefits and the drawbacks **(ST5b)**
  - developing designs and prototypes **(ST5c)**
  - testing and evaluating designs and prototypes on the basis of established criteria **(ST5d)**
- the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems **(ST6)**
- the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability **(ST7)**

Skills (focus on problem solving)

Initiating and Planning **(IP–ST)**
Students will:

- identify questions to investigate arising from practical problems **(IP–ST1)**
- propose and assess alternative solutions to a given practical problem, select one and develop a plan **(IP–ST2)**
- evaluate and select appropriate procedures and instruments for collecting data and information and for solving problems **(IP–ST3)**

Performing and Recording **(PR–ST)**
Students will:

- research, integrate and synthesize information from various print and electronic sources relevant to a practical problem **(PR–ST1)**
- construct and test a prototype device or system and troubleshoot problems as they arise **(PR–ST2)**
- select and use tools, apparatus and materials safely **(PR–ST3)**

Analyzing and Interpreting **(AI–ST)**
Students will:

- evaluate designs and prototypes on the basis of self-developed criteria; e.g., function, reliability, cost, safety, efficient use of materials, impact on the environment **(AI–ST1)**
- analyze alternative solutions to a given problem, identify potential strengths and weaknesses of each and recommend an approach to solving the problem, based on findings **(AI–ST2)**
- solve problems by selecting appropriate technology to perform manipulations and calculations **(AI–ST3)**
- identify new questions and problems that arise from what was learned and evaluate potential applications of findings **(AI–ST4)**

Communication and Teamwork **(CT–ST)**
Students will:

- work collaboratively to test a prototype device or system and troubleshoot problems as they arise **(CT–ST1)**
- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–ST2)**
- evaluate individual and group processes used in planning and carrying out problem-solving tasks **(CT–ST3)**

Framework for Developing a Social and Environmental Contexts Emphasis (Grades 10–12)

The following concepts and skills are developed through this STS emphasis.

Concepts (focus on issues related to the application of science and technology)

Students will develop an understanding that:

- science and technology are developed to meet societal needs and expand human capability **(SEC1)**
- science and technology have influenced, and been influenced by, historical development and societal needs **(SEC2)**
- science and technology have both intended and unintended consequences for humans and the environment **(SEC3)**
- society provides direction for scientific and technological development **(SEC4)**
  - Canadian society supports scientific research and technological development to facilitate a sustainable society, economy and environment **(SEC4a)**
  - Decisions regarding the application of scientific and technological development involve a variety of perspectives, including social, cultural, environmental, ethical and economic considerations **(SEC4b)**
  - Society supports scientific and technological development by recognizing accomplishments, publishing and disseminating results and providing financial support **(SEC4c)**
- scientific and technological activity may arise from, and give rise to, such personal and social values as accuracy, honesty, perseverance, tolerance, open-mindedness, critical-mindedness, creativity and curiosity **(SEC5)**
- science and technology provide opportunities for a diversity of careers based on post-secondary studies, for the pursuit of hobbies and interests, and for lifelong learning **(SEC6)**

Skills (focus on applying science to inform decision-making processes)

Initiating and Planning **(IP–SEC)**
Students will:

- identify questions to investigate that arise from issues related to the application of science and technology **(IP–SEC1)**
- plan complex searches for information, using a wide variety of electronic and print sources **(IP–SEC2)**
- assess and develop appropriate processes for collecting relevant data and information about science-and-technology-related issues **(IP–SEC3)**

Performing and Recording **(PR–SEC)**
Students will:

- research, integrate and synthesize information from various print and electronic sources relevant to a given question, problem or issue **(PR–SEC1)**
- select information and gather evidence from appropriate sources and evaluate search strategies **(PR–SEC2)**

Analyzing and Interpreting **(AI–SEC)**
Students will:

- apply given criteria for evaluating evidence and assess the authority, reliability, scientific accuracy and validity of sources of information **(AI–SEC1)**
- apply a variety of perspectives in assessing the risks and benefits of scientific and technological developments **(AI–SEC2)**
- assess potential decisions and recommend the best one, based on findings **(AI–SEC3)**
- identify new questions that arise and evaluate, from a variety of perspectives, potential implications of findings **(AI–SEC4)**

Communication and Teamwork **(CT–SEC)**
Students will:

- work collaboratively to investigate a science-and-technology-related issue **(CT–SEC1)**
- communicate in a persuasive and an engaging manner, using appropriate multimedia forms, to further understand a complex science-and-technology-related issue **(CT–SEC2)**
- make clear and logical arguments to defend a given decision on an issue, based on findings **(CT–SEC3)**
- evaluate individual and group processes used in investigating an issue and in evaluating alternative decisions **(CT–SEC4)**

Division 4 ICT Outcomes

Category: Communicating, Inquiring, Decision Making and Problem Solving

General Outcomes	Specific Outcomes
C1 **Students will access, use and communicate information from a variety of technologies.**	**C1** 4.1 plan and perform complex searches, using more than one electronic source 4.2 select information from appropriate sources, including primary and secondary sources 4.3 evaluate and explain the advantages and disadvantages of various search strategies 4.4 communicate in a persuasive and engaging manner, through appropriate forms, such as speeches, letters, reports and multimedia presentations, applying information technologies for context, audience and purpose that extend and communicate understanding of complex issues
C2 **Students will seek alternative viewpoints, using information technologies.**	**C2** 4.1 consult a wide variety of sources that reflect varied viewpoints on particular topics 4.2 evaluate the validity of gathered viewpoints against other sources
C3 **Students will critically assess information accessed through the use of a variety of technologies.**	**C3** 4.1 assess the authority, reliability and validity of electronically accessed information 4.2 demonstrate discriminatory selection of electronically accessed information that is relevant to a particular topic
C4 **Students will use organizational processes and tools to manage inquiry.**	**C4** 4.1 use calendars, time management or project management software to assist in conducting an inquiry
C5 **Students will use technology to aid collaboration during inquiry.**	**C5** 4.1 use telecommunications to pose critical questions to experts 4.2 participate in a variety of electronic group formats
C6 **Students will use technology to investigate and/or solve problems.**	**C6** 4.1 investigate and solve problems of prediction, calculation and inference 4.2 investigate and solve problems of organization and manipulation of information 4.3 manipulate data by using charting and graphing technologies in order to test inferences and probabilities 4.4 generate new understandings of problematic situations by using some form of technology to facilitate the process 4.5 evaluate the appropriateness of the technology used to investigate or solve a problem
C7 **Students will use electronic research techniques to construct personal knowledge and meaning.**	**C7** 4.1 use appropriate strategies to locate information to meet personal needs 4.2 analyze and synthesize information to determine patterns and links among ideas 4.3 use appropriate presentation software to demonstrate personal understandings

Division 4 ICT Outcomes (continued)

Category: Foundational Operations, Knowledge and Concepts

General Outcomes	Specific Outcomes
F1 **Students will demonstrate an understanding of the nature of technology.**	**F1** 4.1 assess the strengths and weaknesses of computer simulations in relation to real-world problems 4.2 solve mathematical and scientific problems by selecting appropriate technology to perform calculations and experiments 4.3 apply terminology appropriate to technology in all forms of communication 4.4 demonstrate an understanding of the general concepts of computer programming and the algorithms that enable technological devices to perform operations and solve problems
F2 **Students will understand the role of technology as it applies to self, work and society.**	**F2** 4.1 use technology outside formal classroom settings 4.2 analyze how technological innovations and creativity affect the economy 4.3 demonstrate an understanding of new and emerging communication systems 4.4 evaluate possible potential for emerging technologies 4.5 demonstrate conservation measures when using technology 4.6 demonstrate an understanding of the basic principles and issues of e-commerce, including such topics as security and privacy, marketing, and implications for governments, businesses and consumers alike 4.7 use current, reliable information sources from around the world 4.8 analyze and assess the impact of technology on the global community
F3 **Students will demonstrate a moral and ethical approach to the use of technology.**	**F3** 4.1 demonstrate an understanding of how changes in technology can benefit or harm society 4.2 record relevant data for acknowledging sources of information, and cite sources correctly 4.3 respect ownership and integrity of information
F4 **Students will become discerning consumers of mass media and electronic information.**	**F4** 4.1 discriminate between style and content in a presentation 4.2 evaluate the influence and results of digital manipulation on our perceptions 4.3 identify and analyze a variety of factors that affect the authenticity of information derived from mass media and electronic communication
F5 **Students will practise the concepts of ergonomics and safety when using technology.**	**F5** 4.1 assess new physical environments with respect to ergonomics 4.2 identify safety regulations specific to the technology being used
F6 **Students will demonstrate a basic understanding of the operating skills required in a variety of technologies.**	**F6** 4.1 continue to demonstrate the outcomes addressed within the previous divisions. Students interested in pursuing advanced study in such areas as electronics, programming, computer-aided design and drafting (CADD), robotics and other industrial applications of technology will find opportunities in Career and Technology Studies (CTS) courses

Division 4 ICT Outcomes (continued)

Category: Processes for Productivity

General Outcomes	Specific Outcomes
P1 **Students will compose, revise and edit text.**	**P1** 4.1 continue to demonstrate the outcomes achieved in prior grades and course subjects
P2 **Students will organize and manipulate data.**	**P2** 4.1 manipulate and present data through the selection of appropriate tools, such as scientific instrumentation, calculators, databases and/or spreadsheets
P3 **Students will communicate through multimedia.**	**P3** 4.1 select and use, independently, multimedia capabilities for presentations in various subject areas 4.2 support communication with appropriate images, sounds and music 4.3 apply general principles of graphic layout and design to a document in process
P4 **Students will integrate various applications.**	**P4** 4.1 integrate a variety of visual and audio information into a document to create a message targeted for a specific audience 4.2 apply principles of graphic design to enhance meaning and audience appeal 4.3 use integrated software effectively and efficiently to reproduce work that incorporates data, graphics and text
P5 **Students will navigate and create hyperlinked resources.**	**P5** 4.1 create multiple-link documents appropriate to the content of a particular topic 4.2 post multiple-link pages on the World Wide Web or on a local or wide area network
P6 **Students will use communication technology to interact with others.**	**P6** 4.1 select and use the appropriate technologies to communicate effectively with a targeted audience

PHYSICS 20

Physics 20 consists of four units of study:

A. Kinematics
B. Dynamics
C. Circular Motion, Work and Energy
D. Oscillatory Motion and Mechanical Waves

Attitude Outcomes

Students will be encouraged to develop positive attitudes that support the responsible acquisition and application of knowledge related to science and technology. The following attitude outcomes are to be developed throughout Physics 20, in conjunction with the specific outcomes for Knowledge; Science, Technology and Society (STS); and Skills in each unit.

Interest in Science

Students will be encouraged to:
show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *be interested in science and technology topics not directly related to their formal studies*
- *recognize the importance of making connections among various science disciplines*
- *maintain interest in pursuing further studies in science*
- *explore where further science- and technology-related studies and careers can be pursued*
- *recognize that many careers require science- and technology-related knowledge and skills.*

Mutual Respect

Students will be encouraged to:
appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *use a multiperspective approach, considering scientific, technological, economic, cultural, political and environmental factors when formulating conclusions, solving problems or making decisions on an STS issue*
- *research carefully and discuss openly ethical dilemmas associated with the applications of science and technology*
- *explore personal perspectives, attitudes and beliefs toward scientific and technological advancements*
- *recognize the contribution of science and technology to the progress of civilizations*
- *show support for the development of technologies and science as they relate to human needs*
- *recognize that the scientific approach is one of many ways of viewing the universe*
- *recognize the research contributions of both men and women*
- *recognize the research contributions of Canadians.*

Scientific Inquiry

Students will be encouraged to:
seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *consider the social and cultural contexts in which a theory developed*
- *appreciate how scientific problem solving and the development of new technologies are related*
- *insist on evidence before accepting a new idea or a new explanation*
- *assess, critically, their opinion of the value of science and its applications*
- *question arguments in which evidence, explanations or positions do not reflect the diversity of existing perspectives*
- *criticize arguments that are based on the faulty, incomplete or misleading use of numbers*
- *recognize the importance of reviewing the basic assumptions from which a line of inquiry has arisen*
- *insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged*
- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*
- *seek new models, explanations and theories when confronted with discrepant events.*

Collaboration

Students will be encouraged to:
work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*
- *use appropriate communication technology to elicit feedback from others*
- *participate in a variety of electronic group formats.*

Stewardship

Students will be encouraged to:
demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment; *e.g.,*

- *assume part of the collective responsibility for the impact of humans on the environment*
- *participate in civic activities related to the preservation and judicious use of the environment and its resources*
- *encourage their peers or members of their community to participate in a project related to sustainability*
- *consider all perspectives when addressing issues, weighing scientific, technological and ecological factors*
- *discuss both the positive and negative effects of environmental changes caused by nature and by humans on human beings and society*
- *participate in the social and political systems that influence environmental policy in their community*
- *promote actions that are not injurious to the environment*

- *make personal decisions based on a feeling of responsibility toward less privileged parts of the global community and toward future generations*
- *be critical-minded regarding the short- and long-term consequences of sustainability*.

Safety

Students will be encouraged to:
show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information; *e.g.,*

- *consider safety a positive limiting factor in scientific and technological endeavours*
- *read the labels on materials before using them, interpret the WHMIS symbols and consult a reference document if safety symbols are not understood*
- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*
- *seek assistance immediately for any first-aid concerns, such as cuts, burns or unusual reactions*
- *keep the work station uncluttered, ensuring that only appropriate laboratory materials are present*
- *criticize a procedure, a design or materials that are not safe or that could have a negative impact on the environment*
- *use safety and waste disposal as criteria for evaluating an experiment*
- *write safety and waste-disposal precautions into a laboratory procedure*.

Unit A: Kinematics

Themes: Change and Systems

Overview: In this unit, students investigate changes in the position and velocity of objects and systems in a study of kinematics.

This unit builds on:
- Grade 7 Science, Unit D: Structures and Forces
- Grade 8 Science, Unit D: Mechanical Systems
- Science 10, Unit B: Energy Flow in Technological Systems

This unit prepares students for further study, in subsequent units and physics courses, of dynamics, Newton's laws and particles in gravitational, electric and magnetic fields.

Unit A will require approximately 15% of the time allotted for Physics 20.

Links to Mathematics: The following mathematics topics are related to the content of Unit A but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• trigonometric ratios and triangle solutions	Pure Mathematics 10, specific outcomes 6.1 to 6.3; Applied Mathematics 10, specific outcomes 6.1 to 6.3
• properties of linear functions	Pure Mathematics 10, specific outcome 4.6; Applied Mathematics 10, specific outcomes 5.1, 5.2 and 5.7
• graphing quadratic functions from experimental data	Pure Mathematics 20, specific outcomes 2.3 and 2.4; Applied Mathematics 20, specific outcomes 2.1 and 2.3
• vector components and vector addition	Pure Mathematics 10, specific outcomes 6.1 and 6.3; Applied Mathematics 30, specific outcomes 5.1 to 5.4

Note: The use of systems of equations, the quadratic formula and trigonometric ratios for angles greater than 90º is not required.

Focusing Questions: How do changes in position, velocity and acceleration allow us to predict the paths of moving objects and systems? How do the principles of kinematics influence the development of new mechanical technologies?

General Outcomes: There is one major outcome in this unit.

Students will:

1. describe motion in terms of displacement, velocity, acceleration and time.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the outcomes.
- scalar quantities
- vector quantities
- uniform motion
- uniformly accelerated motion
- two-dimensional motion

General Outcome 1
Students will describe motion in terms of displacement, velocity, acceleration and time.

Specific Outcomes for Knowledge

Students will:

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

20–A1.2k define, operationally, and compare and contrast scalar and vector quantities

20–A1.3k explain, qualitatively and quantitatively, uniform and uniformly accelerated motion when provided with written descriptions and numerical and graphical data

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.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

20–A1.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *identify common applications of kinematics, such as determining the average speed of a run, bike ride or car trip, or the acceleration required to launch an aircraft from a carrier*

20–A1.2sts explain that scientific knowledge is subject to change as new evidence becomes apparent and as laws and theories are tested and subsequently revised, reinforced or rejected **(NS4)**

- *analyze lunar free fall as illustrated in a video*

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]**

- *investigate the application of kinematics principles, such as determining the appropriate length of airport runways, the design of merging lanes or the timing of traffic lights.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will describe motion in terms of displacement, velocity, acceleration and time.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

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

- identify, define and delimit questions to investigate; *e.g., What are the relationships among displacement, velocity, acceleration and time?* **(IP–NS1)**
- *explain why distances are measured in different units (as the crow flies, days of travel, mileage from city centre to city centre, light years)*.

Performing and Recording

Students will:

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; *e.g., interval timers, photo gates* **(PR–NS2, PR–NS3) [ICT C6–4.4]**
- collect information from various print and electronic sources to explain the use of kinematics concepts; *e.g., the synchronization of traffic lights* **(PR–ST1) [ICT C1–4.1]**.

Analyzing and Interpreting

Students will:

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

- construct graphs to demonstrate the relationships among displacement, velocity, acceleration and time for uniform and uniformly accelerated motion **(AI–NS2)**
- analyze a graph of empirical data to infer the mathematical relationships among displacement, velocity, acceleration and time for uniform and uniformly accelerated motion **(AI–NS2) [ICT C7–4.2]**
- solve, quantitatively, projectile motion problems near Earth's surface, ignoring air resistance **(AI–NS3) [ICT C6–4.1]**
- relate acceleration to the slope of, and displacement to the area under, a velocity-time graph **(AI–NS2, AI–NS6) [ICT C7–4.2]**
- *analyze uniform motion examples, using computer simulations* **(AI–NS3) [ICT C6–4.4]**.

Communication and Teamwork

Students will:

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

- use appropriate International System of Units (SI) notation, fundamental and derived units and significant digits **(CT–NS2)**★
- use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results **(CT–NS2)**★
- use delta notation correctly when describing changes in quantities (**CT–NS2**)★.

★To be developed throughout the course.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit B: Dynamics

Themes: Change and Systems

Overview: In this unit, students investigate causes of change in the position and velocity of objects and systems in a study of dynamics and gravitation. The concept of fields is introduced in the explanation of gravitational effects.

This unit builds on:

- Grade 7 Science, Unit D: Structures and Forces
- Grade 8 Science, Unit D: Mechanical Systems
- Science 10, Unit B: Energy Flow in Technological Systems
- Physics 20, Unit A: Kinematics

This unit prepares students for further study, in subsequent units and physics courses, of Newton's laws, periodic motion and particles in electric and magnetic fields.

Unit B will require approximately 25% of the time allotted for Physics 20.

Links to Mathematics: The following mathematics topics are related to the content of Unit B but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• properties of linear functions	Pure Mathematics 10, specific outcome 4.6; Applied Mathematics 10, specific outcomes 5.1, 5.2 and 5.7
• graphing quadratic functions	Pure Mathematics 20, specific outcomes 2.3 and 2.4; Applied Mathematics 20, specific outcomes 2.1 and 2.3
• graphing inverse-square functions	Pure Mathematics 10, specific outcome 3.1; Applied Mathematics 10, specific outcome 3.1
• vector components and vector addition	Pure Mathematics 10, specific outcomes 6.1 and 6.3; Applied Mathematics 30, specific outcomes 5.1 to 5.4

Note: The use of systems of equations, the quadratic formula and trigonometric ratios for angles greater than 90º is not required.

Focusing Questions: How does the understanding of forces help humans improve or change their environment? How do the principles of dynamics influence the development of new mechanical technologies? What role do gravitational effects play in the universe?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. explain the effects of balanced and unbalanced forces on velocity
2. explain that gravitational effects extend throughout the universe.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the outcomes.

- Newton's laws of motion
- inertia
- vector addition
- static and kinetic friction
- gravitational force
- Newton's law of universal gravitation
- gravitational field

General Outcome 1
Students will explain the effects of balanced and unbalanced forces on velocity.

Specific Outcomes for Knowledge

Students will:

20–B1.1k explain that a nonzero net force causes a change in velocity

20–B1.2k apply Newton's first law of motion to explain, qualitatively, an object's state of rest or uniform motion

20–B1.3k apply Newton's second law of motion to explain, qualitatively, the relationships among net force, mass and acceleration

20–B1.4k apply Newton's third law of motion to explain, qualitatively, the interaction between two objects, recognizing that the two forces, equal in magnitude and opposite in direction, do not act on the same object

20–B1.5k explain, qualitatively and quantitatively, static and kinetic forces of friction acting on an object

20–B1.6k calculate the resultant force, or its constituents, acting on an object by adding vector components graphically and algebraically

20–B1.7k apply Newton's laws of motion to solve, algebraically, linear motion problems in horizontal, vertical and inclined planes near the surface of Earth, ignoring air resistance.

Specific Outcomes for Science, Technology and Society (STS) (Social and Environmental Contexts Emphasis)

Students will:

20–B1.1sts explain that the goal of technology is to provide solutions to practical problems, that technological development includes testing and evaluating designs and prototypes on the basis of established criteria, and that the products of technology cannot solve all problems **(ST1, ST5d, ST6) [ICT F2–4.4]**

- *assess the design and use of injury-prevention devices in cars and sports in terms of Newton's laws of motion*
- *explain how buffalo jumps represented a technological solution to food supply problems and describe the advantages and limitations of such a technique*

20–B1.2sts explain that science and technology are developed to meet societal needs and that society provides direction for scientific and technological development **(SEC1, SEC4) [ICT F2–4.8]**

- *discuss the use of seat belts in school buses*

20–B1.3sts explain that scientific knowledge and theories develop through hypotheses, the collection of evidence, investigation and the ability to provide explanations **(NS2)**

- *analyze the trajectory of lunar dust particles as illustrated in a video*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will explain the effects of balanced and unbalanced forces on velocity.

Specific Outcomes for Skills (Science and Technology Emphasis)

Initiating and Planning

Students will:

20–B1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- identify questions to investigate arising from practical problems; *e.g., What are the relationships among acceleration, mass and force acting on a moving object?* **(IP–ST1)**.

Performing and Recording

Students will:

20–B1.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- conduct experiments to determine relationships among force, mass and acceleration, using available technologies; *e.g., using interval timers or motion sensors to gather data* **(PR–ST3) [ICT C6–4.4]**
- research the use of kinematics and dynamics principles in everyday life; *e.g., research traffic accident investigation methods, using the Internet and/or interviews* **(PR–ST1)**.

Analyzing and Interpreting

Students will:

20–B1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze a graph of empirical data to infer the mathematical relationships among force, mass and acceleration **(AI–NS6) [ICT C6–4.1]**
- use free-body diagrams to describe the forces acting on an object **(AI–NS1)**.

Communication and Teamwork

Students will:

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

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–ST2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will explain that gravitational effects extend throughout the universe.

Specific Outcomes for Knowledge

Students will:

20–B2.1k identify the gravitational force as one of the fundamental forces in nature
20–B2.2k describe, qualitatively and quantitatively, Newton's law of universal gravitation
20–B2.3k explain, qualitatively, the principles pertinent to the Cavendish experiment used to determine the universal gravitational constant, G
20–B2.4k define the term "field" as a concept that replaces "action at a distance" and apply the concept to describe gravitational effects
20–B2.5k relate, qualitatively and quantitatively, using Newton's law of universal gravitation, the gravitational constant to the local value of the acceleration due to gravity
20–B2.6k predict, quantitatively, differences in the weight of objects on different planets.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

20–B2.1sts explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**

- *compare apparent weightlessness and zero net gravity*
- *investigate the existence and shape of globular star clusters*
- *explain tidal forces on Earth*
- *describe the forces required to accelerate the Mars rover on Earth and on Mars*
- *explore the evolution of theories of gravity, using different worldviews*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will explain that gravitational effects extend throughout the universe.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

20–B2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- identify, define and delimit questions to investigate; *e.g., What is the relationship between the local value of the acceleration due to gravity and the gravitational field strength?* **(IP–NS1)**.

Performing and Recording

Students will:

20–B2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- determine, empirically, the local value of the acceleration due to gravity **(PR–NS2)**
- explore the relationship between the local value of the acceleration due to gravity and the gravitational field strength **(PR–NS1) [ICT C7–4.2]**.

Analyzing and Interpreting

Students will:

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

- list the limitations of mass-weight determinations at different points on Earth's surface **(AI–NS4)**
- treat acceleration due to gravity as uniform near Earth's surface **(AI–NS3)**.

Communication and Teamwork

Students will:

20–B2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit C: Circular Motion, Work and Energy

Themes: Energy and Equilibrium

Overview: In this unit, students extend their study of kinematics and dynamics to uniform circular motion and to mechanical energy, work and power.

This unit builds on:

- Grade 8 Science, Unit D: Mechanical Systems
- Grade 9 Science, Unit E: Space Exploration
- Science 10, Unit B: Energy Flow in Technological Systems
- Physics 20, Unit A: Kinematics and Unit B: Dynamics

This unit prepares students for further study, in subsequent physics courses, of circular motion, conservation laws and particles in magnetic fields.

Unit C will require approximately 30% of the time allotted for Physics 20.

Links to Mathematics: The following mathematics topics are related to the content of Unit C but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• properties of linear functions	Pure Mathematics 10, specific outcome 4.6; Applied Mathematics 10, specific outcomes 5.1, 5.2 and 5.7
• formula manipulation	Pure Mathematics 10, specific outcome 4.4; Applied Mathematics 10, specific outcome 5.1
• graphing inverse-square functions	Pure Mathematics 10, specific outcome 3.1; Applied Mathematics 10, specific outcome 3.1

Note: The use of systems of equations, the quadratic formula and trigonometric ratios for angles greater than 90º is not required.

Focusing Questions: What conditions are necessary to maintain circular motion? How does an understanding of conservation laws contribute to an understanding of the universe? How can mechanical energy be transferred and transformed?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. explain circular motion, using Newton's laws of motion
2. explain that work is a transfer of energy and that conservation of energy in an isolated system is a fundamental physical concept.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the outcomes.

- uniform circular motion
- planetary and satellite motion
- Kepler's laws
- mechanical energy
- conservation of mechanical energy
- work-energy theorem
- isolated systems
- power

General Outcome 1
Students will explain circular motion, using Newton's laws of motion.

Specific Outcomes for Knowledge

Students will:

20–C1.1k describe uniform circular motion as a special case of two-dimensional motion

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

20–C1.5k explain, quantitatively, planetary and natural and artificial satellite motion, using circular motion to approximate elliptical orbits

20–C1.6k predict the mass of a celestial body from the orbital data of a satellite in uniform circular motion around the celestial body

20–C1.7k explain, qualitatively, how Kepler's laws were used in the development of Newton's law of universal gravitation.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

20–C1.1sts explain that the process of scientific investigation includes analyzing the evidence and providing explanations based upon scientific theories and concepts **(NS5f)**
- *examine the role of orbital perturbations in the discovery of outer planets*
- *examine the evidence for extra-solar planets*

20–C1.2sts explain how science and technology are developed to meet societal needs and expand human capability **(SEC1) [ICT F2–4.8]**
- *explain the functions, applications and societal impacts of geosynchronous satellites*

20–C1.3sts explain that the goal of technology is to provide solutions to practical problems **(ST1)**
- analyze the principles and applications of circular motion in daily situations
  - *explain the use of a centrifuge in industry or research*
  - *explain the motion of a car moving with constant speed through a curve*
  - *explain the motion of carnival or playground rides moving in a horizontal plane and/or a vertical plane*
  - *explain the operation of a potter's wheel.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will explain circular motion, using Newton's laws of motion.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

20–C1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design an experiment to investigate the relationships among orbital speed, orbital radius, acceleration and force in uniform circular motion **(IP–NS2)**
- explore design characteristics of structures that facilitate circular motion; *e.g., How is banking used on a racetrack to make high-speed turns safer?* **(IP–ST1)**.

Performing and Recording

Students will:

20–C1.2s 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 investigate the relationships among net force acting on an object in uniform circular motion and the object's frequency, mass, speed and path radius **(PR–NS3)**.

Analyzing and Interpreting

Students will:

20–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- organize and interpret experimental data, using prepared graphs or charts **(AI–NS1) [ICT C7–4.2]**
- construct graphs to show relationships among frequency, mass, speed and path radius
- summarize an analysis of the relationships among frequency, mass, speed and path radius **(AI–NS6)**
- solve, quantitatively, circular motion problems in both horizontal and vertical planes, using algebraic and/or graphical vector analysis **(AI–NS3) [ICT C6–4.1]**.

Communication and Teamwork

Students will:

20–C1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will explain that work is a transfer of energy and that conservation of energy in an isolated system is a fundamental physical concept.

Specific Outcomes for Knowledge

Students will:

20–C2.1k define mechanical energy as the sum of kinetic and potential energy

20–C2.2k determine, quantitatively, the relationships among the kinetic, gravitational potential and total mechanical energies of a mass at any point between maximum potential energy and maximum kinetic energy

20–C2.3k analyze, quantitatively, kinematics and dynamics problems that relate to the conservation of mechanical energy in an isolated system

20–C2.4k recall work as a measure of the mechanical energy transferred and power as the rate of doing work

20–C2.5k describe power qualitatively and quantitatively

20–C2.6k describe, qualitatively, the change in mechanical energy in a system that is not isolated.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

20–C2.1sts explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**

- *estimate the energy released during a meteoritic impact with Earth's surface*
- *analyze the gravitational collapse of a star*
- *examine how a planet can provide a gravity assist to a space probe*
- *analyze the transformation of kinetic and potential energy of an orbiting object at perihelion and aphelion*

20–C2.2sts explain that the products of technology are devices, systems and processes that meet given needs; however, these products cannot solve all problems **(ST6) [ICT F3–4.1]**

- *evaluate the design and efficiency of energy transfer devices in terms of the relationships among mechanical energy, work and power*
- *analyze the use of irrigation systems and water wheels used by different cultures, such as the Incas*

20–C2.3sts evaluate whether Canadian society supports scientific research and technological development to facilitate a sustainable society, economy and environment **(SEC4a) [ICT F2–4.1]**

- *investigate and report on a technology developed to improve the efficiency of energy transfer as a means of reconciling the energy needs of society with its responsibility to protect the environment and to use energy judiciously*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will explain that work is a transfer of energy and that conservation of energy in an isolated system is a fundamental physical concept.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

20–C2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design an experiment to demonstrate the conservation of energy; *e.g., Is energy conserved in a collision?* **(IP–NS1, IP–NS2)**.

Performing and Recording

Students will:

20–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

- *perform an experiment to demonstrate the law of conservation of energy* **(PR–NS3)**
- *research the development of the law of conservation of energy, using library and Internet sources* **(PR–NS1) [ICT C1–4.1]**.

Analyzing and Interpreting

Students will:

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

- use free-body diagrams to organize and communicate solutions to work-energy theorem problems **(AI–NS1)**
- solve, quantitatively, kinematics and dynamics problems, using the work-energy theorem **(AI–NS3) [ICT C6–4.1]**
- analyze data to determine effective energy conservation strategies; *e.g., analyze whether lowering the speed limit or modifying the internal combustion engine saves more energy in vehicles* **(AI–ST2, AI–SEC3) [ICT C7–4.2]**.

Communication and Teamwork

Students will:

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

- *use integrated software effectively and efficiently to reproduce work that incorporates data, graphics and text* **(CT–NS2) [ICT P4–4.3]**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit D: Oscillatory Motion and Mechanical Waves

Themes: Energy and Matter

Overview: In this unit, students investigate simple harmonic motion and mechanical waves.

This unit builds on:
- Science 10, Unit B: Energy Flow in Technological Systems
- Physics 20, Unit A: Kinematics; Unit B: Dynamics; and Unit C: Circular Motion, Work and Energy

This unit prepares students for further study, in subsequent physics courses, of simple harmonic motion and wave phenomena.

Unit D will require approximately 30% of the time allotted for Physics 20.

Links to Mathematics: The following mathematics topics are related to the content of Unit D but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• graphing quadratic functions	Pure Mathematics 20, specific outcomes 2.3 and 2.4; Applied Mathematics 20, specific outcomes 2.1 and 2.3
• the properties of sinusoidal functions over a single period	Pure Mathematics 10, specific outcome 6.2; Applied Mathematics 10, specific outcome 6.2

Note: The use of systems of equations, the quadratic formula and trigonometric ratios for angles greater than 90º is not required.

Focusing Questions: What are examples of oscillatory motion in the world around us? How do mechanical waves transmit energy? How is structural design and the development of technologies influenced by our understanding of wave properties?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. describe the conditions that produce oscillatory motion
2. describe the properties of mechanical waves and explain how mechanical waves transmit energy.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the outcomes.
- oscillatory motion
- simple harmonic motion
- restoring force
- oscillating spring, pendulum
- mechanical resonance
- mechanical waves—longitudinal and transverse
- universal wave equation
- reflection
- interference
- acoustic resonance
- Doppler effect

General Outcome 1
Students will describe the conditions that produce oscillatory motion.

Specific Outcomes for Knowledge

Students will:

20–D1.1k describe oscillatory motion in terms of period and frequency

20–D1.2k define simple harmonic motion as a motion due to a restoring force that is directly proportional and opposite to the displacement from an equilibrium position

20–D1.3k explain, quantitatively, the relationships among displacement, acceleration, velocity and time for simple harmonic motion, as illustrated by a frictionless, horizontal mass-spring system or a pendulum, using the small-angle approximation

20–D1.4k determine, quantitatively, the relationships among kinetic, gravitational potential and total mechanical energies of a mass executing simple harmonic motion

20–D1.5k define mechanical resonance.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

20–D1.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *analyze, qualitatively, the forces in real-life examples of simple harmonic motion*:
  - *action of springs in vehicle suspensions*
  - *mechanical resonance in cars, bridges and buildings*
  - *seismic waves in Earth's crust*
- *relate the fundamental frequency and amplitude of a vibrating drum membrane to its properties*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will describe the conditions that produce oscillatory motion.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

20–D1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design an experiment to demonstrate that simple harmonic motion can be observed within certain limits, relating the frequency and period of the motion to the physical characteristics of the system; *e.g., a frictionless horizontal mass-spring system or a pendulum* **(IP–NS2)**
- predict the conditions required for mechanical resonance **(IP–NS3)**.

Performing and Recording

Students will:

20–D1.2s 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 determine the relationship between the length of a pendulum and its period of oscillation **(PR–NS3)**
- perform an experiment to illustrate the phenomenon of mechanical resonance **(PR–NS3)**
- perform an experiment to determine the spring constant of a spring **(PR–NS3)**.

Analyzing and Interpreting

Students will:

20–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- *relate the length of a pendulum to its period of oscillation* **(AI–NS2) [ICT C7–4.2]**
- *ask if the mass of the pendulum bob is a factor in the pendulum's period of oscillation* **(AI–NS5)**.

Communication and Teamwork

Students will:

20–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will describe the properties of mechanical waves and explain how mechanical waves transmit energy.

Specific Outcomes for Knowledge

Students will:

20–D2.1k describe mechanical waves as particles of a medium that are moving in simple harmonic motion

20–D2.2k compare and contrast energy transport by matter and by waves

20–D2.3k define longitudinal and transverse waves in terms of the direction of motion of the medium particles in relation to the direction of propagation of the wave

20–D2.4k define the terms wavelength, wave velocity, period, frequency, amplitude, wave front and ray as they apply to describing transverse and longitudinal waves

20–D2.5k describe how the speed of a wave depends on the characteristics of the medium

20–D2.6k predict, quantitatively, and verify the effects of changing one or a combination of variables in the universal wave equation ($v = f\lambda$)

20–D2.7k explain, qualitatively, the phenomenon of reflection as exhibited by mechanical waves

20–D2.8k explain, qualitatively, the conditions for constructive and destructive interference of waves and for acoustic resonance

20–D2.9k explain, qualitatively and quantitatively, the Doppler effect on a stationary observer of a moving source.

Specific Outcomes for Science, Technology and Society (STS) (Science and Technology Emphasis)

Students will:

20–D2.1sts explain that the goal of technology is to provide solutions to practical problems **(ST1) [ICT F2–4.4, F2–4.8]**

- *investigate the application of acoustic phenomena in recreation, medicine, industry and technology (sonography, ultrasound, sonar, pipe organs, wind and brass instruments, noise-reduction devices, noise-measurement devices)*
- *describe the properties of waves that can be used to manipulate direction and speed when travelling (surfing, canoeing or kayaking) in rivers or oceans*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will describe the properties of mechanical waves and explain how mechanical waves transmit energy.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

20–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- *predict the conditions required for constructive and destructive interference to occur* **(IP–NS3)**.

Performing and Recording

Students will:

20–D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- draw wave-front and ray diagrams **(PR–NS4)**
- draw a wave-front diagram of a two-point source interference pattern **(PR–NS4)**
- perform an experiment to illustrate the phenomenon of acoustic resonance **(PR–NS3)**.

Analyzing and Interpreting

Students will:

20–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- determine the speed of a mechanical wave; *e.g., water waves and sound waves* **(PR–NS2)**
- *relate apparent changes in wavelength and frequency to the speed of the source relative to the observer* **(AI–NS2) [ICT C7–4.2]**.

Communication and Teamwork

Students will:

20–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical or linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

PHYSICS 30

Implementation of Physics 30 is mandatory in September 2008.
Implementation prior to this date is **not** approved.

Physics 30 consists of four units of study:

A. Momentum and Impulse
B. Forces and Fields
C. Electromagnetic Radiation
D. Atomic Physics

Attitude Outcomes

Students will be encouraged to develop positive attitudes that support the responsible acquisition and application of knowledge related to science and technology. The following attitude outcomes are to be developed throughout Physics 30, in conjunction with the specific outcomes for Knowledge; Science, Technology and Society (STS); and Skills in each unit.

Interest in Science

Students will be encouraged to:
show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*
- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *use scientific vocabulary and principles in everyday discussions*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *be interested in science and technology topics not directly related to their formal studies*
- *recognize the importance of making connections among various science disciplines*
- *maintain interest in pursuing further studies in science*
- *explore where further science- and technology-related studies and careers can be pursued*
- *recognize that many careers require science- and technology-related knowledge and skills.*

Mutual Respect

Students will be encouraged to:
appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*
- *use a multiperspective approach, considering scientific, technological, economic, cultural, political and environmental factors when formulating conclusions, solving problems or making decisions on an STS issue*
- *research carefully and discuss openly ethical dilemmas associated with the applications of science and technology*
- *explore personal perspectives, attitudes and beliefs toward scientific and technological advancements*
- *recognize the contribution of science and technology to the progress of civilizations*
- *show support for the development of technologies and science as they relate to human needs*
- *recognize that the scientific approach is one of many ways of viewing the universe*
- *recognize the research contributions of both men and women*
- *recognize the research contributions of Canadians.*

Scientific Inquiry

Students will be encouraged to:
seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *consider the social and cultural contexts in which a theory developed*
- *appreciate how scientific problem solving and the development of new technologies are related*
- *insist on evidence before accepting a new idea or a new explanation*
- *assess, critically, their opinion of the value of science and its applications*
- *question arguments in which evidence, explanations or positions do not reflect the diversity of perspectives that exist*
- *criticize arguments that are based on faulty, incomplete or misleading use of numbers*
- *recognize the importance of reviewing the basic assumptions from which a line of inquiry has arisen*
- *insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged*
- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*
- *seek new models, explanations and theories when confronted with discrepant events.*

Collaboration

Students will be encouraged to:
work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*
- *be attentive when others speak, seek the point of view of others, and consider a multitude of perspectives*
- *use appropriate communication technology to elicit feedback from others*
- *participate in a variety of electronic group formats.*

Stewardship

Students will be encouraged to:
demonstrate sensitivity and responsibility in pursuing a balance between the needs of humans and a sustainable environment; *e.g.,*

- *assume part of the collective responsibility for the impact of humans on the environment*
- *participate in civic activities related to the preservation and judicious use of the environment and its resources*
- *encourage their peers or members of their community to participate in a project related to sustainability*
- *consider all perspectives when addressing issues, weighing scientific, technological and ecological factors*
- *discuss both the positive and negative effects on human beings and society of environmental changes caused by nature and by humans*
- *participate in the social and political systems that influence environmental policy in their community*
- *promote actions that are not injurious to the environment*

- *make personal decisions based on a feeling of responsibility toward less privileged parts of the global community and toward future generations*
- *be critical-minded regarding the short- and long-term consequences of sustainability*.

Safety

Students will be encouraged to:
show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information; *e.g.,*
- *consider safety a positive limiting factor in scientific and technological endeavours*
- *read the labels on materials before using them, interpret the WHMIS symbols and consult a reference document if safety symbols are not understood*
- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment by cleaning up after an activity and disposing of materials according to safety guidelines*
- *seek assistance immediately for any first-aid concerns, such as cuts, burns or unusual reactions*
- *keep the work station uncluttered, ensuring that only appropriate laboratory materials are present*
- *criticize a procedure, a design or materials that are not safe or that could have a negative impact on the environment*
- *use safety and waste disposal as criteria for evaluating an experiment*
- *write safety and waste-disposal precautions into a laboratory procedure*.

Unit A: Momentum and Impulse

Themes: Change and Systems

Overview: In this unit, Newton's second law of motion is linked to the concepts of momentum and impulse.

This unit builds on:

- Physics 20, Unit A: Kinematics; Unit B: Dynamics; and Unit C: Circular Motion, Work and Energy

This unit prepares students for further study of mechanics in subsequent units and for post-secondary studies in physics. Unit A will require approximately 15% of the time allotted for Physics 30.

Links to Mathematics: The following mathematics topics are related to the content of Unit A but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• properties of linear functions	Pure Mathematics 10, specific outcome 4.6; Applied Mathematics 10, specific outcomes 5.1, 5.2 and 5.7
• graphing quadratic functions	Pure Mathematics 20, specific outcomes 2.3 and 2.4; Applied Mathematics 20, specific outcomes 2.1 and 2.3
• vector components and vector addition	Pure Mathematics 10, specific outcomes 6.1 and 6.3; Applied Mathematics 30, specific outcomes 5.1 to 5.4

Note: The use of systems of equations, the quadratic formula and trigonometric ratios for angles greater than 90º is not required.

Focusing Questions: What characteristics of an object affect its momentum? How are momentum and impulse related? How does our understanding of concepts relating momentum and impulse influence the design of safety and sporting equipment?

General Outcomes: There is one major outcome in this unit.

Students will:

1. explain how momentum is conserved when objects interact in an isolated system.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the learning outcomes.

- impulse
- momentum
- Newton's laws of motion
- elastic collisions
- inelastic collisions

General Outcome 1
Students will explain how momentum is conserved when objects interact in an isolated system.

Specific Outcomes for Knowledge

Students will:

30–A1.1k define momentum as a vector quantity equal to the product of the mass and the velocity of an object

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

30–A1.5k define, compare and contrast elastic and inelastic collisions, using quantitative examples, in terms of conservation of kinetic energy.

Specific Outcomes for Science, Technology and Society (STS) (Science and Technology Emphasis)

Students will:

30–A1.1sts explain that technological problems often require multiple solutions that involve different designs, materials and processes and that have both intended and unintended consequences **(ST3) [ICT F3–4.1]**

- *investigate the role of impulse and momentum in the design and function of rockets and thrust systems*
- *assess the roles that conservation laws, the concepts of impulse and inertia and Newton's laws play in the design and use of injury-prevention devices in vehicles and sports*
- *describe the limitations of applying the results from studies of isolated systems in solving a practical problem, as occurred with the early design and deployment of airbags*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will explain how momentum is conserved when objects interact in an isolated system.

Specific Outcomes for Skills (Science and Technology Emphasis)

Initiating and Planning

Students will:

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

- design an experiment and identify and control major variables; *e.g., demonstrate the conservation of linear momentum or illustrate the relationship between impulse and change in momentum* **(IP–NS2)**.

Performing and Recording

Students will:

30–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 conservation of linear momentum, using available technologies; *e.g., air track, air table, motion sensors, strobe lights and photography* **(PR–NS2, PR–NS3) [ICT C6–4.4]**
- collect information from various print and electronic sources to explain the use of momentum and impulse concepts; *e.g., rocketry and thrust systems or the interaction between a golf club head and the ball* **(PR–ST1, PR–ST2) [ICT C1–4.1]**.

Analyzing and Interpreting

Students will:

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

- analyze graphs that illustrate the relationship between force and time during a collision **(AI–NS2) [ICT C7–4.2]**
- 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]**.

Communication and Teamwork

Students will:

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

- use appropriate International System of Units (SI) notation, fundamental and derived units and significant digits **(CT–NS2)**★
- use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate ideas, plans and results **(CT–ST2)**★
- use the delta notation correctly when describing changes in quantities **(CT–NS2)**★.

★To be developed throughout the course.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit B: Forces and Fields

Themes: Energy and Matter

Overview: In this unit, students investigate electric and magnetic forces and fields and their applications in technological devices.

This unit builds on:
- Science 9, Unit D: Electrical Principles and Technologies
- Physics 20, Unit A: Kinematics; Unit B: Dynamics; Unit C: Circular Motion, Work and Energy; and Unit D: Oscillatory Motion and Mechanical Waves

This unit prepares students for further study of electromagnetic phenomena in subsequent units and for post-secondary studies in physics. Unit B will require approximately 30% of the time allotted for Physics 30.

Links to Mathematics: The following mathematics topics are related to the content of Unit B but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• properties of linear functions	Pure Mathematics 10, specific outcome 4.6; Applied Mathematics 10, specific outcomes 5.1, 5.2 and 5.7
• graphing quadratic functions	Pure Mathematics 20, specific outcomes 2.3 and 2.4; Applied Mathematics 20, specific outcomes 2.1 and 2.3
• vector components and vector addition	Pure Mathematics 10, specific outcomes 6.1 and 6.2 ; Applied Mathematics 30, specific outcomes 5.1 to 5.4
• formula manipulation	Pure Mathematics 10, specific outcome 4.4; Applied Mathematics 10, specific outcome 5.1
• solving nonlinear equations	Pure Mathematics 20, specific outcome 3.1; Applied Mathematics 20, specific outcome 2.1

Note: The use of systems of equations, the quadratic formula and trigonometric ratios for angles greater than 90º is not required.

Focusing Questions: How was the value of the elementary charge determined? What is the relationship between electricity and magnetism? How does magnetism assist in the understanding of fundamental particles? How has this understanding revolutionized the modern way of life?

General Outcomes: There are three major outcomes in this unit.

Students will:

1. explain the behaviour of electric charges, using the laws that govern electrical interactions
2. describe electrical phenomena, using the electric field theory
3. explain how the properties of electric and magnetic fields are applied in numerous devices.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the learning outcomes.
- electric charge
- conservation of charge
- Coulomb's law
- vector fields
- electric field
- magnetic field
- electric potential difference
- interaction of charges with electric and magnetic fields
- charge quantization—Millikan's experiment
- electromagnetic induction

General Outcome 1
Students will explain the behaviour of electric charges, using the laws that govern electrical interactions.

Specific Outcomes for Knowledge

Students will:

30–B1.1k explain electrical interactions in terms of the law of conservation of charge
30–B1.2k explain electrical interactions in terms of the repulsion and attraction of charges
30–B1.3k compare the methods of transferring charge (conduction and induction)
30–B1.4k explain, qualitatively, the distribution of charge on the surfaces of conductors and insulators
30–B1.5k explain, qualitatively, the principles pertinent to Coulomb's torsion balance experiment
30–B1.6k apply Coulomb's law, quantitatively, to analyze the interaction of two point charges
30–B1.7k determine, quantitatively, the magnitude and direction of the electric force on a point charge due to two or more other point charges in a plane
30–B1.8k compare, qualitatively and quantitatively, the inverse square relationship as it is expressed by Coulomb's law and by Newton's universal law of gravitation.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

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

- *explain that the electric model of matter is fundamental to the interpretation of electrical phenomena*
- *explain that charge separation and transfer from one object to another are fundamental electrical processes*

30–B1.2sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *compare and contrast the experimental designs used by Coulomb and Cavendish, in terms of the role that technology plays in advancing science*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will explain the behaviour of electric charges, using the laws that govern electrical interactions.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–B1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- *design an experiment to examine the relationships among magnitude of charge, electric force and distance between point charges* **(IP–NS2)**
- *predict the results of an activity that demonstrates charge separation and transfer* **(IP–NS3) [ICT C6–4.1]**.

Performing and Recording

Students will:

30–B1.2s 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 activity to demonstrate methods of charge separation and transfer **(PR–NS3)**
- perform an experiment to demonstrate the relationships among magnitude of charge, electric force and distance between point charges **(PR–NS2, PR–NS3) [ICT C6–4.4]**.

Analyzing and Interpreting

Students will:

30–B1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- infer, from empirical evidence, the mathematical relationship among charge, force and distance between point charges **(AI–NS2) [ICT C7–4.2]**
- use free-body diagrams to describe the electrostatic forces acting on a charge **(AI–NS1)**
- use graphical techniques to analyze data; *e.g., curve straightening (manipulating variables to obtain a straight-line graph)* **(AI–NS2) [ICT C6–4.3, C7–4.2]**.

Communication and Teamwork

Students will:

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

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will describe electrical phenomena, using the electric field theory.

Specific Outcomes for Knowledge

Students will:

30–B2.1k define vector fields
30–B2.2k compare forces and fields
30–B2.3k compare, qualitatively, gravitational potential energy and electric potential energy
30–B2.4k define electric potential difference as a change in electric potential energy per unit of charge
30–B2.5k calculate the electric potential difference between two points in a uniform electric field
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–B2.7k define electric current as the amount of charge passing a reference point per unit of time
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–B2.10k explain Millikan's oil-drop experiment and its significance relative to charge quantization.

Specific Outcomes for Science, Technology and Society (STS) (Science and Technology Emphasis)

Students will:

30–B2.1sts explain that the goal of technology is to provide solutions to practical problems **(ST1) [ICT F2–4.4]**

- *assess how the principles of electrostatics are used to solve problems in industry and technology and to improve upon quality of life; e.g., photocopiers, electrostatic air cleaners, precipitators, antistatic clothing products, lightning rods*

30–B2.2sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *explain, qualitatively, how the problem of protecting sensitive components in a computer from electric fields is solved*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will describe electrical phenomena, using the electric field theory model.

Specific Outcomes for Skills (Science and Technology Emphasis)

Initiating and Planning

Students will:

30–B2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- *evaluate and select appropriate procedures and instruments for collecting data and information and for determining and plotting electric fields* **(IP–ST3) [ICT C6–4.5]**.

Performing and Recording

Students will:

30–B2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- plot electric fields, using field lines, for fields induced by discrete point charges, combinations of discrete point charges (similarly and oppositely charged) and charged parallel plates **(PR–NS2)**.

Analyzing and Interpreting

Students will:

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)**
- use accepted scientific convention and express energy in terms of electron volts, when appropriate **(AI–NS1)**
- use free-body diagrams to describe the forces acting on a charge in an electric field **(AI–NS1).**

Communication and Teamwork

Students will:

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

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–ST2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3
Students will explain how the properties of electric and magnetic fields are applied in numerous devices.

Specific Outcomes for Knowledge

Students will:

30–B3.1k describe magnetic interactions in terms of forces and fields

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–B3.6k explain, quantitatively, how uniform magnetic and electric fields affect 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

30–B3.8k explain, quantitatively, the effect of an external magnetic field on a current-carrying conductor

30–B3.9k describe, qualitatively, the effects of moving a conductor in an external magnetic field, in terms of moving charges in a magnetic field.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–B3.1sts explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**

- *discuss, qualitatively, Lenz's law in terms of conservation of energy, giving examples of situations in which Lenz's law applies*
- *investigate the mechanism that causes atmospheric auroras*

30–B3.2sts explain that the goal of technology is to provide solutions to practical problems and that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability **(ST1, ST7) [ICT F2–4.2, F3–4.1]**

- *evaluate an electromagnetic technology, such as magnetic resonance imaging (MRI), positron emission tomography (PET), transformers, alternating current (AC) and direct current (DC) motors, AC and DC generators, speakers, telephones*
- *investigate the effects of electricity and magnetism on living organisms, in terms of the limitations of scientific knowledge and technology and in terms of quality of life*

30–B3.3sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *describe how technological developments were influenced by the discovery of superconductivity*
- *investigate how nanotubes can be used to construct low-resistance conductors*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3
Students will explain how the properties of electric and magnetic fields are applied in numerous devices.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–B3.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- design an experiment to demonstrate the effect of a uniform magnetic field on a current-carrying conductor **(IP–NS2)**
- design an experiment to demonstrate the effect of a uniform magnetic field on a moving conductor **(IP–NS2)**
- *design an experiment to demonstrate the effect of a uniform magnetic field on a moving electric charge* **(IP–NS2)**.

Performing and Recording

Students will:

30–B3.2s 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 effect of a uniform magnetic field on a current-carrying conductor, using the appropriate apparatus effectively and safely **(PR–NS2, PR–NS3) [ICT F5–4.2]**
- perform an experiment to demonstrate the effect of a uniform magnetic field on a moving conductor, using the appropriate apparatus effectively and safely **(PR–NS2, PR–NS3) [ICT F5–4.2]**
- predict, using appropriate hand rules, the relative directions of motion, force and field in electromagnetic interactions **(PR–NS2)**.

Analyzing and Interpreting

Students will:

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

- state a conclusion, based on experimental evidence that describes the interactions of a uniform magnetic field and a moving or current-carrying conductor **(AI–NS6)**
- 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]**
- 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

Students will:

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

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit C: Electromagnetic Radiation

Themes: Diversity and Matter

Overview: In this unit, students study the nature and characteristics of electromagnetic radiation (EMR), using the wave and photon models of light.

This unit builds on:

- Science 8, Unit C: Light and Optical Systems
- Physics 20, Unit C: Circular Motion, Work and Energy
- Physics 30, Unit A: Momentum and Impulse and Unit B: Forces and Fields

This unit prepares students for further study of EMR phenomena and the nature of matter in Unit D and for post-secondary studies in physics. Unit C will require approximately 30% of the time allotted for Physics 30.

Links to Mathematics: The following mathematics topics are related to the content of Unit C but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• formula manipulation	Pure Mathematics 10, specific outcome 4.4; Applied Mathematics 10, specific outcome 5.1
• solving nonlinear equations	Pure Mathematics 20, specific outcome 3.1; Applied Mathematics 20, specific outcome 2.1

Note: Systems of equations and solutions to quadratic equations are not required.

Focusing Questions: What roles do electricity and magnetism play in EMR? Does EMR have a wave or a particle nature? What experimental evidence is required to decide whether EMR has a wave or a particle nature? What technological devices are used today as a result of investigating and applying electromagnetic phenomena?

General Outcomes: There are two major outcomes in this unit.

Students will:

1. explain the nature and behaviour of EMR, using the wave model
2. explain the photoelectric effect, using the quantum model.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the learning outcomes.

- speed of EMR
- propagation of EMR
- reflection
- refraction
- diffraction
- interference
- total internal reflection
- Snell's law
- photoelectric effect
- Compton effect

General Outcome 1
Students will explain the nature and behaviour of EMR, using the wave model.

Specific Outcomes for Knowledge

Students will:

30–C1.1k describe, qualitatively, how all accelerating charges produce EMR

30–C1.2k compare and contrast the constituents of the electromagnetic spectrum on the basis of frequency and wavelength

30–C1.3k explain the propagation of EMR in terms of perpendicular electric and magnetic fields that are varying with time and travelling away from their source at the speed of light

30–C1.4k explain, qualitatively, various methods of measuring the speed of EMR

30–C1.5k calculate the speed of EMR, given data from a Michelson-type experiment

30–C1.6k describe, quantitatively, the phenomena of reflection and refraction, including total internal reflection

30–C1.7k describe, quantitatively, simple optical systems, consisting of only one component, for both lenses and curved mirrors

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

30–C1.9k describe, qualitatively, how the results of Young's double-slit experiment support the wave model of light

30–C1.10k solve double-slit and diffraction grating problems using, $\lambda = \frac{xd}{nl}$, $\lambda = \frac{d \sin\theta}{n}$

30–C1.11k describe, qualitatively and quantitatively, how refraction supports the wave model of EMR, using $\frac{\sin\theta_1}{\sin\theta_2} = \frac{n_2}{n_1} = \frac{v_1}{v_2} = \frac{\lambda_1}{\lambda_2}$

30–C1.12k compare and contrast the visible spectra produced by diffraction gratings and triangular prisms.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–C1.1sts explain that scientific knowledge is subject to change as new evidence becomes apparent and as laws and theories are tested and subsequently revised, reinforced or rejected **(NS4)**

- *use examples, such as Poisson's spot, speed of light in water, sunglasses, photography and liquid crystal diodes, to illustrate how theories evolve*

30–C1.2sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *describe procedures for measuring the speed of EMR*
- *investigate the design of greenhouses, cameras, telescopes, solar collectors and fibre optics*
- *investigate the effects of frequency and wavelength on the growth of plants*
- *investigate the use of interferometry techniques in the search for extrasolar planets.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will explain the nature and behaviour of EMR, using the wave model.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–C1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- predict the conditions required for diffraction to be observed **(IP–NS3)**
- predict the conditions required for total internal reflection to occur **(IP–NS3)**
- design an experiment to measure the speed of light **(IP–NS2)**.

Performing and Recording

Students will:

30–C1.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- perform experiments to demonstrate refraction at plane and uniformly curved surfaces **(PR–NS2)**
- perform an experiment to determine the index of refraction of several different substances **(PR–NS2, PR–NS3, PR–NS4)**
- conduct an investigation to determine the focal length of a thin lens and of a curved mirror **(PR–NS2, PR–NS3, PR–NS4)**
- observe the visible spectra formed by diffraction gratings and triangular prisms **(PR–NS2)**
- perform an experiment to determine the wavelength of a light source in air or in a liquid, using a double-slit or a diffraction grating **(PR–NS2, PR–NS3)**
- perform an experiment to verify the effects on an interference pattern due to changes in wavelength, slit separation and/or screen distance **(PR–NS2, PR–NS3) [ICT C7–4.2]**.

Analyzing and Interpreting

Students will:

30–C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- derive the mathematical representation of the law of refraction from experimental data **(AI–NS2) [ICT C7–4.2]**
- use ray diagrams to describe an image formed by thin lenses and curved mirrors **(AI–NS1)**
- demonstrate the relationship among wavelength, slit separation and screen distance, using empirical data and algorithms **(AI–NS6)**
- determine the wavelength of EMR, using data provided from demonstrations and other sources; *e.g., wavelengths of microwaves from the interference patterns of television signals or microwave ovens* **(AI–NS3, AI–NS4)**.

Communication and Teamwork

Students will:

30–C1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions; *e.g., draw ray diagrams* **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will explain the photoelectric effect, using the quantum model.

Specific Outcomes for Knowledge

Students will:

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

30–C2.2k classify the regions of the electromagnetic spectrum by photon energy

30–C2.3k describe the photoelectric effect in terms of the intensity and wavelength or frequency of the incident light and surface material

30–C2.4k describe, quantitatively, photoelectric emission, using concepts related to the conservation of energy

30–C2.5k describe the photoelectric effect as a phenomenon that supports the notion of the wave-particle duality of EMR

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 Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–C2.1sts explain that scientific knowledge and theories develop through hypotheses, the collection of evidence, investigation and the ability to provide explanations **(NS2)**

- *describe how Hertz discovered the photoelectric effect while investigating electromagnetic waves*
- *describe how Planck used energy quantization to explain blackbody radiation*

30–C2.2sts explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**

- *investigate and report on the development of early quantum theory*
- *identify similarities between physicists' efforts at unifying theories and holistic Aboriginal worldviews*

30–C2.3sts explain that the goal of technology is to provide solutions to practical problems **(ST1) [ICT F2–4.4]**

- *analyze, in general terms, the functioning of various technological applications of photons to solve practical problems; e.g., automatic door openers, burglar alarms, light meters, smoke detectors, X-ray examination of welds, crystal structure analysis.*

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will explain the photoelectric effect, using the quantum model.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–C2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- predict the effect, on photoelectric emissions, of changing the intensity and/or frequency of the incident radiation or material of the photocathode **(IP–NS3)**
- *design an experiment to measure Planck's constant, using either a photovoltaic cell or a light-emitting diode (LED)* **(IP–NS2, IP–NS4)**.

Performing and Recording

Students will:

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

- *perform an experiment to demonstrate the photoelectric effect* **(PR–NS3) [ICT C6–4.4]**
- *measure Planck's constant, using either a photovoltaic cell or an LED* **(PR–NS2, PR–NS3)**.

Analyzing and Interpreting

Students will:

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

- analyze and interpret empirical data from an experiment on the photoelectric effect, using a graph that is either drawn by hand or is computer generated **(AI–NS2, AI–NS4) [ICT C6–4.2, C6–4.3]**.

Communication and Teamwork

Students will:

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

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

Unit D: Atomic Physics

Themes: Energy and Matter

Overview: In this unit, students study the development and modification of models of the structure of matter.

This unit builds on:

- Science 9, Unit E: Space Exploration
- Physics 20, Unit C: Circular Motion, Work and Energy
- Physics 30, Unit A: Momentum and Impulse, Unit B: Forces and Fields and Unit C: Electromagnetic Radiation

This unit prepares students for further study of the nature of matter in post-secondary studies in physics. Unit D will require approximately 25% of the time allotted for Physics 30.

Links to Mathematics: The following mathematics topics are related to the content of Unit D but are not considered prerequisites.

Topics:	These topics may be found in the following courses:
• formula manipulation	Pure Mathematics 10, specific outcome 4.4; Applied Mathematics 10, specific outcome 5.1
• solving nonlinear equations	Pure Mathematics 20, specific outcome 3.1; Applied Mathematics 20, specific outcome 2.1
• properties of the exponential function	Pure Mathematics 20, specific outcome 6.4; Pure Mathematics 30, specific outcomes 2.4 and 2.5; Applied Mathematics 20, specific outcomes 2.3 to 2.5

Note: The use of systems of equations, the quadratic formula and logarithms is not required.

Focusing Questions: How is the atom organized? How can a model of the atom and the nucleus be subjected to experimental tests? How does knowledge of the internal structure of the atom lead to the development of applications of energy supply and to the technology of diagnostic imaging?

General Outcomes: There are four major outcomes in this unit.

Students will:

1. describe the electrical nature of the atom
2. describe the quantization of energy in atoms and nuclei
3. describe nuclear fission and fusion as powerful energy sources in nature
4. describe the ongoing development of models of the structure of matter.

Key Concepts: The following concepts are developed in this unit and may also be addressed in other units or in other courses. The intended level and scope of treatment is defined by the learning outcomes.

- charge-to-mass ratio (Thomson's experiment)
- classical model of the atom (Rutherford, Bohr)
- spectra: continuous, line emission and line absorption
- energy levels (states)
- de Broglie hypothesis
- quantum mechanical model
- half-life
- nuclear decay
- nuclear reactions
- Standard Model of matter

General Outcome 1
Students will describe the electrical nature of the atom.

Specific Outcomes for Knowledge

Students will:

30–D1.1k describe matter as containing discrete positive and negative charges

30–D1.2k explain how the discovery of cathode rays contributed to the development of atomic models

30–D1.3k explain J. J. Thomson's experiment and the significance of the results for both science and technology

30–D1.4k explain, qualitatively, the significance of the results of Rutherford's scattering experiment, in terms of scientists' understanding of the relative size and mass of the nucleus and the atom.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–D1.1sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *analyze how the identification of the electron and its characteristics is an example of the interaction of science and technology*
- *analyze the operation of cathode-ray tubes and mass spectrometers*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 1
Students will describe the electrical nature of the atom.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–D1.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- identify, define and delimit questions to investigate; *e.g.,* "*What is the importance of cathode rays in the development of atomic models?"* **(IP–NS1)**
- evaluate and select appropriate procedures and instruments for collecting evidence and information, including appropriate sampling procedures; *e.g., use electric and magnetic fields to determine the charge-to-mass ratio of the electron* **(IP–NS4) [ICT C6–4.5, F1–4.2]**.

Performing and Recording

Students will:

30–D1.2s 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, or use simulations, to determine the charge-to-mass ratio of the electron **(PR–NS2, PR–NS3) [ICT C6–4.4, F1–4.2]**.

Analyzing and Interpreting

Students will:

30–D1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- determine the mass of an electron and/or ion, given appropriate empirical data **(AI–NS3)**
- derive a formula for the charge-to-mass ratio that has input variables that can be measured in an experiment using electric and magnetic fields **(AI–NS6)**.

Communication and Teamwork

Students will:

30–D1.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will describe the quantization of energy in atoms and nuclei.

Specific Outcomes for Knowledge

Students will:

30–D2.1k explain, qualitatively, how emission of EMR by an accelerating charged particle invalidates the classical model of the atom

30–D2.2k describe that each element has a unique line spectrum

30–D2.3k explain, qualitatively, the characteristics of, and the conditions necessary to produce, continuous line-emission and line-absorption spectra

30–D2.4k explain, qualitatively, the concept of stationary states and how they explain the observed spectra of atoms and molecules

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

30–D2.6k explain, qualitatively, how electron diffraction provides experimental support for the de Broglie hypothesis

30–D2.7k describe, qualitatively, how the two-slit electron interference experiment shows that quantum systems, like photons and electrons, may be modelled as particles or waves, contrary to intuition.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–D2.1sts explain that scientific knowledge and theories develop through hypotheses, the collection of evidence, investigation and the ability to provide explanations **(NS2)**

- *investigate and report on the use of line spectra in the study of the universe and the identification of substances*
- *investigate how empirical evidence guided the evolution of the atomic model*

30–D2.2sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *investigate and report on the application of spectral or quantum concepts in the design and function of practical devices, such as street lights, advertising signs, electron microscopes and lasers*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 2
Students will describe the quantization of energy in atoms and nuclei.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–D2.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- predict the conditions necessary to produce line-emission and line-absorption spectra **(IP–NS3)**
- predict the possible energy transitions in the hydrogen atom, using a labelled diagram showing energy levels **(IP–NS3)**.

Performing and Recording

Students will:

30–D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- observe line-emission and line-absorption spectra **(PR–NS2)**
- observe the representative line spectra of selected elements **(PR–NS2)**
- use library and electronic research tools to compare and contrast, qualitatively, the classical and quantum models of the atom **(PR–NS1) [ICT C1–4.1, C7–4.2]**.

Analyzing and Interpreting

Students will:

30–D2.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- identify elements represented in sample line spectra by comparing them to representative line spectra of elements **(AI–NS6) [ICT C7–4.2]**.

Communication and Teamwork

Students will:

30–D2.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3
Students will describe nuclear fission and fusion as powerful energy sources in nature.

Specific Outcomes for Knowledge

Students will:

30–D3.1k describe the nature and properties, including the biological effects, of alpha, beta and gamma radiation

30–D3.2k write nuclear equations, using isotope notation, for alpha, beta-negative and beta-positive decays, including the appropriate neutrino and antineutrino

30–D3.3k perform simple, nonlogarithmic half-life calculations

30–D3.4k use the law of conservation of charge and mass number to predict the particles emitted by a nucleus

30–D3.5k compare and contrast the characteristics of fission and fusion reactions

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.

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–D3.1sts explain that the goal of science is knowledge about the natural world **(NS1)**

- *investigate the role of nuclear reactions in the evolution of the universe (nucleosynthesis, stellar expansion and contraction*)
- *investigate annihilation of particles and pair production*

30–D3.2sts explain that the products of technology are devices, systems and processes that meet given needs and that the appropriateness, risks and benefits of technologies need to be assessed for each potential application from a variety of perspectives, including sustainability **(ST6, ST7) [ICT F2–4.2, F3–4.1]**

- *assess the risks and benefits of air travel (exposure to cosmic radiation), dental X-rays, radioisotopes used as tracers, food irradiation, use of fission or fusion as a commercial power source and nuclear and particle research*
- *assess the potential of fission or fusion as a commercial power source to meet the rising demand for energy, with consideration for present and future generations*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 3
Students will describe nuclear fission and fusion as powerful energy sources in nature.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

30–D3.1s formulate questions about observed relationships and plan investigations of questions, ideas, problems and issues

- predict the penetrating characteristics of decay products **(IP–NS3)**.

Performing and Recording

Students will:

30–D3.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- *research and report on scientists who contributed to the understanding of the structure of the nucleus* **(PR–NS1)**.

Analyzing and Interpreting

Students will:

30–D3.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- graph data from radioactive decay and estimate half-life values **(AI–NS2) [ICT C6–4.3]**
- interpret common nuclear decay chains **(AI–NS6)**
- graph data from radioactive decay and infer an exponential relationship between measured radioactivity and elapsed time **(AI–NS2) [ICT C6–4.3]**
- compare the energy released in a nuclear reaction to the energy released in a chemical reaction, on the basis of energy per unit mass of reactants **(AI–NS3)**.

Communication and Teamwork

Students will:

30–D3.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 4
Students will describe the ongoing development of models of the structure of matter.

Specific Outcomes for Knowledge

Students will:

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

30–D4.2k explain, qualitatively, in terms of the strong nuclear force, why high-energy particle accelerators are required to study subatomic particles

30–D4.3k describe the modern model of the proton and neutron as being composed of quarks

30–D4.4k compare and contrast the up quark, the down quark, the electron and the electron neutrino, and their antiparticles, in terms of charge and energy (mass-energy)

30–D4.5k describe beta-positive (β^+) and beta-negative (β^-) decay, using first-generation elementary fermions and the principle of charge conservation (Feynman diagrams are not required).

Specific Outcomes for Science, Technology and Society (STS) (Nature of Science Emphasis)

Students will:

30–D4.1sts explain that concepts, models and theories are often used in interpreting and explaining observations and in predicting future observations **(NS6a)**

- *research and report on the development of models of matter*

30–D4.2sts explain that scientific knowledge is subject to change as new evidence becomes apparent and as laws and theories are tested and subsequently revised, reinforced or rejected **(NS4)**

- *observe how apparent conservation law violations led to revisions of the model of the atom; i.e., an apparent failure of conservation laws required the existence of the neutrino*

30–D4.3sts explain that scientific knowledge may lead to the development of new technologies, and new technologies may lead to or facilitate scientific discovery **(ST4) [ICT F2–4.4]**

- *investigate how high-energy particle accelerators contributed to the development of the Standard Model of matter*.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.

General Outcome 4
Students will describe the ongoing development of models of the structure of matter.

Specific Outcomes for Skills (Nature of Science Emphasis)

Initiating and Planning

Students will:

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)**.

Performing and Recording

Students will:

30–D4.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- *research, using library and electronic resources, the relationships between the fundamental particles and the interactions they undergo* **(PR–NS1) [ICT C1–4.1]**.

Analyzing and Interpreting

Students will:

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

- analyze, qualitatively, particle tracks for subatomic particles other than protons, electrons and neutrons **(AI–NS2) [ICT C7–4.2]**
- write β^+ and β^- decay equations, identifying the elementary fermions involved **(PR–NS4)**
- use hand rules to determine the nature of the charge on a particle **(AI–NS6)**
- use accepted scientific convention and express mass in terms of mega electron volts per c^2 (MeV/c^2), when appropriate **(AI–NS1)**.

Communication and Teamwork

Students will:

30–D4.4s work collaboratively in addressing problems and apply the skills and conventions of science in communicating information and ideas and in assessing results

- select and use appropriate numeric, symbolic, graphical and linguistic modes of representation to communicate findings and conclusions **(CT–NS2)**.

Note: Some of the outcomes are supported by examples. The examples are written in italics and **do not form part of the required program** but are provided as an illustration of how the outcomes might be developed.