Atlantic Canada
Science Curriculum

Nova Scotia
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Physics 11 and Physics 12

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Physics 11 and Physics 12

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Foreword

The pan-Canadian *Common Framework of Science Learning Outcomes K to 12*, released in October 1997, will assist in standardizing science education across the country. New science curriculum for the Atlantic Provinces is described in *Foundation for the Atlantic Canada Science Curriculum* (1998). The Atlantic Provinces Education Foundation (APEF) has developed new science curriculum for grades 1–10. One of the implications for implementation of the new curriculum is that the Science 10 course is significantly different from the previous Integrated Science 10 course. This change also necessitates revision of biology, chemistry, and physics courses to bring them into alignment with Science 10.

Physics 11 and Physics 12 include the following units: kinematics; dynamics; momentum and energy; waves; force, motion, work, and energy; fields; waves and modern physics; and radioactivity.

This guide is intended to provide teachers with the overview of the outcomes framework for these courses. It also includes some suggestions to assist teachers in designing learning experiences and assessment tasks.

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Introduction

Background

The curriculum described in *Foundation for the Atlantic Canada Science Curriculum* was planned and developed collaboratively by regional committees. The process for developing the common science curriculum for Atlantic Canada involved regional consultation with the stakeholders in the education system in each Atlantic province. The Atlantic Canada science curriculum is consistent with the framework described in the pan-Canadian *Common Framework of Science Learning Outcomes K to 12*.

Aim

The aim of science education in the Atlantic provinces is to develop scientific literacy.

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities; to become lifelong learners; and to maintain a sense of wonder about the world around them. To develop scientific literacy, students require diverse learning experiences that provide opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment.

Program Design and Components

Learning and Teaching Science

What students learn is fundamentally connected to how they learn it. The aim of scientific literacy for all has created a need for new forms of classroom organization, communication, and instructional strategies. The teacher is a facilitator of learning whose major tasks include

- creating a classroom environment to support the learning and teaching of science
- designing effective learning experiences that help students achieve designated outcomes
- stimulating and managing classroom discourse in support of student learning
- learning about and then using students' motivations, interests, abilities, and learning styles to improve learning and teaching
- assessing student learning, the scientific tasks and activities involved, and the learning environment to make ongoing instructional decisions
- selecting teaching strategies from a wide repertoire

Effective science learning and teaching take place in a variety of situations. Instructional settings and strategies should create an environment that reflects a constructive, active view of the learning process. Learning occurs through actively constructing one's own meaning and assimilating new information to develop a new understanding.

The development of scientific literacy in students is a function of the kinds of tasks they engage in, the discourse in which they participate, and the settings in which these activities occur. Students' disposition towards science is also shaped by these factors. Consequently, the aim of developing scientific literacy requires careful attention to all of these facets of curriculum.

Learning experiences in science education should vary and should include opportunities for group and individual work, discussion among students as well as between teacher and students, and hands-on/minds-on activities that allow students to construct and evaluate explanations for the phenomena under investigation. Such investigations and the evaluation of the evidence accumulated provide opportunities for students to develop their understanding of the nature of science and the nature and status of scientific knowledge.

Writing in Science

Learning experiences should provide opportunities for students to use writing and other forms of representation as ways to learning. Students, at all grade levels, should be encouraged to use writing to speculate, theorize, summarize, discover connections, describe processes, express understandings, raise questions, and make sense of new information using their own language as a step to the language of science. Science logs are useful for such expressive and reflective writing. Purposeful note making is an intrinsic part of learning in science, helping students better record, organize, and understand information from a variety of sources. The process of creating webs, maps, charts, tables, graphs, drawing, and diagrams to represent data and results helps students learn and also provides them with useful study tools.

Learning experiences in science should also provide abundant opportunities for students to communicate their findings and understandings to others, both formally and informally, using a variety of forms for a range of purposes and audiences. Such experiences should encourage students to use effective ways of recording and conveying information and ideas and to use the vocabulary of science in expressing their understandings. It is through opportunities to talk and write about the concepts they need to learn that students come to better understand both the concepts and related vocabulary.

Learners will need explicit instruction in, and demonstration of, the strategies they need to develop and apply in reading, viewing, interpreting, and using a range of science texts for various purposes. It will be equally important for students to have demonstrations of the strategies they need to develop and apply in selecting, constructing, and using various forms for communicating in science.

The Three Processes of Scientific Literacy

An individual can be considered scientifically literate when he/she is familiar with, and able to engage in, three processes: inquiry, problem solving, and decision making.

Inquiry

Scientific inquiry involves posing questions and developing explanations for phenomena. While there is general agreement that there is no such thing as the scientific method, students require certain skills to participate in the activities of science. Skills such as questioning, observing, inferring, predicting, measuring, hypothesizing, classifying, designing experiments, collecting data, analysing data, and interpreting data are fundamental to engaging in science. These activities provide students with opportunities to understand and practise the process of theory development in science and the nature of science.

Problem Solving

The process of problem solving involves seeking solutions to human problems. It consists of proposing, creating, and testing prototypes, products, and techniques to determine the best solution to a given problem.

Decision Making

The process of decision making involves determining what we, as citizens, should do in a particular context or in response to a given situation. Decision-making situations are important in their own right, and they also provide a relevant context for engaging in scientific inquiry and/or problem solving.

Meeting the Needs of All Learners

Foundation for the Atlantic Canada Science Curriculum stresses the need to design and implement a science curriculum that provides equitable opportunities for all students according to their abilities, needs, and interests. Teachers must be aware of, and make adaptations to accommodate, the diverse range of learners in their classes. To adapt instructional strategies, assessment practices, and learning resources to the needs of all learners, teachers must create opportunities that will permit students to address their various learning styles.

As well, teachers must not only remain aware of and avoid gender and cultural biases in their teaching, they must also actively address cultural and gender stereotyping (e.g., about who is interested in and who can succeed in science and mathematics). Research supports the position that when science curriculum is made personally meaningful and socially and culturally relevant, it is more engaging for groups traditionally under-represented in science and, indeed, for all students.

While this curriculum guide presents specific outcomes for each unit, it must be acknowledged that students will progress at different rates.

Teachers should provide materials and strategies that accommodate student diversity, and should validate students when they achieve the outcomes to the best of their abilities.

It is important that teachers articulate high expectations for all students and ensure that all students have equitable opportunities to experience success as they work toward achieving designated outcomes. Teachers should adapt classroom organization, teaching strategies, assessment practices, time, and learning resources to address students' needs and build on their strengths. The variety of learning experiences described in this guide provide access for a wide range of learners. Similarly, the suggestions for a variety of assessment practices provide multiple ways for learners to demonstrate their achievements.

Assessment and Evaluation

The terms *assessment* and *evaluation* are often used interchangeably, but they refer to quite different processes. Science curriculum documents developed in the Atlantic region use these terms for the processes described below.

Assessment is the systematic process of gathering information on student learning.

Evaluation is the process of analysing, reflecting upon, and summarizing assessment information, and making judgments or decisions based upon the information gathered.

The assessment process provides the data, and the evaluation process brings meaning to the data. Together, these processes improve teaching and learning. If we are to encourage enjoyment in learning for students now and throughout their lives, we must develop strategies to involve students in assessment and evaluation at all levels. When students are aware of the outcomes for which they are responsible and of the criteria by which their work will be assessed or evaluated, they can make informed decisions about the most effective ways to demonstrate their learning.

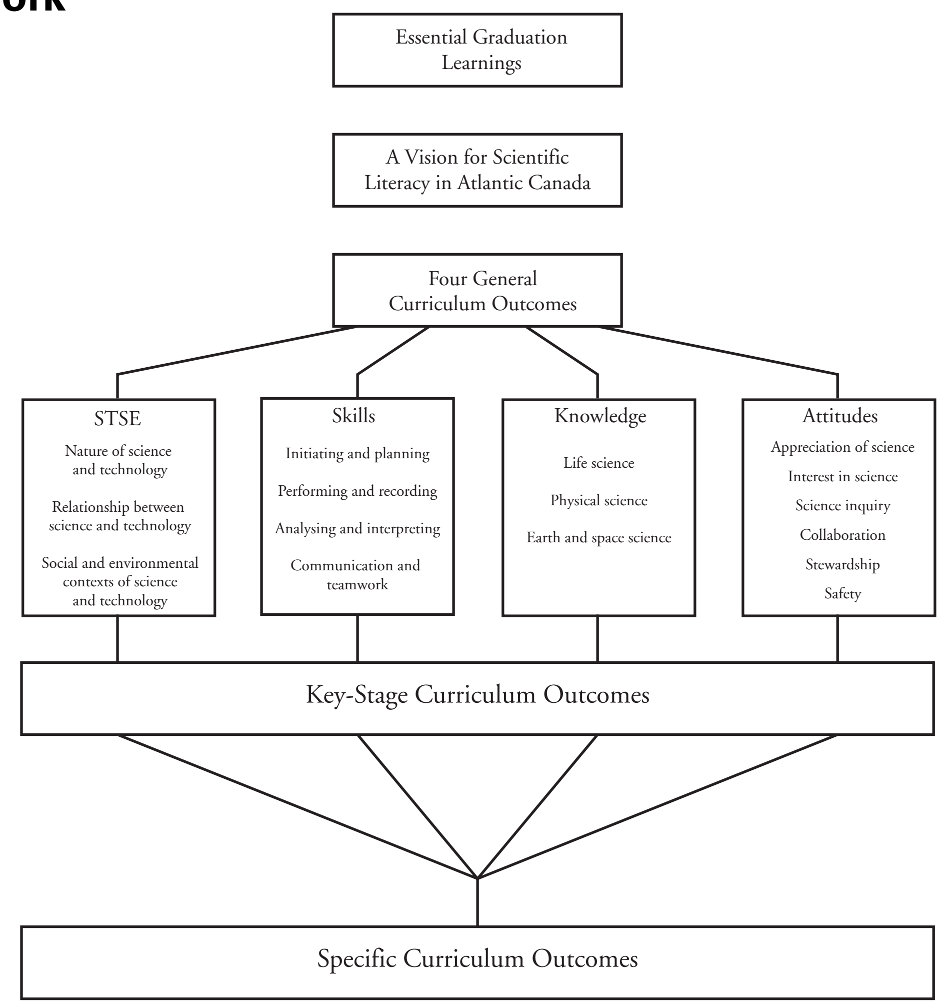
The Atlantic Canada science curriculum reflects the three major processes of science learning: inquiry, problem solving, and decision making. When a teacher assesses student progress, it is helpful to know some activities/skills/actions that are associated with each process of science learning. Student learning may be described in terms of ability to perform these tasks.

Curriculum Outcomes Framework

Overview

The science curriculum is based on an outcomes framework that includes statements of essential graduation learnings, general curriculum outcomes, key-stage curriculum outcomes, and specific curriculum outcomes. The general, key-stage, and specific curriculum outcomes reflect the pan-Canadian C*ommon Framework of Science Learning Outcomes K to 12*. The diagram below provides the blueprint of the outcomes framework.

Outcomes Framework



Essential Graduation Learnings

Essential graduation learnings are statements describing the knowledge, skills, and attitudes expected of all students who graduate from high school. Achievement of the essential graduation learnings will prepare students to continue to learn throughout their lives. These learnings describe expectations not in terms of individual school subjects but in terms of knowledge, skills, and attitudes developed throughout the curriculum. They confirm that students need to make connections and develop abilities across subject boundaries and to be ready to meet the shifting and ongoing opportunities, responsibilities, and demands of life after graduation. Provinces may add additional essential graduation learnings as appropriate. The essential graduation learnings are

Aesthetic Expression

Graduates will be able to respond with critical awareness to various forms of the arts and be able to express themselves through the arts.

Citizenship

Graduates will be able to assess social, cultural, economic, and environmental interdependence in a local and global context.

Communication

Graduates will be able to use the listening, viewing, speaking, reading, and writing modes of language(s) as well as mathematical and scientific concepts and symbols to think, learn, and communicate effectively.

Personal Development

Graduates will be able to continue to learn and to pursue an active, healthy lifestyle.

Problem Solving

Graduates will be able to use the strategies and processes needed to solve a wide variety of problems, including those requiring language, mathematical, and scientific concepts.

Technological Competence

Graduates will be able to use a variety of technologies, demonstrate an understanding of technological applications, and apply appropriate technologies for solving problems.

General Curriculum Outcomes

The general curriculum outcomes form the basis of the outcomes framework. They also identify the key components of scientific literacy. Four general curriculum outcomes have been identified to delineate the four critical aspects of students' scientific literacy. They reflect the wholeness and interconnectedness of learning and should be considered interrelated and mutually supportive.

Science, Technology, Society, and the Environment

Students will develop an understanding of the nature of science and technology, of the relationships between science and technology, and of the social and environmental contexts of science and technology.

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.

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.

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.

Key-Stage Curriculum Outcomes

Key-stage curriculum outcomes are statements that identify what students are expected to know, be able to do, and value by the end of grades 3, 6, 9, and 12 as a result of their cumulative learning experiences in science. The key-stage curriculum outcomes are from the *Common Framework for Science Learning Outcomes K to12*.

Specific Curriculum Outcomes

This curriculum guide outlines specific curriculum outcomes for Physics 11 and Physics 12 and provides suggestions for learning, teaching, assessment, and resources to support students' achievement of these outcomes. Teachers should consult *Foundation for the Atlantic Canada Science Curriculum* for descriptions of the essential graduation learnings, vision for scientific literacy, general curriculum outcomes, and key-stage curriculum outcomes.

Specific curriculum outcome statements describe what students are expected to know and be able to do at each grade level. They are intended to help teachers design learning experiences and assessment tasks. Specific curriculum outcomes represent a framework for assisting students to achieve the key-stage curriculum outcomes, the general curriculum outcomes, and ultimately the essential graduation learnings.

Specific curriculum outcomes are organized in four units for each grade level. Each unit is organized by topic. Physics 11 units and topics follow.

Physics 11

Kinematics

- Presenting Vectors (2 hours)
- Vectors Analysis (3 hours)
- Algebraic Problem Solving (5 hours)

Dynamics

- Dynamics Introduction (5 hours)
- Newton's Laws (8 hours)
- Momentum Introduction (2 hours)

Momentum and Energy

- Conservation of Momentum (5 hours)
- Work, Power, and Efficiency (5 hours)
- Transformation, Total Energy, and Conservation (15 hours)
- Technological Implications (5 hours)

Waves

- Fundamental Properties (12 hours)
- Sound Waves and Electromagnetic Radiation (15 hours)

The following pages outline Physics 11 specific curriculum outcomes grouped by units and topics.

Kinematics

Students will be expected to

Presenting Vectors

- identify the frame of reference for a given motion and to distinguish fixed and moving frames (325-7)
- identify and investigate questions that arise from practical problems/ issues involving motion (212-1)

Vector Analysis

- use vectors to represent position, displacement, velocity, and acceleration (325-5)
- analyse and describe vertical motion using the principles of kinematics (116-2)

Algebraic Problem Solving

- analyse word problems, solve algebraically for unknowns, and interpret patterns in data (325-2)

Dynamics

Students will be expected to

Dynamics Introduction

- analyse the influence of society on scientific and technological endeavours in dynamics (117-2)
- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- analyse natural and technological systems to interpret and explain their structure and dynamics (116-7)
- use vectors to represent forces (325-5)

Newton's Laws

- apply Newton's laws of motion to explain inertia and the relationships among force, mass, and acceleration (325-8)
- design an experiment identifying and controlling major variables (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- carry out procedures controlling the major variables and adapting or extending procedures where required (213-2)
- use instruments effectively and accurately for collecting data (213-3)
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (214-3)
- interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables (214-5)
- analyse and describe examples where knowledge of the dynamics of bodies was enhanced or revised as a result of the invention of a technology (116-2)
- explain how a major scientific milestone revolutionized thinking in dynamics (115-3)

Momentum Introduction

- describe the functioning of technology devices based on principles of momentum (116-5)

Momentum and Energy

Students will be expected to

Conservation of Momentum

- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3)

Work, Power, and Efficiency

- analyse quantitatively the relationships among force, distance, and work (325-9)
- analyse quantitatively the relationships among work, time, and power (325-10)
- design and carry out an experiment to determine the efficiency of various machines (212-3, 213-2, 213-3, 214-7)

Transformation, Total Energy, and Conservation

- analyse quantitatively the relationships among mass, speed, and thermal energy, using the law of conservation of energy (326-1)
- describe quantitatively mechanical energy as the sum of kinetic and potential energies (326-5)
- compare empirical and theoretical values of total energy and account for discrepancies (214-7)
- analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept (326-6)
- analyse common energy transformation situations using the closed system work-energy theorem (326-7)
- analyse and describe examples where technological solutions were developed based on scientific understanding (116-4)
- determine the percentage efficiency of energy transformation (326-8)
- design an experiment, select and use appropriate tools, carry out procedures, compile and organize data, and interpret patterns in the data to answer a question posed regarding the conservation of energy (212-3, 212-8, 213-2, 214-3, 214-5, 214-11, 326-4)
- distinguish between problems that can be solved by the application of physics-related technologies and those that cannot (118-8)
- determine which laws of conservation, momentum, and energy are best used to analyse and solve particular real-life problems in elastic and inelastic interactions (326-4)

Technological Implications

- analyse and describe examples where energy- and momentum-related technologies were developed and improved over time (115-5, 116-4)
- describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum (116-6)
- explain the importance of using appropriate language and conventions when describing events related to momentum and energy (114-9)

Waves

Students will be expected to

Fundamental Properties

- describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves (327-1)
- formulate operational definitions of major variables (212-7)
- select and integrate information from various print and electronic sources (213-7)
- analyse, from a variety of perspectives, the risks and benefits to society and to the environment when applying scientific knowledge or introducing a particular technology (118-2)
- analyse natural and technological systems to interpret their structure and dynamics (116-7)
- analyse society's influence on scientific and technological endeavours (117-2)
- construct and test a prototype of a device and troubleshoot problems as they arise (214-14)
- analyse why and how a particular technology was developed and improved over time (115-5)
- apply the universal wave equation to explain and predict the behaviour of waves (327-2)
- implement appropriate sampling procedures and evaluate the relevance, reliability, and adequacy of data and data collection methods in wave experiments (213-1, 214-8)
- apply the laws of reflection and the laws of refraction to predict wave behaviour (327-7)
- state a prediction and a hypothesis about wave behaviour based on available evidence and background information (212-4)

Sound Waves and Electromagnetic Radiation

- apply the laws of reflection and the laws of refraction to predict wave behaviour (327-7)
- explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler-Fizeau effect (327-8)
- compare and describe the properties of electromagnetic radiation and sound (327-5)
- describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted (327-6)
- analyse and describe examples where scientific understanding was enhanced as a result of the invention of a technological device (116-2)

Physics 12

The following are specific curriculum outcomes organized by topic for Physics 12. The section Electric Circuits (10 hours) is optional.

Force, Motion, Work, and Energy

- Dynamics Extension (10 hours)
- Collisions in Two Dimensions (8 hours)
- Projectiles (8 hours)
- Circular Motion (8 hours)
- Simple Harmonic Motion (SHM) (4 hours)
- Universal Gravitation (5 hours)

Fields

- Magnetic, Electric, and Gravitational Fields (4 hours)
- Coulomb's Law (4 hours)
- Electric Circuits (Optional) (10 hours)
- Electromagnetism and Electromagnetic Induction (5 hours)
- Generators and Motors (4 hours)

Waves and Modern Physics

- Quantum Physics (3 hours)
- Compton and de Broglie (2 hours)
- Particles and Waves (2 hours)
- Bohr Atoms and Quantum Atoms (3 hours)

Radioactivity

- Natural and Artificial Sources of Radiation (3 hours)
- Radioactive Decay (3 hours)
- Fission and Fusion (4 hours)

The following pages outline Physics 12 specific curriculum outcomes grouped by units and topics.

Force, Motion, Work, and Energy

Students will be expected to

Dynamics Extension

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

Collisions in Two Dimensions

- apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions (326-3)
- determine in which real-life situations involving elastic and inelastic interactions the laws of conservation of momentum and energy are best used (326-4)

Projectiles

- construct, test, and evaluate a device or system on the basis of developed criteria (214-14, 214-16)
- analyse quantitatively the horizontal and vertical motion of a projectile (325-6)

Circular Motion

- describe uniform circular motion using algebraic and vector analysis (325-12)
- explain quantitatively circular motion using Newton's laws (325-13)

Simple Harmonic Motion (SHM)

- identify questions, analyse, compile, and display evidence and information to investigate the development over time of a practical problem, issue, or technology (212-3, 214-3, 115-5)
- explain qualitatively the relationship between displacement, velocity, time, and acceleration for simple harmonic motion (327-2)
- explain quantitatively the relationship between potential and kinetic energies of a mass in simple harmonic motion (327-4)
- compile and organize data, using data tables and graphs, to facilitate interpretation of the data (213-5)

Universal Gravitation

- explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law (ACP-2)
- explain and apply the law of universal gravitation to orbital notations by using appropriate numeric and graphic analysis (215-2)
- distinguish between scientific questions and technological problems as applied to orbital situations (115-1)

Fields

Students will be expected to

Magnetic, Electric, and Gravitational Fields

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

Coulomb's Law

- define and delimit problems, estimate quantities, interpret patterns and trends in data, and infer or calculate the relationships among variables (212-2, 213-4, 214-5)
- compare Newton's law of universal gravitation with Coulomb's law, and apply both laws quantitatively (328-4)

Electric Circuits (Optional)

- apply Ohm's law to series, parallel, and combination circuits (ACP-3)
- carry out procedures controlling the major variables, selecting and using instruments effectively, accurately, and safely, and adapting or extending procedures where required (213-2, 213-3, 213-8)
- state a prediction and a hypothesis based on available evidence and background information (212-4)
- design an experiment and identify specific variables (212-6)

Electromagnetism and Electromagnetic Induction

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

Generators and Motors

- compare and contrast the ways a motor and generator function, using the principles of electromagnetism (328-9)
- describe and compare direct current and alternating current (ACP-4)

Waves and Modern Physics

Students will be expected to

Quantum Physics

- apply quantitatively the law of conservation of mass and energy using Einstein's mass-energy equivalence (326-9)
- explain how quantum physics evolved as new evidence came to light and as laws and theories were tested and subsequently restricted, revised, or replaced, and use library and electronic research tools to collect information on this topic (115-7, 213-6)
- describe how the quantum energy concept explains both black-body radiation and the photoelectric effect (327-9)
- explain qualitatively and apply the formula for the photoelectric effect (327-10)

Compton and de Broglie

- explain how a photon momentum revolutionized thinking in the scientific community (115-3)
- apply and assess alternative theoretical models for interpreting knowledge in a given field (214-6)
- explain quantitatively the Compton effect and the de Broglie hypothesis, using the laws of mechanics, the conservation of momentum, and the nature of light (329-1)

Particles and Waves

- summarize the evidence for the wave and particle models of light (327-11)

Bohr Atoms and Quantum Atoms

- explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts (329-2)
- explain the relationship among the energy levels in Bohr's model, the energy difference between levels, and the energy of the emitted photons (329-3)
- use the quantum-mechanical model to explain naturally luminous phenomena (329-7)

Radioactivity

Students will be expected to

Natural and Artificial Sources of Radiation

- describe sources of radioactivity in the natural and constructed environments (329-5)
- identify, analyse, and describe examples where technologies were developed based on scientific understanding, the design and function of these technologies as part of a community's life, and science- and technology- related careers (116-4, 116-6, 117-5, 117-7)
- use quantitatively the law of conservation of mass and energy using Einstein's mass-energy equivalence (326-9)
- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- develop appropriate sampling procedures (212-9)
- select and use apparatus and materials safely (213-8)
- demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials (213-9)

Radioactive Decay

- describe the products of radioactive decay and the characteristics of alpha, beta, and gamma radiation (329-4)
- analyse data on radioactive decay to predict half-life (214-2)

Fission and Fusion

- compare and contrast fission and fusion (329-6)
- analyse examples of Canadian contribution to a particular development of science and technology (115-5, 117-11)
- identify, develop, present, and defend a position or course of action based on identifying multiple perspectives that influence the issue, and on interpreting data and the relationship among variables (214-15, 215-4, 215-5)
- analyse and evaluate, from a variety of perspectives, using a variety of criteria, the risks and benefits to society and the environment of a particular application of scientific knowledge and technology (118-2, 118-4)

Attitude Outcomes

It is expected that the Atlantic Canada science program will foster certain attitudes in students throughout their school years. The STSE, skills, and knowledge outcomes contribute to the development of attitudes, and opportunities for fostering these attitudes are highlighted in the Elaborations—Strategies for Learning and Teaching sections of each unit.

Attitudes refer to generalized aspects of behaviour that teachers model for students by example and by selective approval. Attitudes are not acquired in the same way as skills and knowledge. The development of positive attitudes plays an important role in students' growth by interacting with their intellectual development and by creating a readiness for responsible application of what students learn.

Since attitudes are not acquired in the same way as skills and knowledge, outcome statements for attitudes are written as key-stage curriculum outcomes for the end of grades 3, 6, 9, and 12. These outcome statements are meant to guide teachers in creating a learning environment that fosters positive attitudes.

The following pages present the attitude outcomes from the pan-Canadian *Common Framework of Science Learning Outcomes K to 12* for the end of grade 12.

Key-Stage Curriculum Outcomes: Attitudes

By the end of grade 12, students will be expected to

Appreciation of Science	Interest in Science	Scientific Inquiry
436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not 437 appreciate that the applications of science and technology can raise ethical dilemmas 438 value the contributions to scientific and technological development made by women and men from many societies and cultural backgrounds *Evident when students, for example,* • consider the social and cultural contexts in which a theory developed • use a multi-perspective approach, considering scientific, technological, economic, cultural, political, and environmental factors when formulating conclusions, solving problems, or making decisions on STSE issues • recognize the usefulness of being skilled in mathematics and problem solving • recognize how scientific problem solving and the development of new technologies are related • recognize the contribution of science and technology to the progress of civilizations • carefully research and openly discuss ethical dilemmas associated with the applications of science and technology • show support for the development of information technologies and science as they relate to human needs • recognize that western approaches to science are not the only ways of viewing the universe • consider the research of both men and women	439 show a continuing and more informed curiosity and interest in science and science-related issues 440 acquire, with interest and confidence, additional science knowledge and skills using a variety of resources and methods, including formal research 441 consider further studies and careers in science- and technology-related fields *Evident when students, for example,* • conduct research to answer their own questions • recognize that part-time jobs require science- and technology-related knowledge and skills • maintain interest in or pursue further studies in science • recognize the importance of making connections among various science disciplines • explore and use a variety of methods and resources to increase their own knowledge and skills • are interested in science and technology topics not directly related to their formal studies • explore where further science- and technology-related studies can be pursued • are critical and constructive when considering new theories and techniques • use scientific vocabulary and principles in everyday discussions • readily investigate STSE issues	442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations 443 use factual information and rational explanations when analysing and evaluating 444 value the processes for drawing conclusions *Evident when students, for example,* • insist on evidence before accepting a new idea or explanation • ask questions and conduct research to confirm and extend their understanding • criticize arguments 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 • expend the effort and time needed to make valid inferences • critically evaluate inferences and conclusions, cognizant of the many variables involved in experimentation • critically assess their opinions of the value of science and its applications • criticize arguments in which evidence, explanations, or positions do not reflect the diversity of perspectives that exist • insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged • seek new models, explanations, and theories when confronted with discrepant events or evidence

Key-Stage Curriculum Outcomes: Attitudes *(continued)*

By the end of grade 12, students will be expected to

Collaboration	Stewardship	Safety in Science
445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas *Evident when students, for example,* • willingly work with any classmate or group of individuals regardless of their age, gender, or physical and cultural characteristics • assume a variety of roles within a group, as required • accept responsibility for any task that helps the group complete an activity • give the same attention and energy to the group's product as they would to a personal assignment • are attentive when others speak • are capable of suspending personal views when evaluating suggestions made by a group • seek the points of view of others and consider diverse perspectives • accept constructive criticism when sharing their ideas or points of view • criticize the ideas of their peers without criticizing the persons • evaluate the ideas of others objectively • encourage the use of procedures that enable everyone, regardless of gender or cultural background, to participate in decision making • contribute to peaceful conflict resolution • encourage the use of a variety of communication strategies during group work • share the responsibility for errors made or difficulties encountered by the group	446 have a sense of personal and shared responsibility for maintaining a sustainable environment 447 project the personal, social, and environmental consequences of proposed action 448 want to take action for maintaining a sustainable environment *Evident when students, for example,* • willingly evaluate the impact of their own choices or the choices scientists make when they carry out an investigation • 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 • participate in social and political systems that influence environmental policy in their community • examine/recognize both the positive and negative effects on human beings and society of environmental changes caused by nature and by humans • willingly 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 • are critical-minded regarding the short- and long-term consequences of sustainability	449 show concern for safety and accept the need for rules and regulations 450 be aware of the direct and indirect consequences of their actions *Evident when students, for example,* • read the label on materials before using them, interpret the WHMIS symbols, and consult a reference document if safety symbols are not understood • criticize a procedure, a design, or materials that are not safe or that could have a negative impact on the environment • consider safety a positive limiting factor in scientific and technological endeavours • carefully manipulate materials, cognizant of the risks and potential consequences of their actions • write into a laboratory procedure safety and waste-disposal concerns • evaluate the long-term impact of safety and waste disposal on the environment and the quality of life of living organisms • use safety and waste disposal as criteria for evaluating an experiment • assume responsibility for the safety of all those who share a common working environment by cleaning up after an activity and disposing of materials in a safe place • seek assistance immediately for any first aid concerns like cuts, burns, or unusual reactions • keep the work station uncluttered, with only appropriate lab materials present

Curriculum Guide Organization

Specific curriculum outcomes are organized in units for each grade level. Each unit is organized by topic. Suggestions for learning, teaching, assessment, and resources are provided to support student achievement of the outcomes.

The order in which the units of a grade appear in the guide is meant to suggest a sequence. In some cases, the rationale for the recommended sequence is related to the conceptual flow across the year. That is, one unit may introduce a concept that is then extended in a subsequent unit. Likewise, one unit may focus on a skill or context that will be built upon later in the year.

Some units or certain aspects of units may also be combined or integrated. This is one way of assisting students as they attempt to make connections across topics in science or between science and the real world. In some cases, a unit may require an extended time frame to collect data on weather patterns, plant growth, etc. These cases may warrant starting the activity early and overlapping it with the existing unit. In all cases, the intent is to provide opportunities for students to deal with science concepts and scientific issues in personally meaningful and socially and culturally relevant contexts.

Unit Organization

Each unit begins with a two-page synopsis. On the first page, introductory paragraphs provide a unit overview. These are followed by a section that specifies the focus (inquiry, problem solving, and/or decision making) and possible contexts for the unit. Finally, a curriculum links paragraph specifies how this unit relates to science concepts and skills addressed in other grades so teachers will understand how the unit fits with the students' progress through the complete science program.

The second page of the two-page overview provides a table of the outcomes from the *Common Framework of Science Learning Outcomes K to 12* that the unit will address. The numbering system used is the one in the pan-Canadian document as follows:

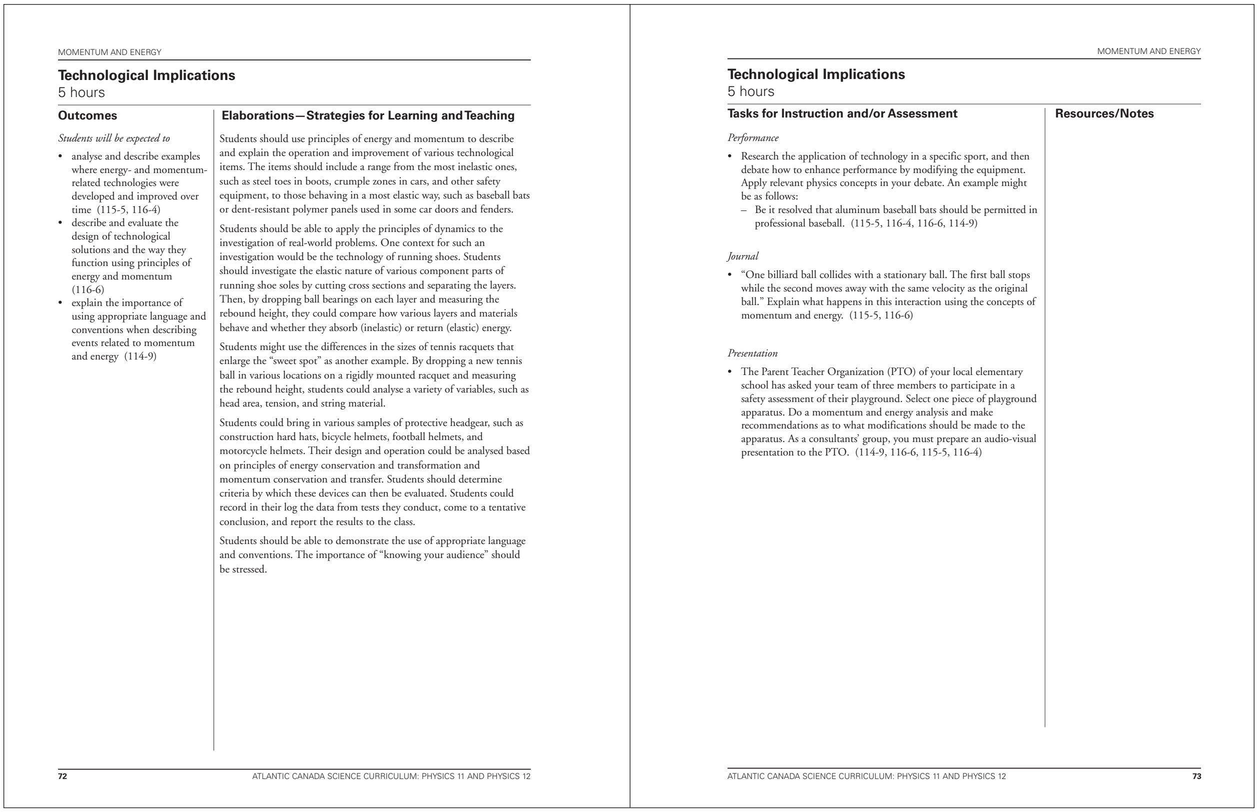
- 100s—Science-Technology-Society-Environment (STSE) outcomes
- 200s—Skills outcomes
- 300s—Knowledge outcomes
- 400s—Attitude outcomes (see pages 20–22)
- ACPs—Atlantic Canada Physics outcomes

These code numbers appear in brackets after each specific curriculum outcome (SCO).

The Four-Column Spread

All units have a two-page layout of four columns as illustrated below. In some cases, the four-column spread continues to the next two-page layout. Outcomes are grouped by a topic indicated at the top of the left page.

Two-Page, Four-Column Spread



MOMENTUM AND ENERGY

Technological Implications
5 hours

Outcomes

Students will be expected to

- analyse and describe examples where energy- and momentum-related technologies were developed and improved over time (115-5, 116-4)
- describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum (116-6)
- explain the importance of using appropriate language and conventions when describing events related to momentum and energy (114-9)

Elaborations—Strategies for Learning and Teaching

Students should use principles of energy and momentum to describe and explain the operation and improvement of various technological items. The items should include a range from the most inelastic ones, such as steel toes in boots, crumple zones in cars, and other safety equipment, to those behaving in a most elastic way, such as baseball bats or dent-resistant polymer panels used in some car doors and fenders.

Students should be able to apply the principles of dynamics to the investigation of real-world problems. One context for such an investigation would be the technology of running shoes. Students should investigate the elastic nature of various component parts of running shoe soles by cutting cross sections and separating the layers. Then, by dropping ball bearings on each layer and measuring the rebound height, they could compare how various layers and materials behave and whether they absorb (inelastic) or return (elastic) energy.

Students might use the differences in the sizes of tennis racquets that enlarge the "sweet spot" as another example. By dropping a new tennis ball in various locations on a rigidly mounted racquet and measuring the rebound height, students could analyse a variety of variables, such as head area, tension, and string material.

Students could bring in various samples of protective headgear, such as construction hard hats, bicycle helmets, football helmets, and motorcycle helmets. Their design and operation could be analysed based on principles of energy conservation and transformation and momentum conservation and transfer. Students should determine criteria by which these devices can then be evaluated. Students could record in their log the data from tests they conduct, come to a tentative conclusion, and report the results to the class.

Students should be able to demonstrate the use of appropriate language and conventions. The importance of "knowing your audience" should be stressed.

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MOMENTUM AND ENERGY

Technological Implications
5 hours

Tasks for Instruction and/or Assessment

Performance

- Research the application of technology in a specific sport, and then debate how to enhance performance by modifying the equipment. Apply relevant physics concepts in your debate. An example might be as follows:
  – Be it resolved that aluminum baseball bats should be permitted in professional baseball. (115-5, 116-4, 116-6, 114-9)

Journal

- "One billiard ball collides with a stationary ball. The first ball stops while the second moves away with the same velocity as the original ball." Explain what happens in this interaction using the concepts of momentum and energy. (115-5, 116-6)

Presentation

- The Parent Teacher Organization (PTO) of your local elementary school has asked your team of three members to participate in a safety assessment of their playground. Select one piece of playground apparatus. Do a momentum and energy analysis and make recommendations as to what modifications should be made to the apparatus. As a consultants' group, you must prepare an audio-visual presentation to the PTO. (114-9, 116-6, 115-5, 116-4)

Resources/Notes

ATLANTIC CANADA SCIENCE CURRICULUM: PHYSICS 11 AND PHYSICS 12 73

Column One: Outcomes

The first column provides the specific curriculum outcomes. These are based on the pan-Canadian *Common Framework of Science Learning Outcomes K to 12*. The statements involve the Science-Technology-Society-Environment (STSE), skills, and knowledge outcomes indicated by the outcome number(s) that appears in parentheses after the outcome. Some STSE and skills outcomes have been written in a context that shows how these outcomes should be addressed.

Specific curriculum outcomes have been grouped by topic. Other groupings of outcomes are possible and in some cases may be necessary to take advantage of local situations. The grouping of outcomes provides a suggested teaching sequence. Teachers may prefer to plan their own teaching sequence to meet the learning needs of their students.

Column One and Column Two define what students are expected to learn and be able to do.

Column Two: Elaborations—Strategies for Learning and Teaching

The second column may include elaborations of outcomes listed in Column One, and describes learning environments and experiences that will support students' learning.

The strategies in this column are intended to provide a holistic approach to instruction. In some cases, they address a single outcome; in other cases, they address a group of outcomes.

Column Three: Tasks for Instruction and/or Assessment

The third column provides suggestions for ways that students' achievement of the outcomes could be assessed. These suggestions reflect a variety of assessment techniques and materials that include, but are not limited to, informal/formal observation, performance, journal, interview, paper and pencil, presentation, and portfolio. Some assessment tasks may be used to assess student learning in relation to a single outcome, others to assess student learning in relation to several outcomes. The assessment item identifies the outcome(s) addressed by the outcome number in brackets after the item.

Column Four: Resources/Notes

This column provides an opportunity for teachers to make note of useful resources.

Physics 11 Outcomes

Kinematics

Introduction

Motion is a common theme in our everyday lives: birds fly, babies crawl, and we ourselves seem to be in a constant state of movement, running, driving, and walking. Kinematics is the study of how objects move, and, as such, makes up a large part of introductory physics.

Because students learn in a variety of ways, they must be given many different opportunities to explore kinematics. The experiences should include kinesthetic learning, where students will feel the effects of different speeds and accelerations and see the difference these make in the records of their own motion. Students need to have varied experiences and time to think, reflect, assimilate, and rethink so that they own their accumulated knowledge.

Students must be encouraged to develop the vocabulary of kinematics by discussing the concepts among themselves and with the teacher. They should be required to describe and explain the motion of objects both verbally and in written and mathematical forms. Students should use algebraic and graphical analytical techniques.

Focus and Context

Inquiry and problem solving are used throughout this unit in a variety of meaningful contexts. These contexts may include examples such as skateboarding, sport, automobile motion, or any other relevant context. Students will learn best when they suggest the context. To foster connections, students must be given sufficient opportunities to observe, manipulate, discuss, predict, describe, and explain the motion of objects in various situations. Only then should problem solving in more abstract situations be undertaken.

Science Curriculum Links

Students are expected to review and extend their understanding of one-dimensional motion acquired in Science 10, culminating in the use of one-dimensional vector representations of relative motion. The concepts developed in the study of kinematics in grade 11 will be applied to two-dimensional situations in Physics 12.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Relationships between Science and Technology** **116-2** analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of technology	*Students will be expected to* **Initiating and Planning** **212-1** identify questions to investigate that arise from practical problems and issues	*Students will be expected to* **325-7** identify the frame of reference for a given motion **325-5** use vectors to represent force, velocity, and acceleration **325-2** analyse graphically and mathematically the relationship among displacement, velocity, and time

Presenting Vectors
2 hours

Outcomes

Students will be expected to

- identify the frame of reference for a given motion to distinguish fixed and moving frames (325-7)
- identify and investigate questions that arise from practical problems/issues involving motion (212-1)

Elaborations—Strategies for Learning and Teaching

The intent of this two-page spread is to use experiences with relative motion to refresh and develop student understanding of kinematics concepts introduced in Science 10.

Skateboard physics is a meaningful context for this concept. Many skateboard manoeuvres require a practical knowledge of relative motion. Some of these could be demonstrated indoors, and some will have to be done outdoors. Students should suggest trials and explore the possibilities. For example, if a skateboarder goes by, how does the motion appear against a fixed background? How does the background appear to the boarder?

Students could use a Nerf™ gun and dynamics cart or other moveable object on a lab table surface to explore frames of reference. Students could try to hit the cart under the following conditions: with the gun and target stationary, with the gun stationary and target moving, and with the gun and target moving relative to each other.

Using two or more toys that move at different constant speeds, students could position them in various ways such as separate but facing one another or separate but facing the same direction. They could determine where to place the toys so they will meet at a designated spot. In catch-up races, they could determine when and where they will be side by side. The emphasis should be on students' constructing a meaningful understanding of the kinematics concepts.

Students should develop the vocabulary of kinematics by being involved in discussions among themselves and with the teacher. They should be expected to describe motions appropriately in both verbal and written form. Frames of reference for motion could be investigated by having students collect displacement data for battery-powered toys as they move across a length of paper towel. Data can be collected when the towel is not moving, when it is moving in the same direction as the toy, and when it is being pulled in a direction opposite to the motion of the the toy. This provides visual confirmation of the concept as well as the possibility of generating data that could be analysed to determine rates of motion relative to different frames of reference.

From the above, students should gain experience with directional motion. Teachers should introduce vector diagramming in one dimension. Students should become familiar with using scaled vectors to represent kinematics quantities. Their understanding of relative velocity could be enhanced by representing it visually. Adding the toy's velocity relative to the table and the towel's velocity relative to the table can best be shown vectorially. How could the towel be moved so that the toy has a velocity relative to the table of zero?

Presenting Vectors
2 hours

Tasks for Instruction and/or Assessment

Informal Observation

- Teachers can observe based on the following rubric: (325-7)

Motion Activities

	Student 1	Student 2	Student 3	Student 4
Uninvolved				
Participating				
Contributing				
Leading				

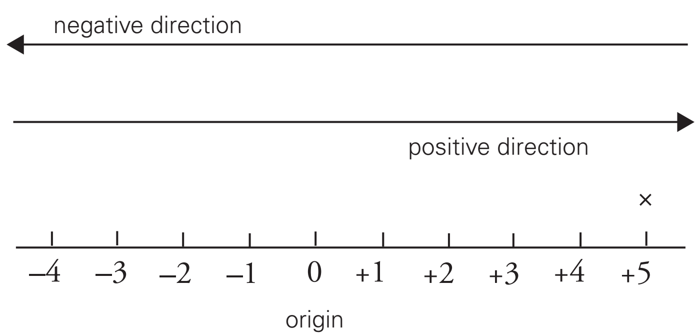
Journal

- What does the speedometer of a car measure: speed, velocity, or both? Explain. (325-7)

Presentation

- Draw a diagram of the picture of the activity you chose for motion. Use coordinate axes where possible. Choose which direction is positive and which is negative. (325-7)
- How are distance and displacement the same? Different? (212-1)
- Using the diagram below, identify which pairs give a positive displacement:

  a) +5m, –2m   b) –3m, +6m   c) –4m, –2m
  (325-7)



Resources/Notes

(325-7)

Textbook resources and labs for this outcome can be found in Appendix C for the following topic:

- Frames of Reference

Vector Analysis
3 hours

Outcomes

Students will be expected to

- use vectors to represent position, displacement, velocity, and acceleration (325-5)
- analyse and describe vertical motion using the principles of kinematics (116-2)

Elaborations—Strategies for Learning and Teaching

Students' data from their skateboards or carts could be used as starting data here. Students need to deal with formal expression of, and operations for, vector quantities. Students should realize that scalar quantities could be assigned an algebraic identifier (such as x, a, λ) and that rules of operations as defined in algebra apply. However, quantities with both magnitude and direction cannot be adequately represented algebraically. Using a Cartesian system, one can draw a line whose length represents magnitude and orientation represents direction. There should also be a means to add, subtract, and do other operations with these quantities.

Students should learn to define and manipulate vectors that represent displacement and velocity using graphical means only. Force and two-dimensional motion are treated in more detail in Physics 12. Students could create "treasure" maps for each other in and around the school. On a city street map, it is possible to practise discriminating between distance and displacement. The sum of the component method and subtraction of vectors will be treated in Physics 12.

Students should conduct a laboratory investigation involving the vertical acceleration of gravity. Possible apparatus might be a picket fence, ticker tape timers, motion sensors, and photogates. Teachers should expect a written lab report from their students. Percentage error should be calculated in this investigation and/or any other where an accepted value is known.

Vector Analysis
3 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct a lab and write a report on your investigation of the acceleration of gravity. (116-2)

Paper and Pencil

- Caroline and Erin planned to meet at the shopping mall. Caroline left her home and walked 4 blocks north, 2 blocks east, and 2 more blocks north to reach the mall. Erin left her house and walked 2 blocks south, 3 blocks west, and 3 more blocks south. Draw a careful vector diagram of both motions and answer the following questions:
  – What distance did each girl walk?
  – Which girl is farthest in a straight line from the mall? (Direct in degrees)
  – What is the straight line distance between Caroline's home and Erin's home?

  Note: *All distances may be expressed in blocks*. (325-5)
- Mark rode his personal water craft at a constant speed of 30 km/h directly across a river running at 5 km/h downstream. What is Mark's velocity relative to the bank? (325-5)
- The sum of two vectors is zero. What can you say about the magnitude and direction of the two initial vectors? (325-5)

Presentation

- Create a short narrative involving several of your friends using the following displacements. List three questions you could ask if the following were points on a test question.
  a. 10 km east
  b. 5.0 km south
  c. 8.0 km west
  d. 3.8 km northwest (325-5)

Resources/Notes

(325-5)

Textbook resources for this outcome can be found in Appendix C for the following topic:

- Vector Basics

Lab resources for this outcome can be found in Appendix C for the following topic:

- Acceleration Due to Gravity

Algebraic Problem Solving

5 hours

Outcomes

Students will be expected to

- analyse word problems, solve algebraically for unknowns, and interpret patterns in data (325-2)

Elaborations—Strategies for Learning and Teaching

In this section, students should begin to develop a rigorous process for solving word problems.

Teachers should begin problem solving by relating the students' trials of displacement/time (*d/t*), to velocity/time (*v/t*). Their skateboard data should be plotted on a *d/t* graph and then a *v/t* graph. Students should do the slope and area analysis of velocity graphs. Students should find the formulae from their graphs. Algebraic formulae are nothing more than definitions and familiar relationships suitably rearranged for problem solving.

Problem solving is an integral part of the study of kinematics. Teachers should approach problem solving as another tool students can use to help them understand kinematics concepts. Problems should be presented at various levels of difficulty, with at least some at a level such as the Sir Isaac Newton (SIN) test level. Good problem-solving strategies should be modelled consistently by the teacher. The first reading of a problem should give the student a general sense of what is given and required. A second reading should be done slowly to glean all usable data from the text. Students often miss expressions such as "starting from rest," which gives the information that v_1 is zero. When presenting solutions, teachers should verbalize the thought process as completely as possible. Students should be encouraged to make a list of given data on the work sheet.

It is also a good practice to estimate the correct answer where possible and to evaluate the solution according to common experience. For example, it is unreasonable to conclude in a solution that the final velocity of an automobile is 350 m/s. The work should be checked for such obvious errors as those involving decimal places.

A further practice that is helpful in evaluating a solution is to carry the units throughout the work. If the answer for final velocity seems to be 35.0 m/s^2, the unit itself suggests a wrong answer. The teacher should model the problem-solving technique expected from students.

Many students are uncomfortable starting a problem when they cannot clearly see the method that will lead to the answer. Since many physics problem have two or more steps, students should learn to solve what they can in the understanding that doing so may lead to something useful. Students should be encouraged to check given data against the basic kinematics formulae until a formula is found for which all but one variable is known. Students should then rearrange for the unknown and solve. This methodology is a part of the systematic analysis of complex problems.

Algebraic Problem Solving

5 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Alex and Raj always try to outdo each other on their skateboards. They decide to have a "hang time" contest. They begin side by side and push their boards to a speed of 5 m/s. At the same time, they jump straight up as high as they can and land on the moving board. Alex's board goes 7.5 m before he lands, and Raj's board goes 6.0 m before he lands. How long was each boy in the air? How high did each jump? (325-2)
- A rock and a sponge were dropped from a rooftop. The rock hit the ground in 1.4 s. The sponge took 2.0 s to fall. How high was the roof? What was the acceleration of the sponge? Why do you think there is a difference? Explain. (325-2)

Presentation

- In groups of two, prepare kinematics problems. Write out the problem and solution(s) on a separate page. Have another group try your problem(s). How is their understanding of the problem like or unlike yours? (325-2)

Resources/Notes

(325-2)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Graphing Motion
- Problem-Solving Techniques
- Algebraic Problem Solving
- Algebraic Problem Solving (SIN)

Algebraic Problem Solving *(continued)*

Outcomes

Students will be expected to

- analyse word problems, solve algebraically for unknowns, and interpret patterns in data (325-2)

Elaborations—Strategies for Learning and Teaching

When students have gained confidence, the teacher might use different symbols to represent familiar quantities. Students should have examples to show that symbols are merely labels, and have meaning only because we define them. Whether displacement is represented by d, s, Δx, or δ, its meaning does not change; Greek symbols are still just symbols.

Problems can be created in a variety of formats. Students could create situations involving friends, public figures, or favourite cartoon characters within which the teacher could insert kinematics problems. It is far more engaging to do a problem involving the principal climbing a flagpole than the traditional "a 5.0 kg body ..." The formulae that students should use include the following:

$$\overrightarrow{v}_{ave} = \frac{\Delta \vec{d}}{\Delta t} = \frac{\vec{v}_F + \vec{v}_2}{2}$$

$$\vec{v}_F = \vec{v}_i + \vec{a}t$$

$$\Delta \vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$v_F^2 = v_i^2 + 2ad$$

Algebraic Problem Solving *(continued)*

Tasks for Instruction and/or Assessment

Journal

- Reflect on your understanding of kinematics now as compared to the beginning of this unit. What evidence do you have to support your understanding? (325-2)

Presentation

- With data collected from your motion trials at the beginning of this unit, make a table of your data and draw *d/t* and *v/t* graphs from this information. Explain what your graphs show. (325-2)

Resources/Notes

Dynamics

Introduction

From real-life experiences, students know that objects speed up, slow down, and change direction, and they accept this as a matter of course. Dynamics is the study of the factors that cause such changes, that is, why an object moves the way it does. It is a logical extension of kinematics, and this unit should pick up with questions arising naturally from the motion of objects studied in the previous unit. Students could begin by investigating the effects of one-dimensional forces on themselves and on objects and, through the application of Newton's laws, move on to an analysis of systems using their knowledge of dynamics.

Focus and Context

As in the kinematics unit, students should draw on their own experiences in attempting to describe and analyse forces. Familiar forces that students feel acting on themselves in cars, on amusement park rides, and during sports activities should be discussed and analysed. A simple activity such as measuring with a spring scale the force needed to start and continue to pull a student along the floor in a wagon or freight dolly can lead to discussion of the outcomes of applied force: acceleration and overcoming friction. Activities with dynamics carts would then allow students to investigate, measure, manipulate, and predict relationships among force, mass, and acceleration. This could lead to many opportunities for individual study and research projects involving the design and operation of such devices as seat belts, airbags, helmets, and sports equipment—all with a view to making connections among the design, principles of physics, and society's concern and influence (an STSE connection).

Science Curriculum Links

This unit completes the study of motion begun in Science 10. It provides student with an opportunity to reinforce their skills in using the graphing calculators. It leads students to the more sophisticated concepts of momentum and energy that are necessary for the study of interactions between masses.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Nature of Science and Technology** 115-3 explain how a major scientific milestone revolutionized thinking in the scientific communities **Relationships between Science and Technology** 116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology 116-5 describe the functioning of domestic and industrial technologies, using scientific principles 116-6 describe and evaluate the design of technological solutions and the way they function, using scientific principles 116-7 analyse natural and technological systems to interpret and explain their structure and dynamics **Social and Environmental Contexts of Science and Technology** 117-2 analyse society's influence on scientific and technological endeavours	*Students will be expected to* **Initiating and Planning** 212-3 design an experiment identifying and controlling major variables 212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **Performing and Recording** 213-2 carry out procedures controlling the major variables and adapting or extending procedures where required 213-3 use instruments effectively and accurately for collecting data **Analysing and Interpreting** 214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots 214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables	*Students will be expected to* 325-5 use vectors to represent force 325-8 apply Newton's laws of motion to explain inertia and the relationships among force, mass, and acceleration

Dynamics Introduction
5 hours

Outcomes

Students will be expected to

- analyse the influence of society on scientific and technological endeavours in dynamics (117-2)
- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- analyse natural and technological systems to interpret and explain their structure and dynamics (116-7)
- use vectors to represent forces (325-5)

Elaborations—Strategies for Learning and Teaching

The focus of this two-page spread is the analysis and interpretation of applied forces using free-body diagrams.

An examination of automobile safety and related STSE issues provides a powerful context to investigate and discuss dynamics. Students should be invited to propose their own questions. For example, students might ask what the advantages and disadvantages are of ABS braking systems, all-wheel drive, or other recent technological advances. These issues could be examined from different perspectives, such as those of the producer, the consumer, and the medical community.

Students should apply more sophisticated concepts to this issue as they progress in the course. In this way, an ongoing focus is maintained. Students could consider other elements of automobile safety besides ABS brakes. They might investigate how these elements function from a physics perspective.

Students could interpret the structure and function of a wide range of systems, such as the human skeleton, spoilers on racing cars, bicycle helmets, the taper of fishing poles, and prosthetic devices. During discussions, students should explore, qualitatively and in terms of forces, questions such as, Why would the bottom vertebrae be bigger than the top? What is the purpose of a spoiler on a race car? What does it do? How does the bicycle helmet spread the force of impact?

Students should investigate the use of vectors and vector diagrams to describe the forces that affect the linear motion of a variety of things, such as airplanes, birds, cars, and boats. The concept of free-body diagrams should be introduced. This analytical tool isolates an object in space and shows vectors representing all forces acting on it. Students should be expected to draw free-body sketches where appropriate for the remainder of the course.

Students should do a laboratory exercise using a block hanging from a spring scale. Students should be able to determine the reading of the spring scale and draw a diagram of the forces acting on the block. Students should look at three situations involving the block: hanging free, being gently supported, and being gently pulled down. They should determine the net force in each case. This will be used later in problem solving. The focus should be on determining the sum of all forces in one-dimensional situations.

Dynamics Introduction

5 hours

Tasks for Instruction and/or Assessment

Performance

- Demonstrate the use of the spring scale appropriately (zeroing and reading). (325-5, 116-6)
- Identify all the forces acting in each of the situations in your lab activity. (325-5)

Journal

- Write an entry in your journal explaining what you have learned about how dynamics concepts apply to automobile safety. This is your opportunity to make personal notes. The journal entry may reflect progress or frustration. It may help you to verbalize your problem(s) to your teacher. (117-2, 116-6)

Paper and Pencil

- Prepare a report that explains a single example of automobile technology that includes the following:
  – the influence of automobile safety on society
  – the design of the example that you pick with respect to the way it functions (117-2, 116-6)

Presentation

- Prepare a short oral presentation from the list of topics generated in class. This is an exploratory exercise. Expectations are that you are questioning, analysing, describing, and/or evaluating the structure using the scientific principles with which you are familiar. Use a KWL chart. (116-7)

KWL Chart

What I know:

____

____

What I want to know:

____

____

What I learned:

____

____

Resources/Notes

(116-6, 116-7)

Textbook resources for these outcomes can be found in Appendix C for the following topic:

- Natural and Technological Systems

Videos

- Safety videos from driver's training programs or personal development and relationships course video list

(325-5)

Textbook resources for this outcome can be found in Appendix C for the following topic:

- Free-Body Diagrams

Labs for this outcome can be found in Appendix C for the following topic:

- Spring Scale

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Newton's Laws

8 hours

Outcomes

Students will be expected to

- apply Newton's laws of motion to explain inertia and the relationships among force, mass, and acceleration (325-8)
- design an experiment identifying and controlling major variables (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- carry out procedures controlling the major variables and adapting or extending procedures where required (213-2)
- use instruments effectively and accurately for collecting data (213-3)
- compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (214-3)

Elaborations—Strategies for Learning and Teaching

Newton's second law is one of the fundamental building blocks of dynamics. It is essential that students have extensive laboratory experiences followed by opportunities to discuss and express in writing their understanding of Newton's second law. Students should do a laboratory investigation of Newton's second law, which explores the relationships among force, mass, and acceleration.

Students could use a device to study motion such as a Hot Wheels™ track. Cars could be accelerated by a push or by gravity. Movement in the track as the car moves is a good indicator of the interaction forces acting along the path. The spring plunger on a dynamics cart could be used as a launcher. A compressible spring used as an end bumper could be used to do energy analysis later. This track could be looped and turned. Cars demonstrate the inertia principle when they leave the track at turns.

Please note that outcomes 212-8, 213-2, 213-3, 214-3, and 214-5 are discussed as a group.

Whatever the method used for Newton's second law experiment, from three-wheel dynamics carts to an air track, good results could be obtained if care is taken in setting up the trials. If rubber bands are used to provide force, they should be pre-stretched and tested for approximately equal elasticity. If the gravitational force on a hung mass is used as a driving method, it is accelerating the *combined* mass that includes the cart and the hung mass. To do trials in which mass is kept constant, the *combined* mass must not change, and mass must be moved from the cart to the hanger to change the driving force. This is an excellent opportunity for students to learn to control variables and minimize errors. During the course of an investigation, student lab groups could be asked to make periodic progress reports and share ideas.

Newton's Laws
8 hours

Tasks for Instruction and/or Assessment

Informal Observation

- A checklist of skills students should develop is appropriate for the teacher to apply here. Possible skills might include using instruments correctly; doing enough trials for a good, average value; and recording the results in an appropriate table. (325-8)

Performance

- Create many situations for the cars and track, and explore them on the track. Keep a list/chart of each situation explored on the track. Include force, mass, acceleration, and general comments. (325-8)
- Conduct a laboratory investigation of the relationships among force, mass, and acceleration. (325-8, 213-2, 213-3)

Journal

- Comment on the following:
  The term "Newton" is merely a convenient shorthand for the actual dimension of inertially defined force. (325-8)

Paper and Pencil

- Write a thorough report on your lab. Analyse and interpret the data in raw form and graphically. From the raw data, it is possible to see whether the relationship is linear or exponential, direct or inverse. Graphs of $a \alpha F$ for trials where mass is kept constant, $a \alpha 1/m$ for trials where applied force is kept constant, and $a \alpha F/m$ for all trials all lead to the equation $a = F/m$. Interpreting the numerical value and the dimensions (unit) of the slope on each graph, you realize that $F = (1)ma$ only if Newtons of force are dimensionally the same as kg*m/s^2. (325-8, 212-3, 212-8, 213-2, 213-3, 214-3, 214-5)
- What force is necessary to accelerate a 1200 kg car along a horizontal surface from rest to 130 km/h in 8.0 s? (325-8)
- What mass would a sled on ice have if it requires a horizontal force of 100.0 N to change its velocity from 30.0 km/h to 120 km/h in 5.0 s? (325-8)
- What is the acceleration of a block having a mass of 0.5 kg that is being pulled in opposite directions by two children? Sean is pulling with a force of 3.0 N to the left, and Diane is pulling to the right with 5.0 N. How far will it move in 3.0 s if these forces combine to be exerted? (325-8)
- What would the tension be in a cable lifting an elevator and a person having a combined mass of 575 kg moving (a) upward at a rate of 5.0 m/s^2 and (b) downward at a rate of 5.0 m/s^2? (325-8)

Resources/Notes

(325-8)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Gravitational Force
- Friction

Activities for this outcome can be found in Appendix C for the following topics:

- Newton's First Law
- Newton's Second Law
- Newton's Third Law
- Friction

Labs for this outcome can be found in Appendix C for the following topics:

- Newton's Second Law
- Newton's Third Law
- Gravitational Force
- Friction

Videos

- *Inertia*
  (Media Services, Learning Resources and Technology)
  22660; 30 minutes
- *The Fundamental Forces*
  (Media Services, Learning Resources and Technology)
  22658; 30 minutes

Newton's Laws *(continued)*

Outcomes

Students will be expected to

- interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables (214-5)
- apply Newton's laws of motion to explain inertia and the relationships among force, mass, and acceleration (325-8)
- analyse and describe examples where knowledge of the dynamics of bodies was enhanced or revised as a result of the invention of a technology (116-2)

Elaborations—Strategies for Learning and Teaching

Students should distinguish between data collection and scientific inquiry. Data collection is a mechanical operation. Data could be collected by computerized systems or directly by a student. The interpretation of the data makes the science. Researchers consult with colleagues on an informal basis. The Internet is a technological development based on the desire to communicate globally. More formal peer review occurs when results are published in a journal and others attempt to duplicate the experiment.

Following the lab, students should be expected to apply Newton's laws to situations where forces are applied horizontally and vertically. Students should learn that weight is the gravitational force.

Over time, students should develop an understanding of the nature of friction and its effect on dynamic systems. They should understand the difference between static friction and dynamic friction.

Students should do an activity in which blocks of wood are pulled across a surface by a spring scale or other device. Students should decide what trials need to be carried out to explore the relationship between the force of kinetic friction and the Normal force, and also between kinetic friction and surface area in contact. Trials must be done in such a manner that the applied force is just great enough to overcome friction and continue the motion of the block without accelerating it. Normal force could be controlled by using blocks of different surface area loaded to the same total mass. Students might want to do some trial and error runs to determine parameters, such as what range of masses can best be moved at a constant low speed. Free-body diagrams should be used for all situations. Students should write down questions for later discussion, for example, what is the net force when the block is moving at constant speed? What is happening as the block is started up and then brought to a stop?

Students should investigate how technology influences science. One example is the telescope, which led to an improved view of the structure of the universe.

Newton's Laws *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Measure various factors that could affect the size of the friction force. These should include Normal force, surface area in contact, and types of surfaces in contact. (325-8)
- Explain/research how the development of high-speed photography has led to a better understanding of the forces involved in automobile collisions. (325-8)

Journal

- Does the speed of an object affect friction? Discuss this. (116-2)
- "The faster you go, the more friction there is." This statement is not true. Explain why. (325-8)

Paper and Pencil

- Write a report on your experimental design, data collection, and data interpretation of the activity you have chosen. (325-8)
- Design a problem that uses Newton's second law. Include an answer sheet. Exchange your problem with that of another student. (325-8)
- Make an original puzzle that includes the following terms and their definitions: acceleration, inertia, applied force, net force, Normal force, static friction, kinetic friction, and coefficient of friction. (325-8)

Presentation

- Write an article for a newspaper weekend edition on your dynamics research involving a technology and changed scientific thinking. (115-3)

Resources/Notes

See *Secondary Science: A Teaching Resource* (1999)

Newton's Laws *(continued)*

Outcomes

Students will be expected to

- explain how a major scientific milestone revolutionized thinking in dynamics (115-3)

Elaborations—Strategies for Learning and Teaching

The video, *Galileo: The Challenge of Reason* is an excellent dramatization of the conflict between codified thought and experimentally verified science. Teachers might want to plan on a second viewing for detailed observation. For later discussion, students should make note of observations or questions that arise during viewing. Some examples include the following: How did Aristotle's view of the universe come to be the only Greek view approved by the seventeenth-century Christian church? What other Greek views had been proposed? Were there African, Oriental, or other theories at that time? What is the apparent role of women in this society? Why were clerics reluctant to accept what they plainly saw demonstrated?

Newton's Laws *(continued)*

Tasks for Instruction and/or Assessment

Journal

- Based on the following scenario, if you were Galileo's friend, how would you help defend him?

  HEADLINE: GALILEO A COPERNICAN!
  DATELINE: ROME

  Officers of the Inquisition have brought the famous scholar Galileo Galilei to Rome for questioning concerning his recent book. With his devil's sceptre, or telescope, as he calls it, he has observed the heavens, in particular, the moon of Jupiter he claims to have seen. He must prove to the Tribunal that what he has written is consistent with the Universal View held by the Holy Roman Church … (115-3)

Presentation

- Research particular milestones individually. Report in small groups. Finally, as a class, assemble a time line from the individual reports. (115-3)
- Draw a cartoon that explains one of the concepts used in dynamics to this point. Be sure that it is simple, specific, and short so the reader can learn from it. (325-8, 116-2, 115-3)
- Present a mock trial of Galileo. (115-3)

Resources/Notes

(115-3)

Textbook resources for this outcome can be found in Appendix C for the following topic:

- Theories of the Universe

Videos

- *Galileo: The Challenge of Reason* (Media Services, Learning Resources and Technology) V2486; 26 minutes
- *Inertia* (Media Services, Learning Resources and Technology) 22660; 30 minutes

Momentum Introduction

2 hours

Outcomes

Students will be expected to

- describe the functioning of technological devices based on principles of momentum (116-5)

Elaborations—Strategies for Learning and Teaching

As students complete their investigations of Newton's second law, teachers should show how the concepts of impulse and momentum are obvious extensions of that law. It may help students to visualize the concept of momentum as Newton did, namely as "quantity of motion." It is important for students to connect their definitions of the new concepts of impulse and momentum with their earlier learning. For example, students might be asked to write showing they understand how impulse and momentum are connected to Newton's second law.

Students might see $F\Delta t = mv_2 - mv_1$ as a more logical expression than $F = m\alpha$ since it isolates the "cause" product at the left and the resulting change in momentum at the right. Newton's "quantity of motion," or momentum, might be more meaningful in this context.

Students should relate these concepts qualitatively to a variety of situations.

Challenging students to find examples involving momentum from daily experience is fun for them and gives students ownership of the task. Some student-generated examples might include the following:

- Why do hockey helmets have rigid foam liners, not soft?
- Why is a gym floor "floating" on a cork layer?
- How are running shoes different from skateboard shoes?
- How does an impact wrench work?
- What happens to a tennis ball during impact?
- How does a 5 km/h bumper on a car work?
- Why is it vitally important that a person be 30.0 cm from an airbag when it inflates? What is it designed to do?

Momentum Introduction
2 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Research one example of a technology of your choice, and prepare an article for publication in a science magazine or your school's science newsletter that explains the application of the principles of impulse and momentum. (116-5)

Resources/Notes

(116-5)

Textbook resources, activities, and labs for this outcome can be found in Appendix C for the following topic:

- Momentum and Impulse

Alternate lab write-ups—See *Secondary Science: A Teaching Resource* (1999)

Momentum and Energy

Introduction

When two or more objects are considered at once, a system is involved. To make sense of what happens between parts of a system, the concepts of momentum and energy are needed. Students have seen many situations where a system of objects is involved. After the students have had a chance to look at the concepts of momentum and energy in familiar contexts, they should apply the concepts to less familiar situations. Students could begin by describing the changes they feel on various playground equipment or amusement park rides and developing an explanation for these changes using the vocabulary and concepts of energy and momentum. Eventually, their understanding of these events will involve the conservation laws, which will allow them to describe, explain, and predict the outcomes of many one-dimensional interactions.

Focus and Context

All students will be familiar with a playground environment. This context provides a wealth of examples of energy transformation and two-body interactions. Other relevant contexts, such as sport, could be used in individual schools. By reviewing their experiences and collecting data, students can begin inquiring and discussing. By examining playground events, students will discover the need to learn the concepts of momentum and energy. There is increasing social concern about playground safety. Students could be expected to pose questions and identify safety concerns by answering such questions as “How high is too high?” or “What material is appropriate?” and to develop a plan to answer their questions. Then they will be able to move from this familiar context to other situations where the concepts can be applied.

Science Curriculum Links

In Physics 12, students should develop a precise understanding of momentum and energy and learn to evaluate situations using these concepts.

Curriculum Outcomes

STSE

Students will be expected to

Nature of Science and Technology

114-9 explain the importance of communicating the results of a scientific or technological endeavour using appropriate language and conventions

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

Relationships between Science and Technology

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

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

Social and Environmental Contexts of Science and Technology

118-8 distinguish between questions that can be answered by science and those that cannot and between problems that can be solved by technology and those that cannot

Skills

Students will be expected to

Initiating and Planning

212-3 design an experiment identifying and controlling major variables

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

Performing and Recording

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

213-3 use instruments accurately for collecting data

Analysing and Interpreting

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

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

214-7 compare theoretical and empirical values and account for discrepancies

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

Knowledge

Students will be expected to

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

325-9 analyse quantitatively the relationships among force, distance, and work

325-10 analyse quantitatively the relationships among work, time, and power

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

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

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

326-7 analyse common energy transformation situations using the work-energy theorem

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

326-8 determine the percentage efficiency of energy transformations

Conservation of Momentum

5 hours

Outcomes

Students will be expected to

- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3)

Elaborations—Strategies for Learning and Teaching

Using dynamics carts, students should carry out trials and collect and interpret data. They should be challenged to predict, observe, and explain what would happen in specific situations with the carts. They should be able to interpret the final conditions of some collisions and describe the initial conditions. Teachers could facilitate student analysis by asking questions such as "What evidence do you have to support your statement?"

The following situations could be set up:

- moving cart A hits stationary identical cart B and sticks
- moving cart A hits stationary heavier cart B and sticks
- moving cart A hits stationary identical cart B and they separate
- moving cart A hits stationary heavier cart B and they separate
- moving heavier cart A hits stationary cart B and they separate
- moving cart A hits identical cart B moving head on at the same speed

Where possible, masses should be kept to simple multiples so that patterns in the data are more apparent. A sonic ranger probe and software could be used to collect data. If an air track or table is available, it could be used to determine values more precisely, but some investigation with dynamics carts gives students a more realistic experience.

It might be possible to arrange for one of the police crash investigators to be a guest speaker. He/she could provide a realistic context for this study.

Students might get a better grasp of momentum conservation if they simulate a variety of situations in slow motion.

As an optional extension, students could determine both final velocities for one-dimensional collisions by the method of simultaneous equations.

Conservation of Momentum
5 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct a collision analysis lab. (326-3)

Journal

- Write down your observations and questions that you have regarding the use of dynamics carts. Organize them. How does writing your observations help your understanding of your collision lab? (326-3)

Paper and Pencil

- Write a report of your collision analysis lab. You are expected to look for patterns in your raw data. For example, you can investigate how Δv is related to mass ratio. Account for the difference in total momentum from trial to trial. You should describe, in detail, the nature of the interaction during the collision as the plunger compresses and rebounds and relate this observation to other interactions such as billiard balls and automobiles. Some discussion of error (less than 100% conservation of momentum) is expected. (326-3)

Resources/Notes

(326-3)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Conservation of Momentum
- Collisions
- Helmets, Running Shoes, and Air Bags

Activities for this outcome can be found in Appendix C for the following topic:

- Skateboard (Momentum)

Labs for this outcome can be found in Appendix C for the following topic:

- Conservation of Momentum

Videos

- Safety videos from driver's training programs or personal development and relationships course video list

Call your local detachment of the RCMP or police for a presentation on the physics of traffic accidents.

Work, Power, and Efficiency
5 hours

Outcomes

Students will be expected to

- analyse quantitatively the relationships among force, distance, and work (325-9)
- analyse quantitatively the relationships among work, time, and power (325-10)
- design and carry out an experiment to determine the efficiency of various machines (212-3, 213-2, 213-3, 214-7)

Elaborations—Strategies for Learning and Teaching

At the end of this five hours, students should have clear and distinct definitions of force, work, energy, and power. They should be able to distinguish between the concepts clearly in writing and they should be able to apply the concepts to problem-solving situations.

Students should be asked to design and carry out an investigation in which they measure the force, distance, and time, and calculate the work and power. Situations to examine should include lifting a dynamics cart 1.0 m, pushing the dynamics cart 1.0 m horizontally, and pushing it up a ramp to a height of 1.0 m. As an optional extension, students could calculate the efficiency of the ramp (the ratio of $W_{lifting}: W_{rolling}$).

Students might benefit from an in-class demonstration lab involving simple machines. The class could design the trials in a teacher-led discussion, and student groups could conduct trials on several machines simultaneously. Hardware or automotive stores stock an inexpensive block and tackle system that could be suspended from the ceiling for large mass trials.

Work, Power, and Efficiency
5 hours

Tasks for Instruction and/or Assessment

Informal Observation

- While trials involving the dynamics carts are being conducted, individual student participation can be monitored. (325-9, 325-10)

Journal

- Referring to the data collected, describe how force, distance, and work are related. Give an analysis with an explanation of your understanding of the situation. (325-9)

Paper and Pencil

- As a written record of the dynamics cart exploration, submit work sheets that include neat sketches, data, and calculations for each of the three situations from your lab activity. (325-10)
- A locomotive exerts a constant forward force of 5.4×10^4 N while pulling a train at a constant speed of 25 m/s for 1.0 h. How much work does the locomotive do? What average power did the locomotive generate while pulling the train? (325-10)

Presentation

- In groups of three to four, demonstrate and discuss your experiment on the machine you chose. Decide on your presentation format. An explanation of your data, procedure, and the efficiency of your machine should be included. (212-3, 213-2, 213-3, 214-7)

Resources/Notes

(325-9, 325-10)

Textbook resources and activities for these outcomes can be found in Appendix C for the following topics:

- Work
- Power

Labs for these outcomes can be found in Appendix C for the following topics:

- Power
- Energy

(212-3, 213-2, 213-3, 214-7)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- Efficiency of Machines
- Efficiency of Pulleys

See *Secondary Science: A Teaching Resource* (1999)

Transformation, Total Energy, and Conservation

15 hours

Outcomes

Students will be expected to

- analyse quantitatively the relationships among mass, speed, kinetic energy, and heat using the law of conservation of energy (326-1)
- describe quantitatively mechanical energy as the sum of kinetic and potential energies (326-5)
- compare empirical and theoretical values of total energy and account for discrepancies (214-7)
- analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept (326-6)

Elaborations—Strategies for Learning and Teaching

Note: *On the next pages, all three outcomes are treated simultaneously.*

During work on these outcomes, students should

- define gravitational potential, elastic potential, and kinetic energies
- relate energy transformations to work done
- discuss ways in which energy leaves the system such as kinetic energy, temperature, and heat
- solve problems using the law of conservation of energy including changes in gravitational potential energy, elastic potential energy, and kinetic energy
- explain the role of friction and the loss of mechanical energy from a system

As with momentum, after students are familiar with the basic concepts, teachers could help students apply algebraical deduction. Students should see the algebraic genesis of the concepts from a cause/effect perspective. Teachers could talk about the concepts by using the following information. "Work" is the name given to the product of force and displacement. Since more work is done if a larger force acts, or if the same force acts through a larger distance, the $F\Delta d$ product is a "cause." What is the "effect"? From kinematics,

$$v_f^2 = v_i^2 + 2a\Delta d$$

rearranging:

$$2a\Delta d = v_2^2 - v_1^2$$

but $F = ma$, so

$$\vec{a} = \frac{\vec{F}}{m}$$

$$2\left(\frac{\vec{F}}{m}\right)\Delta\vec{d} = v_f^2 - v_1^2$$

and

$$\vec{F}\Delta\vec{d} = \frac{mv_{2f}^2}{2} - \frac{mv_i^2}{2}$$

$F\Delta d$ is work, but what is on the right side? This changes an initial value at v_1 to a final value at v_2. This "$mv^2/2$" represents kinetic energy, which has a different value at each velocity. Students need convincing that saying "$mv^2/2$" can be represented by E, or $K.E.$, or E_K or any other symbol and that this is no different from saying mass can be represented by m. Energy is a quantity with a compound unit but it is still a single quantity.

Dimensionally, work is $N{\cdot}m$. Energy is kg m^2/s^2

$N{\cdot}m$ = (kg·m/s^2) (m) = kg m^2/s^2

For convenience, both are called "joules," which is the unit for all forms of energy.

Transformation, Total Energy, and Conservation
15 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct your lab and write a report and results so that you can present them to a grade 7, 8, or 9 class.
(326-1, 326-5, 214-7, 326-6)
- Design and conduct an experiment to demonstrate an energy transformation and account for discrepancies. For example, you could release a block at the top of a ramp, and, using available technology, determine the velocity at several points, including the bottom. You could compare theoretical kinetic energy values to the actual values and account for any differences.
(326-1, 326-5, 214-7, 326-6)

Journal

- Write a note explaining momentum, energy, and their transformations so a grade 8 student could understand them.
(326-1)

Resources/Notes

(326-1, 326-5)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- Mechanical Energy
- Potential Energy
- Kinetic Energy
- Conservation of Energy

Activities and labs for these outcomes can be found in Appendix C for the following topic:

- Conservation of Energy

Transformation, Total Energy, and Conservation *(continued)*

Outcomes

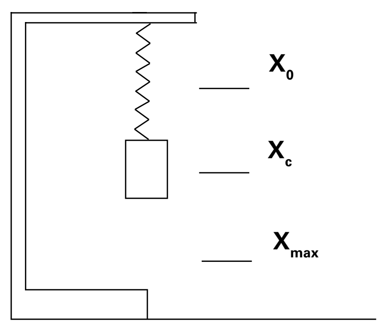
Students will be expected to

- analyse quantitatively the relationships among mass, speed, and thermal energy, using the law of conservation of energy (326-1)
- describe quantitatively mechanical energy as the sum of kinetic and potential energies (326-5)
- compare empirical and theoretical values of total energy and account for discrepancies (214-7)

Elaborations—Strategies for Learning and Teaching

Some students follow the logic of algebraic deduction intuitively. Those who do not may need explanatory detail. Every substitution or rearrangement might be a potential roadblock. Even so, all students need experience with deductive reasoning of this type.

Students should investigate the force/stretch relationship for springs (Hooke's law) and related energy changes when a mass oscillates at the end of spring. Using a spring placed horizontally and a spring scale, students could investigate how much force is required to stretch the spring to various distances. A graph of force versus distance can lead to recognition of work done as the spring is stretched. The spring might be hung vertically with a mass attached that holds the spring stretched to something less than half the elastic limit of the spring, as in the following diagram:



At the rest position, X_c, the change in length of the spring ($X_c – X_0$) is equal to the height of the mass above the bottom-most point, X_{max}, ($X_c – X_{max}$) if the mass had been dropped from a height where the spring is completely unstretched, X_0. ($X_{max} – X_c = X_c – X_0$). If the mass is released at this highest point, it will oscillate up and down for some time before coming to rest at the middle position. Students should determine velocities at various positions. This is an ideal time to use a position sensor and computer software to generate a complete set of kinematics data. This could lead students to such questions as the following:

- What effect would changing the mass have?
- How does the kinetic energy change during an oscillation?
- What happens if a spring with a different constant force is used?

Transformation, Total Energy, and Conservation *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Conduct your lab and write a report. (326-1, 326-5, 214-7)

Resources/Notes

Transformation, Total Energy, and Conservation *(continued)*

Outcomes

Students will be expected to

- analyse quantitatively the relationships among mass, speed, and thermal energy, using the law of conservation of energy (326-1)
- describe quantitatively mechanical energy as the sum of kinetic and potential energies (326-5)
- compare empirical and theoretical values of total energy and account for discrepancies (214-7)
- analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept (326-6)

Elaborations—Strategies for Learning and Teaching

As the bobbing mass is allowed to come to rest, students could be challenged to determine where the "lost" energy has gone. For example, students could discuss whether any energy transformed to thermal energy. Students will not detect a temperature change in the spring as one might after pounding a nail. Students should be able to calculate the work done to stretch the spring to a particular position, the gravitational potential energy, and the velocity at that point.

Students should construct a graph of energy versus stretch for a drop from X_0 to X_{max}, and back to X_0 on which curves are plotted for spring potential energy and gravitational potential energy. If students add energy values at selected positions, they might plot a curve for total stored energy that has a "clothesline" shape. The apparent energy deficit towards the X_c position is a good point from which to collect data. When a total energy line is drawn from maximum gravitational energy to maximum spring energy (a straight line), students discover that the vertical difference between the total energy line and the total *potential* line at any position is just equal to the kinetic energy of the mass at that point.

Transformation, Total Energy, and Conservation *(continued)*

Tasks for Instruction and/or Assessment

Performance Challenge

When a nail is hammered into a piece of wood, energy is lost in a variety of ways. There is obvious noise, friction, and heating of the nail. This is a practical example of multiple transfers of energy. In your group, decide on a similar demonstration you will present to class that shows multiple energy losses, especially hidden ones. They can be simple examples such as rolling a pencil rapidly between your hands, or video or large scale examples such as a carnival ride or construction equipment. You will challenge your classmates to identify the kinds of energy transfer taking place in your example. (326-6)

Resources/Notes

Transformation, Total Energy, and Conservation *(continued)*

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students have developed confidence in kinematics tools for solving motion problems in a straight line. In achieving this outcome, students should come to appreciate energy solutions for vertical motions whether in a straight line or not, and even for relatively complex motions such as oscillations, in which net acceleration is constantly changing.

A good initial problem would be to complete the following table for a 2.0 kg mass dropped from a height of 1.0 m.

Energies of a Falling Mass

h (m)	*t* (s)	*v* (m/s)	E_k (J)	E_g (J)
1.0				
0.8				
0.5				
0.3				
0				

Could you determine the velocity at 0.4 m using energy concepts only?

Transformation, Total Energy, and Conservation *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- An average force of 8.0 N is applied to a 1.2 kg dynamics cart that is initially at rest. If the force is maintained for a distance of 0.80 m, what velocity will the cart attain? If the force is maintained over a distance of 1.6 m, what speed is reached? What is the ratio of the two velocities? Explain in terms of work and energy why this is so. Compared to the first trial, what could you change to give the cart twice the speed? (326-6)
- Kristen is playing on a swing. At her highest swing, the seat is 3.2 m above the rest position. What speed does she have as she passes through the lowest position? (326-6)
- A pole vaulter wants to clear the bar at a height of 7.0 m above the mat. What vertical speed must he/she have to just clear the bar? What role does the pole play in the pole vault? (326-6)
- A 65 kg boy runs at a constant speed of 6.0 m/s. He jumps on a stationary 35 kg freight dolly so that his feet stay in one position and the combined mass (boy + dolly) moves off at a new speed. Assume that the dolly wheels are frictionless. (326-1, 326-5, 214-7, 326-6)
  – What final velocity will the combined mass have?
  – What impulse acted on the dolly? On the boy?
  – Was energy conserved in this interaction?
  – If the best estimate of the time of interaction is 0.20 seconds, what force acted on the dolly?
  – What acceleration did the boy experience?
- When analysing a problem, how do you decide whether to use kinematics, momentum, or energy concepts to solve for unknowns? (326-6)
- What is meant by each of the following? (326-6)

$$W = \Delta E$$

$$E_K = mv^2/2$$

$$E_g = mgh$$

$$E_S = \frac{1}{2}kx^2$$

Presentation

- Present a song, poem, speech, or short story to your classmates that involves the following terms: work, kinetic energy, gravitational potential energy, spring potential energy, and efficiency. Your presentation should show a clear understanding of the relationships between the terms and momentum and energy. (326-1, 326-6)

Resources/Notes

Transformation, Total Energy, and Conservation *(continued)*

Outcomes

Students will be expected to

- analyse common energy transformation situations using the closed system work-energy theorem (326-7)

Elaborations—Strategies for Learning and Teaching

Students should question and investigate other transformational situations, such as wind-up toys, playground equipment like swings and slides, or hydro-electric generators.

In any closed system, work done is equal to change in energy. This equivalence is known as the work-energy theorem. This term is just beginning to appear in textbooks. Students should do an inclined plane investigation of work and energy as a lab activity. A block or Hall's carriage (for less friction) could be pulled slowly up a board ramp placed at various angles from the horizontal to the same vertical height. A spring scale pulling parallel to the plane could be used to determine the required force at each angle. The work done along the ramp could be compared to the gravitational potential energy the block has at the top.

After constructing meaning from hands-on experiences, students could use computer simulation software for additional practice or modelling of other situations.

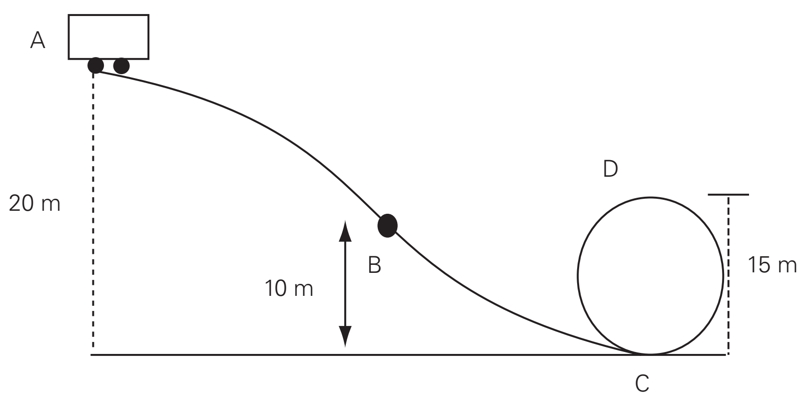
Students should also solve algebraic problems involving energy transformations.

Transformation, Total Energy, and Conservation *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- A golf ball of mass 50.0 g is hit by a golf club at a speed of 35 m/s. If the effective mass of the club head is 0.32 kg and the collision is totally elastic, what velocity will the ball have just after the impact? (326-7)
- After referring to the diagram below, answer the following questions:
  - How much gravitational potential energy does the roller coaster car have at position A if the loaded mass is 1100 kg?
  - What is the maximum kinetic energy the car could have at B?
  - What speed would it have at B?
  - What speed would the car have at position D? (326-7)



- Write up your inclined plane activity in a lab report format. (326-7)
- A 2.4 kg dynamics cart moving at 1.5 m/s undergoes an in-line elastic collision with another stationary cart of the same mass. What will the velocity of the stationary cart be after impact? (326-7)
- A "superball" is dropped from a height of 1.5 m onto a hard floor and bounces back up to virtually the same height. Describe completely the energy changes undergone by the ball from the time it is released until the time it reaches maximum rebound height. In particular, account for the changes that occur while the ball is in contact with the floor. (326-7)

Presentation

- Based on your investigations of toys and other transformation situations, develop a poster or other visual display that illustrates the work-energy theorem. (326-7)

Resources/Notes

(326-7, 326-8)

Textbook resources for these outcomes can be found in Appendix C for the following topic:

- Hydro-electric Energy

Student-directed research on roller coasters and rockets

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Transformation, Total Energy, and Conservation *(continued)*

Outcomes

Students will be expected to

- analyse and describe examples where technological solutions were developed based on scientific understanding (116-4)
- determine the percentage efficiency of energy transformation (326-8)

Elaborations—Strategies for Learning and Teaching

Students should analyse an example of a technological solutions based an understanding of energy concepts. Typical examples include the development of airbags for motor vehicles and ABS braking systems. Students could also investigate design changes in launch vehicles such as rockets since the space program began and the relationship to payload.

Using Hot Wheels™ tracks and cars, students could construct a mini roller coaster. A car could be released at the top of an incline and allowed to go up a second slope. The height of the second "hill" could be adjusted until the car can no longer reach the top with $v = 0$. Strobe photography or photogates could be used to determine velocity at various positions. The setup could also be modelled with computer software.

The transfer of energy from gravitational potential to kinetic and back to potential could be studied, taking into account energy transferred to heat through friction. Students could determine the coefficient of friction as well as the percentage efficiency of the transformation from beginning to end.

Transformation, Total Energy, and Conservation *(continued)*

Tasks for Instruction and/or Assessment

Journal

- While technological solutions may generate new science, such as in the development of Teflon™ in the space program, airbags are a case in which technology used existing scientific knowledge. Explain this. (116-4)

Paper and Pencil

- Write a report on your selected technological example. Your report should clearly demonstrate the development of a technological solution based on *existing* scientific knowledge. Be sure to clarify the relationship of technology to science. (116-4)

Presentation

- Working in groups of two to four, prepare a report for the makers of Hot Wheels™ offering the results of your investigation(s) and recommendations for modifications to the toy. (326-8)

Resources/Notes

Transformation, Total Energy, and Conservation *(continued)*

Outcomes

Students will be expected to

- design an experiment, select and use appropriate tools, carry out procedures, compile and organize data, and interpret patterns in the data to answer a question posed regarding the conservation of energy (212-3, 212-8, 213-2, 214-3, 214-5, 214-11, 326-4)

Elaborations—Strategies for Learning and Teaching

Students should investigate the energy transformation, elasticity, and efficiency involved when inflatable balls are filled to different pressures. A pump with pressure gauge is required, and care must be taken if pressure exceeds the normal recommended inflation. A volleyball is a good choice, but it could be done with an inflatable beach ball. A graph of rebound height versus pressure could be generated to answer questions such as the following:

- Is there a mathematical relationship with an equation?
- Is there a best inflation based on end-use criteria?
- Is it possible to determine an acceptable range of pressures for a given percentage efficiency?

Teachers could consider this a long-term project with separate times for the design phase, the experimental phase, and the reporting phase.

- distinguish between problems that can be solved by the application of physics-related technologies and those that cannot (118-8)

One possible context that students should recognize is that injury prevention in passenger cars is possible with technological solutions, whereas the goal of eliminating car accidents involves human behaviour that cannot be technologically controlled. Convenient, comfortable seat belts have had a positive impact on belt usage. When studying broad issues such as highway safety, students should learn to analyse the problem, categorizing those elements that technology could address, and those elements related to the human factor.

- determine which laws of conservation, momentum, and energy are best used to analyse and solve particular real-life problems in elastic and inelastic interactions (326-4)

Based on investigations students have previously conducted, they should develop operational definitions of elastic and inelastic collisions. Teachers should discuss with students that an elastic event is one in which all of the energy present in the system at the beginning is also present at the end. All other events are considered inelastic. Students should be challenged to decide which conservation law is most useful in explaining the operation of systems of two or more objects. Students should analyse various situations such as those involving golf clubs, tennis racquets, a pile driver, or a jackhammer. Teachers could help discussions with questions such as the following:

- What is “wrong” with an under-inflated basketball?
- Would an “ideal” system be 100 percent elastic?
- In which situations is an elastic collision preferable?
- Are there situations where a 100 percent elastic collision is not desirable?

Transformation, Total Energy, and Conservation *(continued)*

Tasks for Instruction and/or Assessment

Informal Observation

- Using a scale, the teacher can observe students as they conduct the investigation selected for this outcome. (212-3, 213-4, 214-16)
- While groups present their debates about physics-related technologies and the class discusses the situations (see presentation below), the teacher may apply a rubric for assessment. (326-4)

Performance

- Conduct your lab on transformation, total energy, and conservation, and write a lab report on your experiment. Include your data collected, analysis, information, conclusion(s), and a graph. (212-3, 212-8, 213-2, 214-3, 214-5, 214-11)

Paper and Pencil

- Write a scientific abstract about your experiment design, results, and interpretations. (212-3, 212-8, 213-2, 214-3, 214-5, 214-11)
- Write a letter to an editor presenting the scientific elements and the social implications surrounding a relevant issue, e.g., airbags, bicycle helmets, seat-belt use. (118-8)

Presentation

- In groups, debate a problem. Can it be solved by the application of physics-related technologies or not? Some examples include the following:
  - Be it resolved that all major highways in the Atlantic region be twinned.
  - Be it resolved that manufacturers be required to build vehicles which protect occupants from serious injury in all types of collisions up to a speed of 60.0 km/h. **Note:** *Students may not be aware that vans and sport utility vehicles do not have to meet the same standards of safety as passenger cars.* (118-8)

Resources/Notes

(326-4)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Elastic Collisions
- Inelastic Collisions

Labs for this outcome can be found in Appendix C for the following topic:

- Collisions

Videos

- Safety videos from driver's training programs or personal development and relationships course video list

Call your local detachment of the RCMP or police for a presentation on the physics of traffic accidents.

Lab write-ups—See *Secondary Science: A Teaching Resource* (1999)

Technological Implications
5 hours

Outcomes

Students will be expected to

- analyse and describe examples where energy- and momentum-related technologies were developed and improved over time (115-5, 116-4)
- describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum (116-6)
- explain the importance of using appropriate language and conventions when describing events related to momentum and energy (114-9)

Elaborations—Strategies for Learning and Teaching

Students should use principles of energy and momentum to describe and explain the operation and improvement of various technological items. The items should include a range from the most inelastic ones, such as steel toes in boots, crumple zones in cars, and other safety equipment, to those behaving in a most elastic way, such as baseball bats or dent-resistant polymer panels used in some car doors and fenders.

Students should be able to apply the principles of dynamics to the investigation of real-world problems. One context for such an investigation would be the technology of running shoes. Students should investigate the elastic nature of various component parts of running shoe soles by cutting cross sections and separating the layers. Then, by dropping ball bearings on each layer and measuring the rebound height, they could compare how various layers and materials behave and whether they absorb (inelastic) or return (elastic) energy.

Students might use the differences in the sizes of tennis racquets that enlarge the “sweet spot” as another example. By dropping a new tennis ball in various locations on a rigidly mounted racquet and measuring the rebound height, students could analyse a variety of variables, such as head area, tension, and string material.

Students could bring in various samples of protective headgear, such as construction hard hats, bicycle helmets, football helmets, and motorcycle helmets. Their design and operation could be analysed based on principles of energy conservation and transformation and momentum conservation and transfer. Students should determine criteria by which these devices can then be evaluated. Students could record in their log the data from tests they conduct, come to a tentative conclusion, and report the results to the class.

Students should be able to demonstrate the use of appropriate language and conventions. The importance of “knowing your audience” should be stressed.

Technological Implications
5 hours

Tasks for Instruction and/or Assessment

Performance

- Research the application of technology in a specific sport, and then debate how to enhance performance by modifying the equipment. Apply relevant physics concepts in your debate. An example might be as follows:
  - Be it resolved that aluminum baseball bats should be permitted in professional baseball. (115-5, 116-4, 116-6, 114-9)

Journal

- "One billiard ball collides with a stationary ball. The first ball stops while the second moves away with the same velocity as the original ball." Explain what happens in this interaction using the concepts of momentum and energy. (115-5, 116-6)

Presentation

- The Parent Teacher Organization (PTO) of your local elementary school has asked your team of three members to participate in a safety assessment of their playground. Select one piece of playground apparatus. Do a momentum and energy analysis and make recommendations as to what modifications should be made to the apparatus. As a consultants' group, you must prepare an audio-visual presentation to the PTO. (114-9, 116-6, 115-5, 116-4)

Resources/Notes

Waves

Introduction

Everyone has seen waves in many forms, such as water waves hitting a beach, standing waves in telephone lines, and travelling waves in a skipping rope. Students should observe, predict, and explain specific wave behaviours, such as reflection, refraction, and diffraction. Students could begin their study of waves with familiar mechanical waves, extend their study to sound waves, and then use wave principles that they have developed to explain and predict the behaviour of light and other electromagnetic waves. Students should be encouraged to develop their vocabulary and working definitions of wave terminology from their own experiences and from directed activities in class. Through various investigations, they should recognize that any periodic disturbance creates a wave and that the disturbance transmits energy (and therefore information) from one place to another. Familiar activities with Slinkies™ and ripple tanks would allow students to observe, predict, and explain specific wave behaviours, such as reflection, refraction, and diffraction.

Focus and Context

Problem-solving activities should be linked with STSE connections in various activities. Examples could include resonance and earthquakes or the quest for energy. For example, in considering offshore exploration for oil and gas, students must assess risk and benefit.

Because the study of waves is so broad, students have many opportunities to research and investigate different topics—musical instruments, optics, communications systems, electronics, medical imaging, non-destructive testing, and sound pollution, to suggest just a few. As they move from phenomena that can be observed directly, such as mechanical and water waves, to those less directly observable, such as sound and EM waves, students should be challenged to make inferences based on wave phenomena. They should increasingly recognize the power of physics in general, and wave concepts in particular, to convey information and permit exploration where the unaided human senses fail. The range of tools used to make indirect observations is vast—from simple hand lenses to compound microscopes to scanning electron microscopes, from radio telescopes to MRI, CAT, and PET scanning technology. However, in all scientific and technological endeavours, the tools to extend our senses were developed using the concepts and principles of physics.

Science Curriculum Links

In grade 8, students studied optics in relation to their scientific properties, their use in technological devices, and their relationship to society. Physics 12 continues wave theory with the relationship between potential and kinetic energies of a mass in simple harmonic motion and the properties of electromagnetic radiation and sound.

Curriculum Outcomes

STSE

Students will be expected to

Nature of Science and Technology

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

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

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

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology

Skills

Students will be expected to

Initiating and Planning

212-4 design an experiment identifying and controlling major variables

212-7 formulate operational definitions of major variables

Performing and Recording

213-1 implement appropriate sampling procedures

213-7 select and integrate information from various print and electronic sources or from several parts of the same source

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

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

Knowledge

Students will be expected to

327-1 describe the characteristics of longitudinal and transverse waves

327-2 apply the wave equation to explain and predict the behaviour of waves

327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour

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

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Fundamental Properties

12 hours

Outcomes

Students will be expected to

- describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves (327-1)
- formulate operational definitions of major variables (212-7)

Elaborations—Strategies for Learning and Teaching

Disturbances in a medium create pulses and waves, and these transfer energy. The students should use their understanding of energy and its analysis in systems to examine how waves are produced and interact. Through a variety of experiences with waves on springs and ripple tanks, students should develop operational definitions that might be refined or expanded as the study of waves continues. To begin, long helical springs and Slinkies™ are ideal for observing large, slow pulses.

Teachers should be mindful of the treatment of particle and wave theories of light in Physics 12. It might be wise to reflect on how particles move and to make comparisons with wave behaviours as they are explored. Some teachers might wish to follow a sequence in which students explore behaviour first and theories of light afterward. The roles of theorizing and modelling are an integral part of the scientific process, and this is an excellent opportunity to follow the development of physics over more than two centuries.

In completing this outcome, students should be able to describe the following: mechanical wave, electromagnetic wave, longitudinal wave, transverse wave, pulse, amplitude, period, frequency, wavelength, speed, phase, interference, and superposition. Students should be provided with extensive experience diagramming wave phenomena.

Students should be able to solve problems involving period, wavelength, frequency, and speed, using the universal wave equation $v = f\lambda$.

Fundamental Properties

12 hours

Tasks for Instruction and/or Assessment

Informal Observation

- Observe students demonstrating and making measurements of the characteristics of waves and experimentally verifying the universal wave equation. (327-1, 212-7)

Performance

- Demonstrate using a Slinky™ and diagrams of two waves in a phase and two waves completely out of phase. (327-1, 212-7)
- Sketch examples of constructive and destructive interference. (327-1, 212-7)

Paper and Pencil

- Distinguish between the period and frequency of a wave. (327-1, 212-7)
- Which property of a wave is a measure of the energy in the wave? Use the work-energy theorem to explain your answer. (327-1, 212-7)
- An oscillator vibrates the end of a spring at a frequency of 10.0 Hz. The distance between adjacent crests in the wave pattern formed is 1.50 m. What is the speed of the wave? (327-1)
- Two waves are created from opposite ends of a 10.0 m long spring. The wave from end A has an amplitude of 50.0 cm to the left of the relaxed position and a frequency of 5.00 Hz. The wave from end B has an amplitude of 30.0 cm on the opposite side of the spring and a frequency of 10.0 Hz.
  – What will the spring look like when the lead pulses meet? Draw a sketch.
  – Can you predict at what point on the spring the two pulses meet? (327-1)
- How is a longitudinal wave different from a transverse wave? Give a common example of each. (327-1)
- Describe how energy can be transmitted by wave action. (327-1)

Resources/Notes

(327-1, 212-7)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- Wave Characteristics and Behaviours
- Transverse Waves
- Longitudinal Waves

Activities and labs for these outcomes can be found in Appendix C for the following topic:

- Making Waves

Fundamental Properties *(continued)*

Outcomes

Students will be expected to

- select and integrate information from various print and electronic sources (213-7)
- analyse, from a variety of perspectives, the risks and benefits to society and to the environment when applying scientific knowledge or introducing a particular technology (118-2)
- analyse natural and technological systems to interpret their structure and dynamics (116-7)
- analyse society's influence on scientific and technological endeavours (117-2)

- construct and test a prototype of a device and troubleshoot problems as they arise (214-14)

Elaborations—Strategies for Learning and Teaching

Students should research the application of the wave to a specific technology such as supersonic aircraft. They could identify problems related to wave theory that have kept the technology from becoming more commonplace, even though the Concorde has been flying for more than 20 years. The medical applications of ultrasound make another excellent topic. Students could research this technology from the points of view of energy efficiency, cost effectiveness, product safety, potential health hazards, and other criteria the students might suggest.

Students could research the design and construction of the Confederation Bridge between New Brunswick and Prince Edward Island. They could develop a set of questions for further investigation such as the following:

- What unique component designs and construction techniques were involved in the project?
- What wave phenomena were anticipated by the designers?
- How does the bridge meet these criteria?
- What competing social pressures had to be considered by the planners?

Students should discuss and analyse society's influence on the natural and technological example they have researched.

Students could design and build a device to measure and record the maximum amplitude of periodic waves in springs. Students could suggest possibilities before doing their design. Construction and testing could be done at various times throughout the unit. Students could document the time, trials, and tasks that led them to their finished product.

Fundamental Properties *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Demonstrate to the class your invented device and explain its effectiveness. (214-4)

Paper and Pencil

- Simulate the writing process for a weekend newspaper feature article by one student in each group acting as features editor, setting deadlines for research, draft copies, and final version. Responsibilities should be divided. Publish this article in your school's newspaper. Suggestions may include the following:
  – resonance in bridges or buildings
  – impact of sound in your daily life
  – musical instruments such as brass and wind
  – sonar in ships (116-7, 117-2)

Presentation

- Give an oral presentation on the technology you researched. Use visuals effectively in your presentation. (213-7, 118-2)

Resources/Notes

(116-7)

Textbook resources for this outcome can be found in Appendix C for the following topic:

- Waves and Technology

Research project on Confederation Bridge (Internet and various other media)

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Fundamental Properties *(continued)*

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students might use technologies already mentioned or they might suggest ultrasound, radar, or any other relevant context. There have been several attempts (particularly in Great Britain) to develop technologies to gain energy from wave motion. At least one Canadian attempt has been made. Students should investigate why and how wave energy has been harnessed in the past and what possibilities exist for the near future. A time line might be helpful to see the development of the technology.

- apply the universal wave equation to explain and predict the behaviour of waves (327-2)
- implement appropriate sampling procedures and evaluate the relevance, reliability, and adequacy of data and data collection methods in wave experiments (213-1, 214-8)

Using a Slinky™, students should create a standing wave and collect data to enable them to calculate speed. The frequency should be determined by counting and timing a number of oscillations; the wavelength can be determined by direct measurement (the distance between crests is half the wavelength) and speed calculated. By creating different standing patterns and repeating measurements, students could verify that the wave speed in the medium is constant. The teacher might wish to do this as a demonstration with half the class at a time. Several tables placed end to end could be used to do trials with a Slinky™. A helix could be used vertically. The spring will sag in the middle, but it will not affect the wavelength or frequency measurements.

- apply the laws of reflection and the laws of refraction to predict wave behaviour (327-7)
- state a prediction and a hypothesis about wave behaviour based on available evidence and background information (212-4)

Based on their experiences, students should be asked to predict and draw sketches to represent what reflection, refraction, and standing waves would look like on a ripple tank. Students might work in groups where each group tries a different perspective on waves. Then students could report their findings to the class. Similarly, students should be asked to predict how destructive resonance causes large structure damage during an earthquake.

Fundamental Properties *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Prepare a written report about the wave-related technology you researched. (115-5)
- Create a “Help Wanted” notice advertising for a person to work in a wave-related employment field. Your notice will be part of a classroom bulletin board display. (115-5)
- Record observations, both sketches and data, and draw conclusions from a wave activity that you have completed. (327-2, 213-1, 214-8)
- Explain how engineers must take resonance into account when building large structures. (327-7)

Presentation

- Prepare a presentation of your technology using PowerPoint or similar technology. (115-5)

Resources/Notes

(327-2)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Standing Waves
- Reflection and Refraction
- Geology Connections

Labs for this outcome can be found in Appendix C for the following topic:

- Ripple Tank

Sound Waves and Electromagnetic Radiation

15 hours

Outcomes

Students will be expected to

- apply the laws of reflection and the laws of refraction to predict wave behaviour (327-7)
- explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect (327-8)

Elaborations—Strategies for Learning and Teaching

During students' investigations of these outcomes, they should be encouraged to go back and forth from a ripple tank to light behaviour. Wave front activity is shown by ripple tanks, while rays are investigated for light. Students should draw idealized sketches of water wave reflection and refraction and indicate on them how a ray diagram is related.

The properties of light could be investigated in a series of group activities. Questions students might wish to address are "Do wave diagrams and ray diagrams of reflection predict similar results?" and "Can a virtual source be located when circular waves are reflected from a straight barrier?"

Students should investigate the refraction of light and look for a relation between incident angle and refracted angle. An investigation using a variety of liquids in semicircular plastic containers could be conducted by pairs of students to develop Snell's law and the formula

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

This should be followed by the study of relative index and critical angle.

Students should solve a variety of problems using Snell's law as well as water and light interference. Students should define and use the terminology associated with waves: reflected ray, refracted ray, normal, angle of incidence, angle of reflection, angle of refraction, principal axes, principal focus, and nodes and nodal lines. Students should describe and give examples of reflection, refraction, index of refraction, relative index, critical angle, total internal reflection, diffraction, scattering, interference, and the Doppler effect.

Given the index of refraction, students should draw accurate diagrams for a ray of light passing through a variety of materials.

Students should conduct investigations on wave interference. These should include interference of light (Young's experiment). Teachers might wish to do a numerical investigation of water wave interference on a ripple tank before doing Young's experiment.

A ray-optics study of image formation with plane mirrors, curved mirrors, and lenses is *not* required for this outcome.

Sound Waves and Electromagnetic Radiation
15 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct Young's experiment. Make a chart of your results. (327-8, 327-7)

Paper and Pencil

- Submit a written report on a Snell's law investigation. (327-8, 327-7)
- Write a memo on Young's experiment from his point of view. Explain, with references to your data, how the experiment makes it impossible to dismiss the wave nature of light from Young's time onward. (327-8, 327-7)
- Write a short report that summarizes your experiences with light and waves. Refer to both the particle and wave models in explaining what you have seen and experienced to this point in the unit on waves. (327-8, 327-7)

Presentation

- Create a display that shows the relationship between a ray diagram and a wave-front diagram for a specific situation, such as circular reflections from a straight barrier. (327-8, 327-7)

Resources/Notes

(327-7, 327-8)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- The Doppler Effect
- Shock and Bow Waves
- Reflection and Refraction
- Young's Experiment
- Diffraction of Light
- Young's Double Slit Experiment

Labs for these outcomes can be found in Appendix C for the following topics:

- Ripple Tank
- Refraction of Light
- Snell's Law
- Young's Experiment
- Young's Double Slit Experiment

See *Secondary Science: A Teaching Resource* (1999)

Sound Waves and Electromagnetic Radiation *(continued)*

Outcomes

Students will be expected to

- apply the laws of reflection and the laws of refraction to predict wave behaviour (327-7)
- explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect (327-8)

Elaborations—Strategies for Learning and Teaching

The study of diffraction and interference should begin on the ripple tank. Students should observe that if a small slit or opening $< \lambda$ is set up, a diffraction pattern is created which resembles a circular pattern from a point source. Faint lines fanning out from the slit should suggest superposition, which is occurring because the pattern is really a composite of two edge patterns. When two slits are set up several wavelengths apart, a classic interference pattern is created that is similar to the pattern created by bobbing two fingers simultaneously in the water. This observation is central to the rationale of Young's experiment.

The experiment could be duplicated with commercially available slitfilms and a monofilament bulb or by projection using a laser. Homemade viewers could be made by drawing two sharp blades across a painted or soot-covered microscope slide. Besides linking interference of waves and the behaviour of light, this experiment gives students a real situation in which significant figures are useful. Measurements are made with a metre stick and are used to calculate a value in the order of 10^{-7} m. Problem solving should be done using the following formula:

$$\lambda = \Delta x(d)/L$$

where Δx is average spacing of the maxima or minima, d is the spacing of the slits, and L is the distance from the source to the pattern.

Sound Waves and Electromagnetic Radiation *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Given the index of refraction, draw accurate diagrams for a ray of light passing through a variety of materials. (327-8, 327-7)

Journal

- Combine your observations on the ripple tank with a ray-tracing experiment. What does this mean in terms of waves? Does it make sense logically? Why or why not? Do you need other information? (327-8, 327-7)
- Write a short story about the life of a wave. (327-8, 327-7)
- Draw a physics cartoon about a ray. Include information on incident ray, reflected ray, refracted ray, normal, angle of incidence, angle of reflection, and angle of refraction. (327-8, 327-7)

Presentation

- In groups of two to three students, create a crossword puzzle, a word search, or other puzzle activity of the terms and explanations associated with waves. Include an answer sheet. Trade your puzzle(s) with that of another group to see if you can do each other's puzzle. Some terms to consider include incident ray, reflected ray, refracted ray, normal, angle of incidence, angle of reflection, angle of refraction, and nodes and nodal lines. (327-8, 327-7)
- Do a multimedia presentation on waves. Describe and give examples of reflection, refraction, index of refraction, relative index, critical angle, total internal reflection, diffraction, scattering, interference, and Doppler-Fizeau effect. (327-8, 327-7)

Resources/Notes

Sound Waves and Electromagnetic Radiation *(continued)*

Outcomes

Students will be expected to

- compare and describe the properties of electromagnetic radiation and sound (327-5)
- describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted (327-6)

Elaborations—Strategies for Learning and Teaching

During work on these outcomes, students should

- describe how sound is produced and transmitted
- list the factors on which the speed of sound depends
- explain the phenomenon of beats
- produce beats (physically) using two sources of slightly different frequency
- explain how standing waves are produced in closed and open pipes
- make use of the phenomenon of resonance in pipes to experimentally determine the speed of sound in air
- explain the phenomenon of the sonic boom, describe the problems it causes, and explain how such problems can be minimized

The discussion of electromagnetic waves will be covered in more detail in Physics 12. One possible context for this section might be the study of communications technology, which has Canadian connections from the invention of the telephone to the design of communication satellites.

After listening to a series of common sounds, students should be asked to comment on the cause and nature of the sound. Students should conduct an investigation on the speed of sound. Students should explore the properties that are used to distinguish sounds. Characteristics such as pitch, intensity, tone, and harmonics could be investigated. Tuning forks, sonometers, keyboards, amplifiers, oscilloscopes, and computer software with appropriate probes could be used to investigate the frequency, wavelength, amplitude, and harmonic complexity of waveforms. A simple interference pattern could be created with tuning forks creating a beat frequency. A student could demonstrate how this is used to tune a guitar or violin. Two loudspeakers producing the same pure tone could be used to set up a two-point source interference pattern large enough to walk through. For example, two sources producing tones of frequency 256 Hz placed 4.0 m apart will produce a good pattern. On a line parallel to the speaker plane three metres away from the sources, nodes will be spaced about 1 metre apart. It is even possible to make reasonable measurements on the interference pattern and determine the wavelength of the sound source.

Students could be encouraged to ask questions such as “How can the sound of a specific instrument be synthesized?” and “Why are digitally coded signals, such as in CDs and digital phones, superior to analogue systems such as cassette tapes and cellular phones?”

Wave properties such as reflection, refraction, diffraction, and interference should be examined for both sound and light. For example, what characteristic of sound compares to colour for light? Resonant air columns could be used to investigate the speed of sound in air. Resonance and coupling could be examined with mounted tuning forks. Resonance of specific strings could be seen in a piano or on a guitar. Students could be involved in demonstrating how instruments control sound quality by selective resonance.

Sound Waves and Electromagnetic Radiation *(continued)*

Tasks for Instruction and/or Assessment

Performance

- Conduct a lab to determine the speed of sound using close-tube resonance. (327-5, 327-6)
- Using a set of mounted resonance turning forks, try to produce beat frequencies of five beats per second and the ten beats per second. Try to duplicate this effect with small-sized pop bottles filled with water to slightly different heights. (327-5, 327-6)

Journal

- Describe how sound is produced, giving an example of each in nature and technology. Describe how sound is transmitted. List the factors on which the speed of sound depends. (327-5, 327-6)
- In your journal, explain how a particular musical instrument makes use of resonance to produce its characteristic sound. (327-5, 327-6)

Paper and Pencil

- Explain the phenomenon of the Doppler-Fizeau effect and give examples. (327-5, 327-6)
- Explain the phenomenon of the sonic boom, describe the problems it causes, and how such problems can be minimized. (327-5, 327-6)
- Explain how standing waves are produced in closed and open pipes. (327-5, 327-6)

Presentation

- Compare and contrast properties of electromagnetic radiation and sound. (327-5, 327-6)

Resources/Notes

(327-5, 327-6)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- Speed of Sound
- Transmission of Sound
- Reflection, Refraction, and Interference
- Beat Frequency and Vibrating Strings
- Resonance
- Speed of Light
- CD and Videodisc

Activities for these outcomes can be found in Appendix C for the following topic:

- Sound and Vibrations

Labs for these outcomes can be found in Appendix C for the following topics:

- Speed of Sound
- Sound Waves and Beats
- Resonance
- Interference of Sound Waves

Sound Waves and Electromagnetic Radiation *(continued)*

Outcomes

Students will be expected to

- analyse and describe examples where scientific understanding was enhanced as a result of the invention of a technological device (116-2)

Elaborations—Strategies for Learning and Teaching

Students should relate their understanding of resonance to situations in everyday life. The teacher could pose questions such as, "How is resonance involved in the destructive force of earthquakes?" Most have probably seen a car with weak shocks go over small bumps and bounce wildly. Possibly some students could videotape a wheel balancing machine in operation at a tire store and present it to the class. What examples of "good" and "bad" resonance can students identify? Students could prepare lengths of two-inch diameter PVC pipe to study open and closed tube resonance in a laboratory setting. Does light resonate in a similar way, resulting in "amplified" light?

Students could ask questions such as, "What has been learned about waves through the use of ultrasound technology in medicine?" Students could research how a device such as the ultrasound transponder, the microwave magnetron, or the seismograph helped scientists expand their knowledge of wave behaviour. Students should analyse an example with reference to its technology and talk about their understanding of the example.

Sound Waves and Electromagnetic Radiation *(continued)*

Tasks for Instruction and/or Assessment

Journal

- Reflect on the wave principle's influence in your everyday life. (116-2)
- Are there any uncertainties in the explanations of the behaviour of waves and light? (116-2)
- Will other applications of waves be possible with new technology? Will other questions be investigated? How do you feel this will affect science? (116-2)

Presentation

- Prepare presentations to report on your research. Include discussion on how technology has solved a practical problem. What influence did society's needs and interests have on the research of the device? Who has responsibility for the science used in technology? (116-2)

Resources/Notes

(116-2)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Medical Applications
- Geology Connections

Tacoma Narrows Bridge Disaster (Internet or video)

Physics 12 Outcomes

Force, Motion, Work, and Energy

Introduction

From the first intelligent musings of the human species came questions that are answered in this unit. A rock falls or is thrown; the sun, moon, and stars move about in the heavens; a bird flies; fire consumes. Early civilizations explained the mysteries of the natural world with spiritual answers. By the Greco-Roman era, mathematics had advanced and more worldly theories were proposed.

But it was the Renaissance and the Galilean method of doing science that began the classical period in physical science. Concepts of force, momentum, and energy; precise observations of orbital motions; and a mathematical system to handle rates of change led to explanations that satisfy all ordinary experiences.

Focus and Context

At the beginning of the twenty-first century, we still live in a Newtonian world. Students should relate their study of mechanics to everyday occurrences. They should come to understand that the engineered world in which we live is built on the principles of classical physics. From skateboards to space shuttles, the cause and effect of motion are understood and applied. Activities and investigations of everyday events that are generated by class discussion should be encouraged. Students should have many opportunities to express their understanding of physics concepts, both verbally and in writing.

Science Curriculum Links

The study of motion was begun in Science 10, and expanded in Physics 11 to include wave motion as well as the movement of solid objects. Students will use their ability to describe motion to move on to an understanding of the forces that *cause* motion. They will then apply this knowledge to interactions between objects. This is the conceptual framework on which students can build a wider understanding in post-secondary science studies.

Curriculum Outcomes

STSE

Students will be expected to

Nature of Science and Technology

115-1 distinguish between scientific questions and technological problems

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

Relationships between Science and Technology

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

Social and Environmental Contexts of Science and Technology

117-2 analyse society's influence on scientific and technological endeavours

Skills

Students will be expected to

Initiating and Planning

212-1 identify questions to investigate that arise from practical problems and issues

212-3 design an experiment identifying and controlling major variables

Analysing and Interpreting

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

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

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

Communication and Teamwork

215-2 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

213-5 compile and organize data, using data tables and graphs, to facilitate interpretation of the data

Knowledge

Students will be expected to

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

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

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

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

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

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

325-5 use vectors to represent force

327-2 apply the wave equation to explain and predict the behaviour of waves

327-4 explain quantitatively the relationship between potential and kinetic energies of a mass in simple harmonic motion

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Dynamics Extension
10 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Outcome ACP-1 is intended to extend the concepts and skills acquired in Physics 11 in one-dimensional situations to applications requiring two-dimensional analysis. The sample list below is the minimum requirement to meet outcome ACP-1. Dynamics extension topics include

- systems involving two or more masses including horizontal situations, inclined planes, and the Atwood machine
- relative motion such as navigation problems
- static equilibrium applications such as clotheslines and cranes
- static torques applications such as the seesaw and bridge supports

As an opening discussion of two-dimensional motions, students could explore the movement of chess pieces, especially the knight. From this starting point, students could develop a list of two-dimensional motions that they have experienced. Carnival rides are a rich source of two-dimensional situations.

Students should be able to resolve a vector into its right-angled components, add vectors at right angles, and add multiple vectors using the sum of the components method. Some teachers might elect to do the sine law/cosine law method as an optional mathematical extension.

Using Newton's laws of motion, and the concepts of weight and Normal force, students should apply free body analysis using thumbnail sketches in all cases.

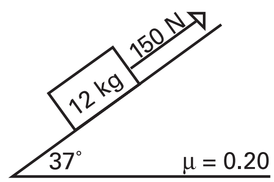
Dynamics Extension

10 hours

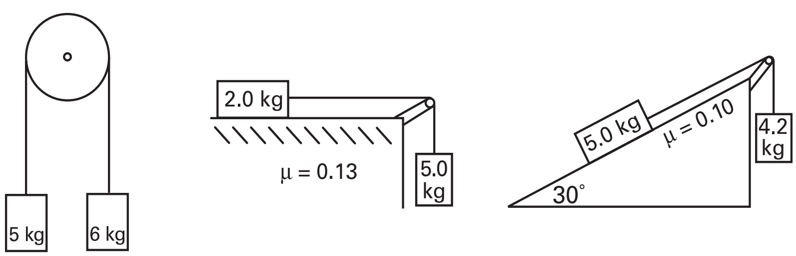
Tasks for Instruction and/or Assessment

Paper and Pencil

- What is the resultant displacement if Elizabeth walks 420 m west and then 650 m north? (ACP-1)
- An archer shoots an arrow at 120 m/s at a 60° angle from the horizontal. Determine the initial horizontal and vertical components of the velocity. (ACP-1)
- Three dogs are pulling a sled. The middle dog pulls with a force of 7×10^2 N along the centre line of the sled. The dog on the left pulls with a force of 900. N at an angle of 20° from the centre line, and the other dog pulls with a 600. N force at 30° from the centre line. What is the net force pulling on the sled? This problem could be done by scaled diagram as well as by the "sum of components" algebraic method. (ACP-1)
- Examine the diagram and answer the following questions:
  – What acceleration will result?
  – What applied force would be required to result in an acceleration of 3.0 m/s^2? (ACP-1)



- Determine the acceleration of the 5.0 kg mass in each of the following situations. (ACP-1)



- Nadia tries to paddle her canoe directly across a river. She keeps the canoe pointed straight across and maintains a speed of 12 km/h. The river is flowing from her left to her right at 5. 0 km/h. What is the resulting velocity of the canoe? (ACP-1)
- Pat and Ahmed are playing on a 4 m long seesaw that is supported at the centre. If Pat has a mass of 30 kg and sits at *t*=one end of the seesaw, where should Ahmed (mass = 35 kg) sit so that the seesaw balances? (ACP-1)

Presentation

- Make a short oral presentation providing a free-body analysis of your favourite carnival ride. (ACP-1)

Resources/Notes

ACP-1

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Vector Components
- Systems Involving Two or More Masses—Horizontal
- Systems Involving Two or More Masses—Atwood's Machine
- Relative Motion
- Static Equilibrium
- Torques

Activities for this outcome can be found in Appendix C for the following topics:

- Vector Components
- Torques

Labs for this outcome can be found in Appendix C for the following topics:

- Vector Components
- Systems Involving Two or More Masses—Incline Plane
- Systems Involving Two or More Masses—Atwood's Machine
- Static Equilibrium
- Torques

Dynamics Extension *(continued)*

Outcomes

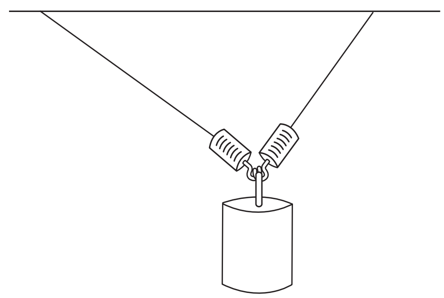
Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students should have a laboratory experience with static equilibrium using a force board or other suitable apparatus.

A hanging mass apparatus could be constructed using two spring scales supporting an unknown mass. Each spring scale should be attached by a string (unequal lengths) to a horizontal support rod. By measuring appropriate angles and performing vector calculation, the unknown mass can be determined.



Dynamics Extension *(continued)*

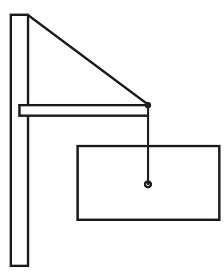
Tasks for Instruction and/or Assessment

Journal

- Keep a journal throughout this course. This is a place to write personal reflections as you progress. This is also a good place to record things you need to clarify so that you can look back at a later date and ensure your problem is resolved. The journal should include a new entry at least every week. Your first entry could be to distinguish between net forces that cause motion and situations in which all forces are in static equilibrium. (ACP-1)

Paper and Pencil

- Prepare a written report of your experiment about static equilibrium. (ACP-1)
- A 1.5×10^3 kg car is crossing a flat bridge, 120 m long, which is supported at both ends. When the car is 32 m from one end, what force must each end support be able to provide? (ACP-1)
- Determine the tension in the cable and the compression force in the boom to support the 1.0×10^2 kg boom. The angle between the boom and the supporting cable is 37° C. (ACP-1)



Resources/Notes

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Collisions in Two Dimensions

8 hours

Outcomes

Students will be expected to

- apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions (326-3)
- determine in which real-life situations involving elastic and inelastic interactions the laws of conservation of momentum and energy are best used (326-4)

Elaborations—Strategies for Learning and Teaching

In presenting these outcomes to students, teachers should not move to algebraic solutions too quickly. Students need the experience of manipulating momentum vectors in order to truly understand what is happening when vectors are added. When vectors are broken down into components prematurely, students do not have the opportunity to visualize the actual addition process. When drawing scaled diagrams, they are working with the actual vectors and tend to understand the concept more completely.

Students have already seen that in one-dimensional interactions the law of conservation of momentum always applies and the law of conservation of energy applies only to those special cases in which total elasticity is demonstrated. The collisions between billiard balls are close to translationally elastic when one ignores rotation. The force of separation is very nearly the same as the force of interaction at corresponding positions. No physical deformation is permanently visible, although some small amount of energy must leave the system as heat and sound.

On the other hand, when two vehicles collide, they often remain stuck together after impact or separate only minimally, and very little, if any, energy of motion remains after impact. Crash test dummies are designed to measure and record the forces and velocities experienced by various parts of the dummy's body during a collision. Some students might be able to create a short video showing a variety of billiard shots, or demonstrate a computer pool program.

From observing these examples, students could move to the study of more idealized collisions using a rolling ball two-dimensional collision apparatus or an air table if one is available. In either case, students should conduct investigations at a glancing angle with equal masses, with a piece of masking tape on the target ball in the same situation, and with unequal masses. They should measure displacements, calculate velocities, and create scaled momentum diagrams for each collision. A scaled momentum diagram includes a drawing done to reasonable scale representing each initial momentum, the total momentum before impact, each final momentum, and the total momentum after impact. It should clearly show how the separate momenta are added to determine total momentum before and after. This should be done either using the tip-to-tail method or the parallelogram method. Total kinetic energy before and after should be compared.

Collisions in Two Dimensions

8 hours

Tasks for Instruction and/or Assessment

Performance

- Using Interactive Physics create a two-dimensional elastic collision involving equal masses and a glancing collision. Using appropriate tools in the program, carry out a vector analysis using velocities to show conservation of momentum. As an extension, analyse the kinetic energies of the masses before and after the collision. Different combinations of masses could be analysed. As well, the elasticity could be changed if desired. (326-3)
- Two streets intersect at a 40.0° C angle. Car A has a mass of 1500 kg and is travelling 50.0 km/h. Car B has a mass of 1250 kg and is travelling 60.0 km/h. If they collide in the intersection and remain stuck together, what will be the velocity of the combined mass immediately after impact? (326-4)

Pencil and Paper

- Prepare a written report for this investigation. (326-3)
- A collision between two vehicles occurs at a right-angled intersection. Vehicle A is a car of mass 1800 kg, travelling at 65 km/h north. Vehicle B is a delivery truck of mass 3500 kg, initially travelling east at 45 km/h. If the two vehicles remain stuck together after the impact, what will be the velocity (speed and direction) of the combined mass after impact? (326-4)
- A collision investigator is called to the scene of an accident where two small cars collided at a right-angled intersection. From skid marks, the investigation determined that car A, mass 1400 kg, was travelling 55 km/h west before impact. The two vehicles remained stuck together after impact, and the investigator was able to calculate from the distance they moved after impact that velocity after impact was 12 km/h at a bearing of 330°. What was the mass of the other car? (326-4)

Resources/Notes

(326-3, 326-4)

Textbook resources and labs for these outcomes can be found in Appendix C for the following topics:

- Laws of Conservation of Momentum
- Elastic and Inelastic

Video

- *Conservation of Momentum* (Media Services, Learning Resources and Technology) 22656; 30 minutes

Projectiles
8 hours

Outcomes

Students will be expected to

- construct, test, and evaluate a device or system on the basis of developed criteria (214-14, 214-16)
- analyse quantitatively the horizontal and vertical motion of a projectile (325-6)

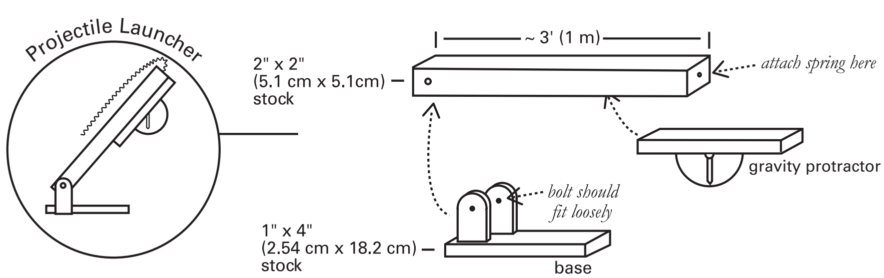
Elaborations—Strategies for Learning and Teaching

Students should undertake an exploratory activity with simple equipment. They could be given the challenge of building a device that would launch marbles from the edge of a table to land in a cup placed at various positions on the floor. They could use materials such as a grooved ruler, a piece of cove moulding, or a curtain track as a launcher. They could then conduct trials to calibrate the launcher for distance from the table. When they are confident they can predict the outcome, the teacher could place a paper cup randomly on the floor to test their accuracy. Students should be monitored to see if they control release position on the launcher and repeat trials when calibrating.

Another activity students could undertake would be to walk at a steady pace and drop small objects into a cup. They could explore the effect of changing walking speed.

Students should conduct a more formal laboratory investigation of projectile motion using a suitable apparatus in which they predict the path of a horizontal projectile using independent horizontal and vertical calculations. The predicted path can be verified by creating a scaled diagram of the predicted path, making an overhead transparency, and projecting it to life size against a wall.

Students (or the teacher) could construct a projectile launcher as diagrammed below. A hole can be drilled in the muzzle end so that a wire spring can be hooked at the end and stretched a measured length along the barrel. A spring with a force constant of about 30 N/m is ideal. It is easy to calculate spring energies at various stretch positions and the spring velocity if the spring is pulled back to a marked position and released, since virtually all spring energy is converted to kinetic energy $\frac{1}{2}kx^2 = \frac{1}{2}mv^2$.



Projectiles
8 hours

Tasks for Instruction and/or Assessment

Teacher Observation

- Since this is an exploratory activity, students should be assessed on their participation and engagement. (214-14, 214-16)

Paper and Pencil

- A written lab report should be presented on the investigation of projectile motion. (325-6)
- A projectile is launched at a muzzle velocity of 20.0 m/s at an angle of 57° from the horizontal. Determine the position, horizontally and vertically, from the launch point at 1.5 s. Determine the instantaneous velocity at 1.5 s. At what later time would the *speed* be the same? (325-6)
- A trained dog can jump forward at an angle of 37° to the horizontal and with a speed of 3.5 m/s. Where should the trainer hold a hoop so the dog passes through it at his highest point (how far horizontally from the dog's initial position, and how high)? What would be different if the dog jumped from one platform to another each 2.0 m high? (325-6)
- A human cannonball is setting up his act in a new big top. The highest point of the roof of the tent is 12 m from the ground. His "cannon" launches him at an angle of 45° from horizontal. What is the maximum muzzle velocity he can have so as not to punch a hole in the tent roof? (325-6)
- A daredevil stunt driver is planning a scene for a movie. She must drive a car horizontally off the roof of a tall building and crash into a window 8.0 m lower in the next building, which is a horizontal distance of 15 m away. Can you help her determine what speed she must have as she reaches the edge of the higher roof? (325-6)

Resources/Notes

(214-14, 214-16, 325-6)

Textbook resources, activities, and labs for these outcomes can be found in Appendix C.

Video

- *Motion: Newton's 3 Laws* (Media Services, Learning Resources and Technology) V2210; 18 minutes

Projectiles *(continued)*

Outcomes

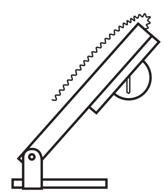
Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

From Physics 11, students should know how to calculate the muzzle velocity. Once muzzle velocity is determined, students should determine horizontal and vertical components of position and velocity at 0.1 s intervals, as well as the magnitude and direction of the instantaneous velocity. Most classrooms have a usable ceiling of 2.0 m, so values should be calculated until a vertical drop greater than 2.0 m occurs. If a mark is placed on the wall 2.0 m from the floor, the launcher can be positioned for a horizontal launch. The spring will follow a path projected to full scale against the wall. Also, a target, such as a book on the floor or a chalk brush on the ledge, can be hit for effect.

Suppose the muzzle velocity is 5.0 m/s. To calculate the position at 0.3 s, the student must use the initial vertical position of 2.0 m.



Vertical: $d_2 = d_1 + v_y t + \frac{1}{2}at^2$

$d_2 = 2\text{ m} + 0 = \frac{1}{2}(-9.8\text{m/s}^2)(0.3\text{s})^2$

$d_2 = 2\text{ m} - 0.441\text{ m} = 1.56\text{ m}$

Horizontal: $d_2 = d_1 + v_x t + \frac{1}{2}at^2$

$d_2 = 0 + 5\text{ m/s}(0.3\text{ s}) + 0$

$d_2 = 1.5\text{ m}$

Projectiles *(continued)*

Tasks for Instruction and/or Assessment

Performance

- We have studied projectile motion and, as a result, have developed some equations which can be used to predict maximum height and range.

  It is the range that we are concerned with today. Your group will be given the following: one metre stick, one large elastic band, one large metal washer (projectile), and a 10.0 m measuring tape.

  Your task is to determine the necessary angle and stretch to launch the projectile from a fixed launch point to the target, which will be 5.00 m away (horizontally) from the launch point. You are going to use your metre stick as your launcher. You will need to determine the launch velocity of your washer when the elastic is stretched to a certain length. You will need to shoot the washer with different stretches to do this. The only permitted trials before your launch to the target are either straight up with a certain stretch or horizontally with a certain stretch. You cannot use repeated trial and error launches at different angles and stretches until you hit the target.

  Once you have what you believe to be the proper angle and stretch, let your teacher know, and you will be placed on the list for actually launching towards a target previously set up. You will be given three trials in which to try and succeed.

  At the end of the challenge your group will be asked to write up the method used to determine the initial velocity of the washer as well as showing the calculations that support the angle and the stretch that you decided to use for your actual trials. (325-6)

Resources/Notes

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Projectiles *(continued)*

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

A similar approach can be taken with launches at any angle. The launcher can be modified as shown in the diagram (on pages 98 and 100) by adding a gravity protractor, or attaching a protractor scale to the rear of the base so it is visible from the front.

Students should also draw in velocity vectors to scale at each 0.1 s and show the graphical addition of the components. If the instantaneous velocities at two different times are subtracted, a Δv value can be determined, which is directed vertically down. It is important that students have the opportunity to draw this diagram in order to visualize how the force of gravity affects both the magnitude and direction of the velocity. This will reinforce the concept that acceleration is a vector quanitity and no simple algebraic operation can give the desired result.

Since $a=\frac{\Delta v}{\Delta t}$, the acceleration can be determined to be gravitational.

This is particularly engaging when one uses one point on the "down" side and a point earlier in time on the "up" side of a non-horizontal projectile.

As an optional extension, the teacher might want to develop special formulae for total time in air, maximum height, and range. It could be shown that these are developed for convenience but are not necessary for the complete analysis of the projectile path.

The teacher might also want to collaborate with the math teacher to compare these expressions with the equation for quadratic functions.

Programmable/graphic calculators would also be useful in this study, as would a computer simulation program such as Interactive Physics.

Projectiles *(continued)*

Tasks for Instruction and/or Assessment

Teacher Information for Performance Assessment on p. 101

This lab information for a projectile activity uses a washer and an elastic to attempt to hit a target.

The elastic is passed through the hole in the washer and looped through itself to result in a washer with an elastic attached. Have the students launch the projectile by securing the open loop of the elastic to the end of the metre stick and stretching the elastic back to some launch position. Use a chalkboard protractor to measure the angle between the floor and the metre stick when they are ready to launch.

Use either a garbage can or a pizza box as the target, giving the groups points for either getting the projectile in the can, or hitting the pizza box, in one of their three launches. The use of the larger target allows for some error in the stretch and angle, and the students can still succeed in the challenge. Avoid using too big a target.

Bonus points can be assigned for hitting the target: +5 for hitting target on the first try, +3 for hitting the target on the second try, and +2 for hitting the target on the third try. No bonus points if they miss on all three tries.

Some care must be taken to make sure that the target is at the same level as the projectile when it is released from the metre stick (unless you want to have the students factor in hitting a target higher or lower than the launch level). Have the students stand well away from the launcher when the projectile is launched at any time. It is a good idea to make the students wear eye protection whenever they are stretching the elastic to launch the projectile. It may be helpful to have one of the group stand behind the target to make sure that the metre stick launcher is aimed at the target. Students often miss not because of range, but because they were shooting left or right of the target.

Extension

- The range for a level-to-level projectile is given by: $\frac{v^2 \sin 2\theta}{g}$.

  Prove that the maximum range for a given muzzle velocity will occur at a launch angle of 45°. (325-6)

Resources/Notes

Circular Motion
8 hours

Outcomes

Students will be expected to

- describe uniform circular motion using algebraic and vector analysis (325-12)
- explain quantitatively circular motion using Newton's laws (325-13)

Elaborations—Strategies for Learning and Teaching

Students have considerable experience with circular motion. The playground carousel, bicycle wheels, the Ferris wheel, and their knowledge of orbital motion have all contributed to a practical sense of circular motions. What happens to passengers when a car takes a turn very fast? Or more precisely, does the car pull into the passengers, or do they slam into the side of the car?

Two students could do a demonstration, with one student standing in one position but free to rotate and the second holding on by one hand and at right angles to the first student. If the outer student tries to move straight ahead, and maintains the right-angled orientation, a circular path should result. The result may be more visible if a short cord (about a metre) is used to separate the two students. Other students could be asked to show on the board or overhead the orientation and relationship between centripetal force and velocity.

Students should move from a discussion of familiar experiences to a more analytical examination. Teachers should point out to students that the following progression in concept development has occurred. First, linear motions were studied in which a force changes only the magnitude of an object's velocity. Second, in the study of projectiles, students learned that a force can change both the magnitude and direction of a velocity. Finally, in the case of circular motion, students saw that a force applied at a right angle to a velocity changes only the direction of motion. This is a very abstract concept. It is difficult to accept that a force can result in a change in direction only.

The traditional centripetal force experiment involving weights being swung in circular motion while held in place by a suspended mass should be done at this point as a teacher demonstration. This ensures safety and the proper technique required to operate the sling apparatus. Students can measure and record data. Through discussion, students could suggest ways to control variables during trials. The relationship of frequency to velocity should be developed. The students should be able to verify that

$F_c \alpha \mathrm{m}$, $F_c \alpha v^2$, $F_c \alpha \frac{1}{r}$ and develop the formulae $F_c = \frac{mv^2}{r} = \frac{4\pi^2 mr}{T^2}$

Circular Motion

8 hours

Tasks for Instruction and/or Assessment

Journal

- Look around your environment for situations that involve circular motion. Reflect and comment on three examples. (325-13)

Paper and Pencil

- Prepare a written lab report on the centripetal force experiment/ demonstration. (325-12)
- In a Celtic field event called the hammer throw, a 12 kg ball is whirled in a circle of radius 2.0 m with a frequency of 1.5 Hz. What is the velocity when it is released? What is the centripetal force? (325-13)
- How can a motion with constant speed be an accelerated motion? (325-13)
- Suppose a plane flies in a circular path of circumference 20.0 km at a speed of 200.0 km/h. What is the change in velocity in one quarter of a revolution? What is the change in velocity in half a revolution? (325-13)
- If centripetal acceleration is given by the expression v^2/r, prove that the dimensions are correct for acceleration. (325-13)
- If the speed of an object in circular motion is doubled, what effect will this have on the centripetal force? (325-13)
- How fast must a plane fly in a loop-the-loop stunt of radius 2.0 km if the pilot experiences no force from either the seat or the safety harness when he is at the top of the loop? To be considered "weightless," all forces on the pilot must be in balance, or the gravitational force must be entirely used up in providing the centripetal force. (325-13)
- The radius of the earth is 6.4×10^6 m. A new satellite is required to orbit just above the earth's surface. (a) What would the period of rotation be? (b) What is the orbital speed of the satellite? (c) What launch energy would be required if the mass of the satellite were 2.0×10^3 kg? (325-13)
- Due to the rotation of the earth, an object has less apparent weight at the equator than at the North Pole. (Some of the gravitational force is used to maintain the circular path on the surface of the earth.)
  - What does a 100.0 kg person weigh at the north pole?
  - What does the same person weigh at the equator? (325-13)
- A string used to make a pendulum has a breaking strength of 12.0 N and a length of 0.80 m. A 1.00 kg mass is used as a bob and set in motion.
  - If the bob moves with a speed of 1.00 m/s at the bottom of the swing, will the string break?
  - What is the critical speed (the highest speed at the bottom of the arc so that the string does not break)?
  - What is the maximum release height so that the string does not break? (325-13)

Resources/Notes

(325-12, 325-13)

Textbook resources, activities, and labs for these outcomes can be found in Appendix C.

Simple Harmonic Motion (SHM)

4 hours

Outcomes

Students will be expected to

- identify questions, analyse, compile, and display evidence and information to investigate the development over time of a practical problem, issue, or technology (212-3, 214-3, 115-5)
- explain qualitatively the relationship between displacement, velocity, time, and acceleration for simple harmonic motion (327-2)
- explain quantitatively the relationship between potential and kinetic energies of a mass in simple harmonic motion (327-4)
- compile and organize data, using data tables and graphs, to facilitate interpretation of the data (213-5)

Elaborations—Strategies for Learning and Teaching

There are numerous life experiences to which students could relate in the exploration of simple harmonic motion (SHM). All suspension bridges have as part of their design a flexibility that is an inherent advantage. As a result, the normal movement of traffic causes the bridge deck to bounce vertically, and the bridge is easily able to ride out any wind forces it might experience. The torsional harmonic buildup in the Tacoma bridge is still an impressive sight. From this perspective, students should be asked to bring up related experiences such as water beds, pendulums, skyscraper damper floors, automobile suspension, or other topics.

Students have recently completed the circular motion topic. Teachers should present a vector analysis of SHM in terms of a one-plane analogy of the circle. This avoids the need for calculus solutions and integrates knowledge of the circle, vector analysis, energy analysis, and Hooke's law.

In Physics 11, a laboratory investigation of energy changes of a mass oscillating on a string was done and students explained, in writing, the relationship among kinetic energy, gravitational potential energy, and spring potential energy. Teachers should supply sample data and graphs from this lab to the students for a brief review discussion.

In this new investigation, students should explore the relationships among position, velocity, and acceleration (force) during the oscillation. This could be accomplished if students generate graphs for each variable against time. Students should develop the formula for the period of an oscillating mass in this system with a vertically mounted spring and load mass. New data could be generated or data from a previous experiment could be used. Physics simulation software allows students to manipulate masses and spring force constants to explore how the variables relate.

Teachers should show students that a pendulum is another example of simple harmonic motion. Students should see the similarity between the expressions for the period of an oscillating mass and the period of a pendulum. Students should solve problems relating to the period of harmonic motion using the following formulae:

$$T = 2\pi\sqrt{\frac{\ell}{g}}$$

$$T = 2\pi\sqrt{\frac{m}{k}}$$

At this time, there is no need to consider damped or coupled situations.

Simple Harmonic Motion (SHM)

4 hours

Tasks for Instruction and/or Assessment

Journal

- "Force and spring stretch are always in opposite directions." Explain this statement using diagrams. (327-2)

Paper and Pencil

- A 5.00 x 10^2 g mass is attached to a vertical spring of force constant 40.0 N/m.
  - How far below the bottom of the empty spring will the rest position of the mass be?
  - If the mass is lifted about halfway, what period of oscillation will result?
  - Determine the gravitational potential energy, the spring potential energy, and the kinetic energy at the centre of oscillation if the mass is released from the empty spring position. (327-2, 327-4)
- A 0.60 kg mass is vibrating at the end of spring on a frictionless horizontal surface. If the spring constant is 26 N/m and the maximum displacement (end to end) of the mass is 0.15 m, what is the speed of the object at its equilibrium position? (327-2, 327-4)
- A 0.40 kg mass vibrates at the end of a horizontal spring on a frictional surface, reaching a maximum speed of 0.50 m/s. If the maximum displacement is 0.11 m, what is the spring constant? (327-2, 327-4)
- An earthling exploring Mars wants to find the mass of an object. She finds a metal strip which she knows has a deflection force constant of 25 N/m. When she attaches the mass and gives it a push, the maximum displacement is 0. 11 m and the maximum speed is 0.15 m/s. What is the mass of the object? (327-2, 327-4)
- A pendulum is 0.80 m long. What is the period? (327-2, 327-4)
- What length must a pendulum be to have a period of 1.0 seconds? (327-2, 327-4)

Presentation

- Develop and present a research paper on the design history of a particular example. Alternatively, this topic lends itself to a visual display, such as a poster or video. (212-3, 214-3, 115-5)

Resources/Notes

(327-2, 327-4)

Textbook resources and labs for these outcomes can be found in Appendix C.

Video

- *Harmonic Motion* (Media Services, Learning Resources and Technology) 22659; 30 minutes

Universal Gravitation
5 hours

Outcomes

Students will be expected to

- explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law (ACP-2)
- explain and apply the law of universal gravitation to orbital notations by using appropriate numeric and graphic analysis (215-2)
- distinguish between scientific questions and technological problems as applied to orbital situations (115-1)

Elaborations—Strategies for Learning and Teaching

Students should investigate the elliptical properties of orbital motion. This is a good example of scientists' efforts to find patterns in data. Kepler found the patterns and Newton explained the cause of the motion.

Students could do the following investigation. Using two push pins, a piece of string, a sheet of paper, and a cardboard sheet as a punch board, create an elliptical pattern. The pins are placed 8–10 cm apart, and a loop is tied in a piece of string several centimetres longer than twice the separation between the pins. If a pencil is used to pull out the string to a snug position, it can then carefully be pulled around the pins, creating an ellipse. Remove the pins and string, and draw a small star at one pin position. The ellipse represents the path a planet would take around its sun. **Note:** *In reality, the path is more nearly circular, but it helps to study an exaggerated version that more closely resembles a comet's orbit.* Compare ellipses. At a point on the path the longest straight-line distance from the star, draw in a vector 1.0 cm long to represent the gravitational force on the planet. Can you determine the proportional force at other positions? Remember the gravitational field strength varies inversely as the square of the distance. Mark the point on the orbit that is the shortest distance from the star. How large a vector must be drawn to represent the force at this position? Calculate the proportional force at several other positions. At which position do you think the planet will be moving at its fastest speed? Why?

Kepler also discovered that no matter which planet he studied, the cube of the average radius of orbit divided by the time period of one orbit squared always came out to the same value. Using a table of planetary values, students should calculate this r^3/T^2 value for several planets. Does it come out to be the same? Students should prepare an oral or written presentation based on this investigation. Students should be expected to solve problems using the relationship $T_a^2/T_b^2 = r_a^3/r_b^3$. (ACP-2). Students should calculate r^3/T^2 for the moon orbiting the earth. How does this answer compare? Explain your result.

Students could be led through Newton's cannon thought experiment. Students should make the connection that orbital motion will occur when centripetal force equals gravitational force. At what height above the surface of the earth will the two forces be equal? Could a satellite orbit within the earth's atmosphere? Why is the moon where it is? Can a satellite be placed in a specific spot over the earth (geo-synchronous)?

Since the pattern will reapply in Coulomb's law, the proportionalities in the equation for universal gravitation should be discussed.

$$F \propto m_1, F \propto m_2, F \propto \frac{1}{r^2}, \text{ and } F_t = G\frac{m_1 m_2}{r^2}$$

Universal Gravitation
5 hours

Tasks for Instruction and/or Assessment

Performance

- The following data represent the force of attraction between a 100 kg mass and a 1.00 x 10^2 kg mass when they were placed at various separation distances (r). Plot a graph of F versus r with r plotted on the x-axis, and then manipulate the data to try to create a linear relationship so that you eventually see the pattern $F \alpha 1/r^2$. (215-2)

Gravitational Force vs. Separation Distance

Separation distance (m)	Force (N) x 10^{-5}
10.0	0.1
5.0	0.3
2.5	1.1
1.3	4.3

Journal

- Conduct research into Canada's participation in the design of artificial satellites such as communication, remote-sensing, and weather observation. Write a journal entry that presents a specific contribution. Do you think Canada played a leadership role in developing this technology? (115,1, 116-4, 117-2)

Paper and Pencil

- Write a summary report for the investigation of Kepler's laws. (ACP-2)
- Two masses, 4.0 kg and 8.0 kg, are located 2.0 m apart. What is the gravitational interaction force between them? (215-2)
- What is the mass of an object that experiences a pull of 10.0 N at the earth's surface? (215-2)
- At what height above the earth's surface would an object's weight be one half the value at the surface? (215-2)
- At what height will a satellite moving in the plane of the equator stay over the same location on the earth? (215-2)
- If the earth's orbit has an average radius of 1.5 x 10^{11} m, calculate the mass of the sun. (215-2)
- At what position between the earth and the moon would a spaceship experience no net force? (215-2)

Resources/Notes

(ACP-2, 215-2)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- Kepler's Laws
- Universal Law of Gravitation

Activities and labs for these outcomes can be found in Appendix C for the following topic:

- Universal Gravitation

Videos

- *From Kepler to Einstein* (Media Services, Learning Resources and Technology) 22657; 30 minutes
- *Moving in Circles* (Media Services, Learning Resources and Technology) 22664; 30 minutes
- *The Kepler Problem* (Media Services, Learning Resources and Technology) 22661; 30 minutes

Reports—See *Secondary Science: A Teaching Resource* (1999)

Fields

Introduction

Students have had experience with contact forces. Forces that exert influence through space without contact are more difficult to visualize. Historically, the notion of a field of influence that could be mapped and within which results are predictable went a long way in explaining and relating a wide range of different forces. The field remains one of the major unifying concepts of physics.

Focus and Context

We live in a world where the technological exploitation of our knowledge of electricity is expanding at an astonishing rate. Alexander Graham Bell would not recognize today's ultra-small digital phones. Maxwell could hardly have predicted that we would be cooking our dinner with radio waves. Plasma displays for computers are finding their way onto our walls as large, thin television screens. A space probe has been recently placed in orbit around an asteroid.

There is a rich context for the study of fields in everyday experience. It is important, however, to present also the historical context of the discovery and development in these areas. This historical context provides students with opportunities to explore the interconnectedness of science and technology. Students can improve their understanding of the concepts by reading and writing about their historical development.

When a force is applied to a mass by direct contact, it is not difficult to understand the event. When a magnet attracts a nail, or a plastic comb attracts a piece of paper, or a meteorite is pulled to Earth by gravity, an explanation is more challenging. When a force acts over a distance without obvious contact, what is the mechanism by which it acts?

Michael Faraday, in the mid-nineteenth century, first used the field concept to explain electric effects. In the early twentieth century, Albert Einstein used field principles to develop general relativity, his explanation of gravitation.

Field theory has provided a common lens through which to view phenomena that at first seemed unrelated. Beginning in the 1960s, physicists began to search in earnest for a unified field theory that would combine electromagnetism and gravitation as different aspects of a single field.

The search continues.

Science Curriculum Links

The basic introduction of force was included in the Physics 11 curriculum. This unit is an extension of this work. The study of fields is essential for an understanding of structure in physics and chemistry.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
Nature of Science and Technology 114-2 explain the roles of evidence, theories, and paradigms in the development of scientific knowledge 114-5 describe the importance of peer review in the development of scientific knowledge 115-3 explain how a major scientific milestone revolutionized thinking in the scientific communities 115-4 describe the historical development of a technology **Relationships between Science and Technology** 116-5 describe the functioning of domestic and industrial technologies, using scientific principles 116-7 analyse natural and technological systems to interpret and explain their structure and dynamics	**Initiating and Planning** 212-2 define and delimit problems to facilitate investigation 212-4 state a prediction and a hypothesis based on available evidence and background information 212-6 design an experiment and identify specific variables **Performing and Recording** 213-2 carry out procedures controlling the major variables and adapting or extending procedures where required 213-3 use instruments effectively and accurately for collecting data 213-4 estimate quantities 213-7 select and integrate information from various print and electronic sources or from several parts of the same source 213-8 select and use apparatus and materials safely **Analysing and Interpreting** 214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables **Communication and Teamwork** 215-1 communicate questions, ideas, and intentions, and receive, interpret, understand, support, and respond to the ideas of others	328-1 describe gravitational, electric, and magnetic fields as regions of space that affect mass and charge 328-2 describe gravitational, electric, and magnetic fields by illustrating the source and directions of the lines of force 328-3 describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles 328-4 compare Newton's universal law of gravitation and Coulomb's law, and apply both laws quantitatively ACP-3 apply Ohm's law to series, parallel, and combination circuits 328-7 analyse, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor 328-5 analyse, qualitatively and quantitatively, the forces acting on a moving charge and on an electric current in a uniform magnetic field 328-6 describe the magnetic field produced by current in both a solenoid and a long, straight conductor ACP-4 describe and compare direct current and alternating current 328-9 compare the ways a motor and a generator function, using the principles of electromagnetism

Magnetic, Electric, and Gravitational Fields
4 hours

Outcomes

Students will be expected to

- explain the roles of evidence, theories and paradigms, and peer review in the development of the scientific knowledge associated with a major scientific milestone (114-2, 114-5, 115-3)
- communicate questions, ideas and intentions, and receive, interpret, understand, support, and respond to the ideas of others (215-1)

Elaborations—Strategies for Learning and Teaching

Students could begin a long-term group project that will tie together all the concepts in this unit. Writing about these concepts enhances students' learning. They should select a modern device that employs knowledge of one or more of the principles of magnetism, electricity, or electromagnetism studied in this unit; research the historical development of the science and technology involved; predict future developments in related areas; and prepare a multimedia presentation.

Teachers could consider treating the magnetic and electric fields first, since the scale of equipment necessary to explore them is much smaller than for the gravitational field. At the end of the unit, students could revisit the law of universal gravitation to see the similarity to Coulomb's law.

Magnetic, Electric, and Gravitational Fields

4 hours

Tasks for Instruction and/or Assessment

Presentation

- Present your report, construct your own rubric as a group, and evaluate your report. (114-2, 114-5, 115-3, 215-1)

Resources/Notes

(114-2, 114-5, 115-3, 215-1, 328-1, 328-2, 328-3)

Textbook resources, activities, and labs for these outcomes can be found in Appendix C for the following topics:

- Magnetic Fields
- Electric Fields

Video

- *The Electric Field* (Media Services, Learning Resources and Technology) 22669; 30 minutes

Magnetic, Electric, and Gravitational Fields *(continued)*

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Although students will have studied magnetism in earlier grades, it is appropriate to look again at magnetic fields using iron filings and bar magnets. Students should sketch the field around a single magnet, the field between two like poles, and the field between unlike poles. The concept of north-seeking pole should be reviewed. The concept of magnetic domain should be introduced to explain the structure and behaviour of magnets.

The process of drawing together the work of group members will require at least one group meeting. The teacher should use an interaction diagram or other observation recording technique to assess outcome.

Static electric charge should be explored in the lab and in historical context. It is interesting for students to note that two types of charge and three conditions (positive, negative, and neutral) were identified before any explanation of the cause of the charge was proposed. It is pure chance that the type of charge identified traditionally as negative is, in fact, caused by an excess of negatively charged electrons. Students could explore and describe the field around various charged objects using a suspended pith ball. Many texts have pictures of grass seeds in oil used to display the electric field in much the same manner as iron filings show the magnetic field. Students should draw field diagrams that show the lines of force related to a positive test charge around single objects and between two objects. It might be useful to map the field in terms of equipotential lines, which indicate the inverse square nature of the field.

If a Van de Graaf generator is available, a graphite-coated Styrofoam™ ball suspended from a metre stick makes a good tool for exploring the field around a charged globe. Students could model fields using Styrofoam™ balls and pipe cleaners.

Students should conduct a lab investigation of electric charge. Students could use an electroscope to examine temporary charges produced by induction and permanent charges produced by conduction and induction. Teachers might explain that only electrons are being moved and electrons are not created or destroyed.

Students should describe the Earth's magnetic field and how it changes with time.

Magnetic, Electric, and Gravitational Fields *(continued)*

Tasks for Instruction and/or Assessment

Journal

- What is your understanding of magnetic, electric, and gravitational fields? How are these related? (328-2, 328-3)
- Magnets have poles and electric fields have charges. Explain this similarity to a group of grade 9 students. (328-3)

Paper and Pencil

- Write a report, including diagrams, that indicates in steps how various charges can be placed on an electroscope. (328-1)
- Draw diagrams to represent the fields around a point positive or negative charge, the region between two point positive charges, the region between two point negative charges, and the region between a point positive and a point negative charge. (328-2)
- Draw a diagram to represent the field between oppositely charged parallel plates. Draw diagrams to represent the field around a single bar magnet, the field and the region between like poles of two bar magnets, and the region between unlike poles of two bar magnets. (328-2, 328-3)

Presentation

- In groups, prepare a multimedia presentation on the history of the development of the modern electric motor. (115-4, 116-5, 116-7, 213-7)
- In groups, research and discuss the past changes in the orientation of the Earth's magnetic field over geological periods of time. (328-3)

Resources/Notes

Lab report organizers—See *Secondary Science: A Teaching Resource* (1999)

Coulomb's Law

4 hours

Outcomes

Students will be expected to

- define and delimit problems, estimate quantities, interpret patterns and trends in data, and infer or calculate the relationships among variables (212-2, 213-4, 214-5)
- compare Newton's law of universal gravitation with Coulomb's law, and apply both laws quantitatively (328-4)

Elaborations—Strategies for Learning and Teaching

Although it is possible to conduct a laboratory investigation of Coulomb's law using pith balls in a chimney apparatus, the results are often frustrating. Leakage of charge during the conduct of trials makes it virtually impossible to demonstrate the relationship effectively. On the one hand, it is an excellent opportunity to appreciate the vagaries of the scientific process, and the need for ongoing interpretation and refinement. On the other, when the results are unconvincing, what are the students to believe? To save time and still allow for discussion of a typical Coulomb's law experiment, teachers could supply simulated data that the students could then analyse and interpret.

Students should apply Coulomb's law quantitatively to one- and two-dimensional situations involving two or more charges using the formula

$$F_e = k\frac{q_1 q_2}{r^2}$$

Students should be reminded that the inverse square relation is one of the recurring mathematical patterns in nature. Einstein is reported to have said: "The most incomprehensible thing about the universe is its utter comprehensibility." Time and again scientists have found that when a theory is complex it is often wrong. The search for simple, comprehensive explanations is one of the driving forces of physics. The modern search for a unified theory that relates the four forces continues.

As an optional extension, it would be useful to present a set of typical data to the students with an explanation of the procedure, and have them develop the inverse square relationship for distance using manual graphing, graphing calculators, or a computer and a suitable data analysis program. Interactive Physics can be used to simulate the collection of data.

Coulomb's Law

4 hours

Tasks for Instruction and/or Assessment

Performance

- We know that when we rub our heads with a balloon, the balloon becomes statically charged. Assuming that the balloon becomes negatively charged, the balloon must be stealing electrons from our hair. A simple experiment and some vector work can give us an idea of how many electrons we take from our heads. You will use two balloons, two metre sticks, scale/balance, and 2.0 m of string.

  Blow up the two balloons so that they are approximately the same size. Measure and record the mass of the balloon. Tie the two balloons together with a piece of string approximately 150 cm long. Drape them over one of the metre sticks or a bar that is at least one or two metres above the ground. Make sure the balloons are side by side and not touching any other objects. Measure and record the length from the centre of the balloon to the point where the string meets the bar. Take the two balloons and rub them vigorously on your head. Let the two balloons touch each other for a few seconds to ensure that both balloons have the same charge. Determine the distance between the centres of the balloons and the angle at the top of the string. You now have enough data to determine the number of electrons on each balloon.

  In your analysis, draw a free-body diagram for one of the balloons showing vectors representing gravitational force, tension force, and electric repulsion force. Use Coulomb's law to determine the amount of charge on each balloon and, from the charge, determine the number of electrons. (212-2, 213-4, 214-5, 328-4)

Paper and Pencil

- Suppose that a friend has missed class for several days and was not present when Coulomb's law was covered. Write a complete explanation of the law and how to use it to solve problems. (328-4)
- Four 2.0×10^{-6} C charges are placed at the corners at a 5.00 cm square. What is the net force acting on one of the charges due to the other three? (328-4)

Resources/Notes

(328-4)

Textbook resources for this outcome may be found in Appendix C.

Electric Circuits (Optional)

10 hours

Outcomes

Students will be expected to

- apply Ohm's law to series, parallel, and combination circuits (ACP-3)
- carry out procedures controlling the major variables, selecting and using instruments effectively, accurately, and safely, and adapting or extending procedures where required (213-2, 213-3, 213-8)

Elaborations—Strategies for Learning and Teaching

During work on this outcome, students should

- extend the work-energy theorem to develop the concept of electric potential *energy*
- define electric potential *difference*
- describe factors that control electrical resistance
- define electric current
- draw a schematic diagram for series, parallel, and simple combination circuits
- investigate the relationship between voltage rises and voltage drops across circuit elements
- solve for unknown values in series, parallel, and combination circuits involving no more than four resistors
- describe the energy transformations at various points in a circuit
- define and calculate energy and power
- define and calculate the efficiency of an electrical appliance

Teachers should understand that an introduction to circuits was part of the grade 9 science curriculum and use students' prior knowledge to determine the approach taken in each class. Teachers should refer to the grade 9 science guide.

Students could begin this topic with a discussion of familiar applications of electric circuits. They should be encouraged to ask questions such as the following: Why don't birds get electrocuted? Are there electric circuits in the human body? How does an EKG or EEG work? Why is the earphone cord to a walkman so much thinner than a booster cable for jump-starting a car? Why are many appliance plugs made with one large spade? How does a circuit breaker (fuse) work? How can one light be switched on or off at two different switches? How can a house be safely connected to a very powerful line that serves many other houses? How does the electric company know how much energy we have used? These questions could be collected on a side board or poster and referred to as the study progresses.

Students should refine their operational definitions of current, potential difference, resistance, and power. Although students might have a generally acceptable understanding of current as the ratio of quantity of charge to elapsed time and know that ampere equals coulombs/second, they might need to clarify the definition of the coulomb. Students might have learned definitions of the volt as a unit of force or pressure; this definition should be changed to a more appropriate energy difference per charge. This is not an easy change for students to accept. First, they must "unlearn" meanings constructed several years ago. Second, they must replace that meaning with an energy definition that is much less intuitive. Teachers should consistently use the new definition and students should be given opportunities to verbalize and write about this new concept. In the same way, electrical resistance measured in ohms should be redefined as the ratio of potential difference to current. The everyday use of the term "power," when, in fact, the scientifically correct term is energy, must also be clarified, and the unit kWh revealed for what it really is. Students should calculate energy and power for sources and resistances. Cost of energy is a grade 9 outcome and should not be done here.

Electric Circuits (Optional)

10 hours

Tasks for Instruction and/or Assessment

Informal Observation

- During the laboratory investigation, the teacher could use a checklist to assess student participation. Student groups could present their results to the class orally. (213-2, 213-3, 213-18)

Journal

- Indicate what you have learned in the class discussion about electric circuits and what questions you would like to have answered on this topic. (ACP-3)

Resources/Notes

(ACP-3)

Textbook resources for this outcome can be found in Appendix C for the following topics:

- Current, Resistance, Potential Difference, and Power
- Series and Parallel Circuits

Activities and labs for this outcome can be found in Appendix C.

Videos

- Electricity Series from TV Ontario:
  - *Charging and Discharging* (Media Services, Learning Resources and Technology) V9477; 10 minutes
  - *Charging by Induction* (Media Services, Learning Resources and Technology) V9478; 10 minutes
  - *Conductors and Insulators* (Media Services, Learning Resources and Technology) V9476; 10 minutes
  - *Current Electricity* (Media Services, Learning Resources and Technology) V9479; 10 minutes
  - *Potential Difference* (Media Services, Learning Resources and Technology) V9480; 10 minutes
  - *Resistance* (Media Services, Learning Resources and Technology) V9481; 10 minutes

Electric Circuits (Optional) *(continued)*

Outcomes

Students will be expected to

- apply Ohm's law to series, parallel, and combination circuits (ACP-3)
- carry out procedures controlling the major variables, selecting and using instruments effectively, accurately, and safely, and adapting or extending procedures where required (213-2, 213-3, 213-8)
- state a prediction and a hypothesis based on available evidence and background information (212-4)
- design an experiment and identify specific variables (212-6)

Elaborations—Strategies for Learning and Teaching

If time permits, students could build a clearer understanding if they first conducted a laboratory investigation of resistivity as a property of conductors.

Students should carry out an investigation of Ohm's law with a single resistor. Students should determine the relationship between voltage and current in a circuit with a single resistance (Ohm's law). Then students should predict the voltage and current readings for the following circuits and test their predictions experimentally:

- two resistors in series
- three resistors in series
- two in parallel
- one in series with two in parallel
- one in parallel with two in series

The teacher must give consideration to current flow convention. Current is assumed to be electron flow. It is, however, a good idea to introduce the flow of positive charge or conventional current for the benefit of those students who will do further study of electricity.

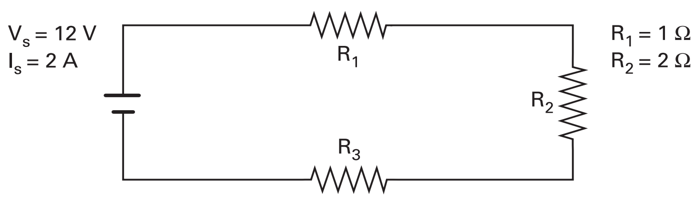
Students should conduct a laboratory investigation comparing mechanical work done to electrical energy consumed. For example, a small electric motor (3 V toy) could be mounted with the shaft parallel to the floor at a some height greater than 1.0 m. A mass is attached with a string to the shaft so that when the motor is running the mass is raised off the floor. Measure the vertical height, the current, and the length of time to raise the mass. Record the voltage of the motor. Determine the work done to lift the mass ($W=mgh$) and the electrical energy consumed ($E=VIt$) and the efficiency of the motor (W/E x 100%). As an optional extension, determine the efficiency of the motor using several different masses and plot a graph of efficiency versus load mass. What can account for the result?

Electric Circuits **(Optional)** ***(continued)***

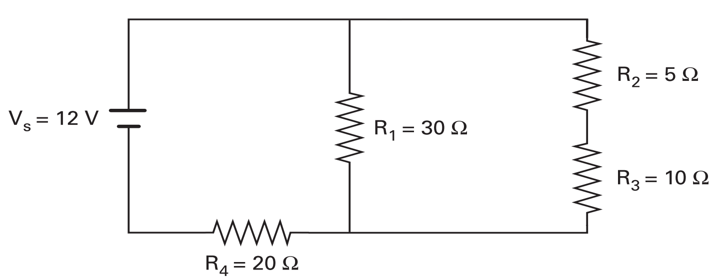
Tasks for Instruction and/or Assessment

Paper and Pencil

- Prepare a written report based on the lab investigation. (ACP-3)
- Solve problems such as the following: Two resistors are connected in series across a 30 V source. Draw a diagram of the circuit.
  - If the current from the source is 1.3 A, what is the current through each resistor?
  - If the voltage across one resistor is 12.4 V, what is the voltage across the other?
  - Find the resistance for each resistor. (ACP-3)
- Three resistors having values of 18Ω, 9Ω, and 6Ω are connected to a 3.0 V source. Find the current through each resistor if they are connected:
  - in parallel
  - in series (ACP-3)
- A 6.0 V battery is set up in a circuit. All of the current passes through a 6Ω resistor, and then splits between two branches, one of which has a 2Ω resistor and the other a 4Ω resistor. Determine the total resistance and the current and voltage in each resistor. (ACP-3)
- The following circuit is connected to a source that can provide a current of 2A when the potential difference (voltage) is 12 V.



  What is the resistance of R_3? Show all your work. (ACP-3)
- A series-parallel electric circuit is illustrated below.



  What is the potential difference across the terminals of resistor R_1?

  a) 4V
  b) 6V
  c) 8V
  d) 12V (ACP-3)

Resources/Notes

Electric Circuits (Optional) *(continued)*

Outcomes

Students will be expected to

- apply Ohm's law to series, parallel, and combination circuits (ACP-3)
- carry out procedures controlling the major variables, selecting and using instruments effectively, accurately, and safely, and adapting or extending procedures where required (213-2, 213-3, 213-8)
- state a prediction and a hypothesis based on available evidence and background information (212-4)
- design an experiment and identify specific variables (212-6)

Elaborations—Strategies for Learning and Teaching

A class lab could be conducted to compare heating water with a kettle and with a microwave. In class, 1.0 L of water could be taken from 20°C to boiling. The voltage, current, and time should be recorded and the electrical energy calculated. As a take-home component, each student could conduct the same trial using a microwave at home. Again V, I, and t should be recorded and the efficiency calculated. In class, the results could be collected in a table on the board or overhead and compared.

Finally, students should do diagrams and solve circuit problems.

As an optional extension, the teacher could investigate the application of Kirchoff's laws to circuits with more than one emf.

Students should realize that Ohm's law applies only in certain cases. Students should consider a qualitative view of the factors that influence resistance, namely length, diameter, type of metal, and temperature in the wire.

Teachers should limit circuit analysis problems to simple combinations of no more than four resistors. Internal resistance is not considered.

Electric Circuits (Optional) *(continued)*

Tasks for Instruction and/or Assessment

Journal

- How has your understanding of voltage, current, and resistance changed since grade 9? (ACP-3, 213-2, 213-3, 213-8, 212-4, 212-6)

Resources/Notes

Electromagnetism and Electromagnetic Induction
5 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students have had a preliminary introduction to electromagnetic induction in grade 9 science. Teachers could present a series of review demonstrations in which there is relative motion between a magnet and a coil, including changing the number of coils, changing the relative speed, and using magnets of different strength. Following this review, students should develop an understanding of Lenz's law and predict the direction of the current in a coil produced by a changing magnetic flux, using appropriate hand rules.

Students should research the connection between induction and transformers to try to answer the question, "Why do we distribute electricity as high voltage AC and not DC?"

Students should explain the relationship among force, F, magnetic field strength, B, and the length of conductor in a magnetic field to understand the factors for the force on a charge moving in a uniform magnetic field, charge, voltage, and angle. Emphasis should include determining the direction of the force based on whether the charge that is moving is negative or positive, but not problem solving.

To meet outcome 328-7, students should use Lenz's law to predict the directions of induced current and describe the construction and operation of step-up and step-down transformers, including ratio of turns and power-in, power-out calculations.

Using iron filings or small compasses, the students should map out the magnetic field lines produced around a long straight conductor. The students should extend this mapping to the area around a single loop of wire, and they should map the magnetic field around a solenoid. Students should describe the way that the magnetic field exists in space in these cases. Students could explore the interaction between two current-carrying wires placed close to each other.

Electromagnetism and Electromagnetic Induction

5 hours

Tasks for Instruction and/or Assessment

Performance

- Use a long piece of wire carrying a current and a piece of cardboard to act as a plane perpendicular to the wire. Then using either iron filings or small compasses, sketch the field lines around the conducting wire. Next shape the wire into a single coil passing through the cardboard, and again sketch the field lines. Finally shape the wire into a solenoid with several coils, and sketch the field lines. Prepare a set of diagrams to illustrate the distribution of the field lines in each case. (328-6)

Journal

- Write an entry in your journal that summarizes your understanding of Lenz's law and the left hand rule for conductors. This could take the form of a series of diagrams and explanatory notes. (328-5)
- Make a journal entry comparing the field line distribution around a long straight conductor, a single coil, and a solenoid. (328-6)

Paper and Pencil

- The output coil of a transformer has three times as many coils as the input coil. Proportionally compare the following:
  - output voltage to input voltage
  - output current to input current
  - output energy to input energy (328-7)
- The north pole of a permanent magnet is thrust into a coil of wire. Using diagrams, indicate the direction of the current in the coil as the magnet is inserted and withdrawn. (328-6)

Resources/Notes

(328-6, 328-5, 328-7)

Textbook resources and labs for these outcomes can be found in Appendix C for the following topics:

- Electromagnetism
- Electromagnetic Induction

Activities for these outcomes may be found in Appendix C for the following topic:

- Electromagnetism

Videos

- *Electromagnetism* (Media Services, Learning Resources and Technology) V0663; 6 10-minute videos. Relevant topics for this outcome are *Earth's Magnetic Field, Magnetism and Electron Flow, Domain Theory, Electromagnetism Induction, Life in the Field*.
- *Electromagnetism* (Media Services, Learning Resources and Technology) 22538; 29 minutes

Generators and Motors

4 hours

Outcomes

Students will be expected to

- compare and contrast the ways a motor and generator function, using the principles of electromagnetism (328-9)
- describe and compare direct current and alternating current (ACP-4)

Elaborations—Strategies for Learning and Teaching

A teacher demonstration of the force on a current-carrying wire in the field of a strong horseshoe magnet is a good way to introduce the notion of force. Students should try to devise a hand rule that takes into account the direction of the field, the direction of the current, and the direction of force (movement of the wire loop). Knowing two of the variables, students should use the thumb-and-two-fingers rule to determine the third variable. This is sometimes also called the third right-hand rule. Students should be able to describe how a galvanometer works on this principle.

Students should do a lab challenge in which they must build a rudimentary electric motor using a D-cell, enamelled wire, a disc or ring magnet, and tape. The magnet can be taped to the dry cell to provide a field; wires can be taped to the poles and bent to support a simple coil rotor. The challenge could be to see which group can build a motor that turns the heaviest rotor. Students should appreciate that an operating motor produces a back EMF (electromotive force).

Students should explain that a generator produces current that varies in strength in relation to the position of the rotor, and changes direction every half rotation. If the commutator is changed from a slip ring to a split ring design, students can be shown that a "rectified" current is produced in which the second phase is inverted.

Generators and Motors

4 hours

Tasks for Instruction and/or Assessment

Informal Observation

- The motor-building activity is intended to be an engaging exploration and can best be assessed by observation. (328-9)

Journal

- Automobiles have a device in their electrical system called an alternator, yet all parts of the car are supplied with direct current electricity from a 12-volt battery. How is this possible? Explain how the alternator functions in the system. (328-9, ACP-4)

Resources/Notes

(328-9, ACP-4)

Textbook resources for these outcomes can be found in Appendix C for the following topics:

- Transformers
- Generators
- Motors

Labs for these outcomes can be found in Appendix C for the following topic:

- Generators and Motors

Videos

- *Magnetism and Electricity* (Media Services, Learning Resources and Technology) V9642; 21 minutes
- *Electromagnetism* (Media Services, Learning Resources and Technology) V0663; 6 10-minute videos. Relevant topic for this outcome is *The Motor Principle*.

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Waves and Modern Physics

Introduction

The time period between 1890 and 1930 saw the development of concepts that are still referred to as "modern physics." At the same time, research was being carried out on the nature of electromagnetic phenomena, including the nature of light. It was in this period that these branches of research became linked.

Focus and Context

This historical context provides students with a means to connect developments that occurred independently and seem, at first, to be unrelated. The objective should be for students to develop an integrated view of the achievements that form the essence of twentieth-century physics. By reading and writing about activities and investigations that occurred during this period, students will consolidate their knowledge and understanding.

Science Curriculum Links

In Physics 11, students will have begun to compare the merits of wave and particle models in explaining the behaviour of light. In this unit, they will extend their understanding to the wider range of electromagnetic phenomena and make connections to theories relating to the structure of matter.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
Nature of Science and Technology 115-7 explain how scientific knowledge evolves as new evidence comes to light and as laws and theories are tested and subsequently restricted, revised, or replaced 115-3 explain how a photon momentum revolutionized thinking in the scientific community	**Performing and Recording** 213-6 use library and electronic research tools to collect information on a given topic **Analysing and Interpreting** 214-6 apply and assess alternative theoretical models for interpreting knowledge in a given field	326-9 apply quantitatively the law of conservation of mass and energy using Einstein's mass-energy equivalence 327-9 describe how the quantum energy concept explains black-body radiation and the photoelectric effect 327-10 explain qualitatively and quantitatively the photoelectric effect 329-1 explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts 327-11 summarize the evidence for the wave and particle models of light 329-2 explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts 329-3 explain the relationship among the energy levels in Bohr's model, the energy difference between levels, and the energy of the emitted photons

Quantum Physics
3 hours

Outcomes

Students will be expected to

- apply quantitatively the law of conservation of mass and energy using Einstein's mass-energy equivalence (326-9)

Elaborations—Strategies for Learning and Teaching

At the end of the nineteenth century, physicists seemed poised to be able to present a complete explanation of this natural world. Newtonian mechanics and Maxwell's electro-magnetic theory had solved most of the problems related to the behaviour of matter and light.

They were overly optimistic. It took the introduction of two concepts in the early twentieth century to resolve outstanding issues: the theory of relativity and quantum theory. Students should learn what impact these ideas had on the Newtonian model of the universe. They should be able to explain Einstein's general and special theories of relativity and use $E=mc^2$ to calculate equivalent total energy and mass.

- explain how quantum physics evolved as new evidence came to light and as laws and theories were tested and subsequently restricted, revised, or replaced, and use library and electronic research tools to collect information on this topic (115-7, 213-6)
- describe how the quantum energy concept explains both black-body radiation and the photoelectric effect (327-9)

The section on waves, including the parts dealing with Planck's "quanta," the photoelectric effect, Compton scattering, de Broglie's hypothesis and the Bohr model of the atom, is designed as an integrated unit in which student research and presentation are the key components. As students carry out their research and prepare their presentations, the quantitative nature of these phenomena should be addressed in class or by the teacher. The assigning of groups and their topics could be done a week before the start of this unit to give students an opportunity to begin their research.

Students should be able to make connections with their understanding of the behaviour of light and its explanation using the wave model from Physics 11. In building on this, the students could be asked to think about their everyday experiences with things that produce light. For example, the metal wire in a light bulb glows white when electricity is passed through it. A piece of steel will glow first red then eventually white hot as it is heated. Some gases, like neon, glow with a characteristic colour when electricity is applied to the gas in an evacuated tube.

Students should describe black-body radiation. Students could investigate the connection between the predictions about black-body radiation that result from Maxwell's equations and the empirical evidence that does not support the predictions.

Students could research the sequence of events that led to Planck's prediction of "quanta." This model predicted the behaviour, but it did not explain why it happened.

Students could be asked to brainstorm the electrical devices that use the principle of the photoelectric effect, including such things as solar cells in calculators and infra-red remote control devices.

Using an ultraviolet light source, a piece of polished zinc, and a gold leaf electroscope, the teacher could demonstrate the photoelectric effect. A solar cell could be used to demonstrate the photoelectric effect as well.

- explain qualitatively and apply the formula for the photoelectric effect (327-10)

Students could once again revisit the list of electrical devices that operate from light. Students could be given data for frequency and photocurrent for various metals and use the data and a plotting program to describe the idea of a threshold frequency and the concept of cutoff potential.

Students should be introduced to Einstein's photoelectric equation: $E_k = hf - W$ and the concept of the work function. Students should use the photoelectric formula only in simple applications.

Quantum Physics

3 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- When electromagnetic radiation with a wavelength of 350 nm falls on a metal, the maximum kinetic energy of the ejected electrons is 1.20 eV. What is the work function of the metal? (327-10).

Presentation

- Six groups of students could be created in each class. Three groups will do this presentation and the other three will do the presentation on p. 135.

  One group is given the task of preparing a multimedia presentation on the breakdown of classical theory as it applies to the "ultraviolet catastrophe." Another group should research the historical context of the photoelectric effect and where that fits into the historical context following Planck's theory and present their findings. A third group should research Einstein's role in explaining the photoelectric effect and once again fit that into the historical context as it relates to his use of the "quanta" that Planck proposed. Other groups should prepare presentations on Compton and de Broglie.
  (115-7, 213-6, 327-9, 327-10)

Resources/Notes

(326-9, 327-9, 327-10)

Textbook resources and activities for these outcomes can be found in Appendix C.

Videos

- *Structure of the Atom* Video Series:
  - *The Earliest Models* (Media Services, Learning Resources and Technology) V9446; 10 minutes
  - *Smaller than the Smallest* (Media Services, Learning Resources and Technology) V9447; 10 minutes
  - *Rutherford Model* (Media Services, Learning Resources and Technology) V9448; 10 minutes

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Compton and de Broglie

2 hours

Outcomes

Students will be expected to

- explain how photon momentum revolutionized thinking in the scientific community (115-3)
- apply and assess alternative theoretical models for interpreting knowledge in a given field (214-6)
- explain quantitatively the Compton effect and the de Broglie hypothesis, using the laws of mechanics, the conservation of momentum, and the nature of light (329-1)

Elaborations—Strategies for Learning and Teaching

Students should make the connection between the photoelectric effect and the work of Compton with X-ray scattering that led to the concept of photon momentum.

Students, through their research, should be aware of the scattering results of Compton. Emphasis here would be on the idea that this effect is connected to conservation of momentum and conservation of energy. As well, when investigating de Broglie (pronounced “de Broy”) wavelengths, the students should calculate de Broglie wavelength for real-world-sized objects such as a basketball to help them develop an understanding of why we do not see the wave nature of objects of that scale.

Compton and de Broglie

2 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- What is the momentum of a photon whose wavelength is 450 nm? (329-1)
- Find the speed of an electron having the same momentum as a photon having a wavelength of 0.80 nm. (329-1)
- What is the de Broglie wavelength of an electron that has been accelerated from rest to a velocity of 4.8 x 10^6 m/s? (329-1)
- Calculate the de Broglie wavelength of a 1000 kg car moving at 90.0 km/h. (329-1)

Presentation

- This is a continuation of the project from quantum physics on p. 131. One group of students should research and prepare multimedia presentations on Compton's scattering and its historical connection to the photoelectric effect as well as its consequences. Another group should research and prepare a presentation on the consequences to the wave model of light as a result of the photoelectric effect and Compton's scattering experiment. A third group should research the work of de Broglie and his prediction of a particle wavelength. (115-3, 214-6, 329-1)

Resources/Notes

(329-1)

Textbook resources for this outcome can be found in Appendix C.

Video

- *Wave Mechanical Model* (Media Services, Learning Resources and Technology) V9451; 10 minutes

Particles and Waves
2 hours

Outcomes

Students will be expected to

- summarize the evidence for the wave and particle models of light (327-11)

Elaborations—Strategies for Learning and Teaching

Students could reflect on the changes to the model of light that have arisen since the discovery of the photoelectric effect. The results of the student research and the need to think differently about light under certain conditions should be emphasized.

Students should begin with a summary of the successes and shortcomings of the Newtonian particle model and Huygens' wave model in exploring common light phenomena. They should discuss the impact of the photoelectric effect on the credibility of the two models. Finally, they should explain the need to synthesize elements of both theories in the form of the modern wave–particle duality model.

Particles and Waves

2 hours

Tasks for Instruction and/or Assessment

Journal

- Summarize your understanding of the conditions under which light can be thought of as a wave and when it is better to think of light as a particle. (327-11)

Presentation

- Organize a debate among teams of students and debate the following: Be it resolved that the particle model is a superior explanation of the behaviour of light. (327-11)

Resources/Notes

(327-11)

Textbook resources for this outcome can be found in Appendix C.

Videos

- *The Particle Model* (Media Services, Learning Resources and Technology) V8987; 10 minutes
- *The Wave Model* (Media Services, Learning Resources and Technology) V8988; 10 minutes
- *The Electromagnetic Model* (Media Services, Learning Resources and Technology) V8989; 10 minutes

Bohr Atoms and Quantum Atoms
3 hours

Outcomes

Students will be expected to

- explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts (329-2)
- explain the relationship among the energy levels in Bohr's model, the energy difference between levels, and the energy of the emitted photons (329-3)
- use the quantum-mechanical model to explain naturally luminous phenomena (329-7)

Elaborations—Strategies for Learning and Teaching

Students should calculate specific energy levels and the difference between any two energy levels of the Bohr atom.

As an optional extension, teachers might lead the students through the derivation of the energy level equation developed by Bohr to explain the hydrogen atom. The derivation should emphasize how Bohr connected this concept to the quanta of energy they were introduced to when they looked at Planck's work.

Students should observe the spectra of various gases, particularly hydrogen, with a spectroscope. Emphasis should be placed on the production of light by the excitation of electrons from one permitted energy level to another and returning to ground state and the agreement between the known spectral lines produced by hydrogen and Bohr's calculation of the constant E_n ($E_n = -13.6/n^2$ eV).

Students should make connections between the Bohr model of the atom and examples of natural luminosity occuring without stimulation, such as phosphorescence and fluorescence.

Bohr Atoms and Quantum Atoms
3 hours

Tasks for Instruction and/or Assessment

Journal

- Write a memo that explains how Bohr integrated ideas from classical and quantum physics. (329-2)
- Write a note that explains how to relate the energy levels identified by Bohr to natural luminous phenomena. (329-7)

Paper and Pencil

- Find the energy of the second allowed orbit in the hydrogen atom. (329-2, 329-3)
- Determine the wavelength of the light given off when an electron in hydrogen moves from the $n = 4$ to the $n = 2$ orbit. (329-2, 329-3)

Resources/Notes

(329-2, 329-3, 329-7)

Textbook resources for these outcomes can be found in Appendix C.

Videos

- *The Quantum Idea* (Media Services, Learning Resources and Technology) V8990; 10 minutes
- *Photons* (Media Services, Learning Resources and Technology) V8991; 10 minutes
- *Matter Waves* (Media Services, Learning Resources and Technology) V8992; 10 minutes
- *Spectra* (Media Services, Learning Resources and Technology) V9450; 10 minutes
- *Bohr Model* (Media Services, Learning Resources and Technology) V9449; 10 minutes

Radioactivity

Introduction

In their daily lives, people are exposed to radiation from a variety of sources. Some radiation is harmless; other radiation is potentially harmful. Some kinds of radiation can be used in beneficial ways. Students should explore the full range of types of radiation, including natural and artificial sources, and assess the risks and benefits of exposure to each of them.

Focus and Context

Perhaps the most awesome achievement of the twentieth century was the development of fission and fusion technologies. Our world is still threatened by vast stockpiles of nuclear weapons. Their storage and their decommissioning present a challenge to our very existence. At the same time, our fission reactors are aging rapidly. Design flaws are becoming apparent, and the technology has spread to countries whose motives are suspect and safety practices inadequate.

This unit presents an excellent STSE issue with which to end the course. Students can apply the knowledge they have gained to the problems of future development, storage and handling, and alternative energy sources for the new millennium. This investigation will help students become informed about political decisions our society must soon face.

Science Curriculum Links

The structure of the atom was introduced in grade 9 Science. This unit helps to further develop skills in dealing with social issues in science.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	*Students will be expected to*	*Students will be expected to*
Nature of Science and Technology	**Performing and Recording**	**329-5** describe sources of radioactivity in the natural and constructed environments
115-5 analyse why and how a particular technology was developed and improved over time	**213-7** select and integrate information from various print and electronic sources or from several parts of the same source	**329-7** use the quantum mechanical model to explain natural luminous phenomena
Relationships between Science and Technology	**212-9** develop appropriate sampling procedures	**326-9** apply quantitatively the law of conservation of mass and energy, using Einstein's mass-energy equivalence
116-4 analyse and describe examples where technologies were developed based on scientific understanding	**213-8** select and use apparatus and materials safely	**329-4** describe the products of radioactive decay, and the characteristics of alpha, beta, and gamma radiation
116-6 describe and evaluate the design of technological solutions and the way they function, using scientific principles	**213-9** demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials	**329-6** compare and contrast fission and fusion
Social and Environmental Contexts of Science and Technology	**Analysing and Interpreting**	
117-5 provide examples of how science and technology are an integral part of their lives and their community	**214-12** explain how data support or refute the hypothesis or prediction	
117-7 identify and describe science- and technology-based careers related to the science they are studying	**214-15** propose alternative solutions to a given practical problem, identify the potential strengths and weaknesses of each, and select one as the basis for a plan	
117-11 analyse examples of Canadian contributions to science and technology	**Communication and Teamwork**	
118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology	**215-4** identify multiple perspectives that influence a science-related decision or issue	
118-4 evaluate the design of a technology and the way it functions on the basis of a variety of criteria that they have identified themselves	**215-5** develop, present, and defend a position or course of action, based on findings	

Natural and Artificial Sources of Radiation

3 hours

Outcomes

Students will be expected to

- describe sources of radioactivity in the natural and constructed environments (329-5)
- identify, analyse, and describe examples where technologies were developed based on scientific understanding, their design and function as part of a community's life, and science- and technology-related careers (116-4, 116-6, 117-5, 117-7)
- apply quantitatively the law of conservation of mass and energy using Einstein's mass-energy equivalence (326-9)

Elaborations—Strategies for Learning and Teaching

Students could begin the radioactivity unit with an individual research project. It is important that students realize that radiation is a fact of everyday life. This research could be assigned a week ahead of beginning the topic in class. The research would then form the context for initial classroom discussion. Students should explore geological sources (ores, radon gas), cosmic and atmospheric sources (background radiation, solar wind, airborne contaminants), and human-made sources (radium dials, imaging technology, cancer therapy).

Students should explore uses of radiation. From agriculture to medicine, applications of our understanding of radiation abound. Potatoes are irradiated to control sprouting, tracer isotopes are used in medical diagnosis, the cobalt "bomb" is used in cancer therapy. Because of this, there is a great demand for persons trained in radiation technology. Students could work in pairs or small groups to prepare a Bristol board-sized poster presenting what they have learned about any one radiation technology/application. A guest speaker could help students focus on actual cases. For example, an engineer could speak about radon gas accumulation in basements, someone from the Industrial Hygiene Association could talk about monitoring equipment, or a person from the agrifood industry could explain the uses of radiation from seeds to preserving produce.

Einstein's famous equation, $E = mc^2$, may well be the most often quoted and least understood expressions in physics. Students should learn the context in which it has meaning. They should be able to determine mass defect and use the equivalence equation to calculate the energy released in a decay or fusion reaction.

Natural and Artificial Sources of Radiation

3 hours

Tasks for Instruction and/or Assessment

Journal

- Write a short note explaining how a medical X ray and an airplane flight can be related. (329-5)
- Write a note that shows you understand what we mean when we say mass and energy are equivalent. (326-9)

Presentation

- Prepare an overhead transparency summarizing your research and present a brief oral elaboration. (329-5)
- Organize your posters as a cafeteria display, or display them elsewhere in the school or community. (116-4, 116-6, 117-5, 117-7)
- Solve problems such as the following:
  - In a fission reaction, the loss of mass was 0.0075 g. How much energy would have been released in this event?
  - 150 atoms were split in a fission reaction. If each atom releases 2.5 x 10^{-8} J, what mass was converted into energy? (326-9)

Resources/Notes

(329-5, 326-9)

Textbook resources for these outcomes can be found in Appendix C.

Videos

- *Discovery of Radioactivity* (Media Services, Learning Resources and Technology) V9470 ; 10 minutes
- *Too Hot to Handle: The Nature of Radioactivity*, (Media Services, Learning Resources and Technology) V0798; 17 minutes

Graphic organizers—See *Secondary Science: A Teaching Resource* (1999)

Natural and Artificial Sources of Radiation *(continued)*

Outcomes

Students will be expected to

- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)
- develop appropriate sampling procedures (212-9)
- select and use apparatus and materials safely (213-8)
- demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials (213-9)

Elaborations—Strategies for Learning and Teaching

Students should conduct a laboratory investigation of the intensity of beta or gamma radiation. A source of low-level beta radiation could be brought gradually nearer to a Geiger counter with a rate-meter display until a full-scale reading is achieved. With this distance from the counter recorded as separation "*r*," the source could be moved away at regular intervals, perhaps *r*/4 steps, until the reading approximates the background value. A graph of radiation level versus separation should be drawn and interpreted. This could be repeated for a gamma source if one is available.

With the source placed again at separation "*r*," various thicknesses of a variety of materials can be placed in front of the source, and the effect on the radiation reading recorded. For example, strips of Bristol board can be added one at a time and the reading recorded. Transparency sheets, aluminium foil, lead strips, glass, or other materials can also be investigated. If plots of radiation versus thickness are plotted on the same graph, the effect of the different materials can be readily compared.

Students should investigate WHMIS rules to see if they apply to radioactive materials.

Natural and Artificial Sources of Radiation *(continued)*

Tasks for Instruction and/or Assessment

Paper and Pencil

- Prepare a written lab report for the investigation of the intensity of beta and gamma radiation. (213-7, 212-9, 213-8, 213-9)

Resources/Notes

Radioactive Decay

3 hours

Outcomes

Students will be expected to

- describe the products of radioactive decay, and the characteristics of alpha, beta, and gamma radiation (329-4)
- analyse data on radioactive decay to predict half-life (214-2)

Elaborations—Strategies for Learning and Teaching

Students should become familiar with the symbolism used to describe radioisotopes and the products of decay. They should be able to interpret a decay equation such as the following:

$$^{238}_{92}U \rightarrow \, ^{234}_{90}Th + \, ^{4}_{2}He + \delta$$

Students should interpret radioactive decay graphs and determine the half-life from the graph. Mathematical problem solving is not expected.

Radioactive Decay

3 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- An experiment was performed to determine the half-life of Tc-99. The activity was measured over a 24-hour period, and students recorded the results below.

time (h)	0	3	6	9	12	15	18	21
activity (kBq)	17.0	12.2	8.9	6.5	4.5	3.2	2.3	1.5

  Plot a graph of activity versus time. Using the graph, determine the half-life of Tc-99. Predict the activity for 7 hours and 26 hours. (214-12)
- Using the periodic table, determine the missing product.

  a) $^{27}_{13}Al + ^{4}_{2}He \rightarrow ? + ^{1}_{1}H$

  b) $^{141}_{58}Ce \rightarrow ? + ^{0}_{-1}e$ (329-4)

Presentation

- Prepare a page-sized poster that displays and explains the complete decay chain of a specific radioisotope. (329-4)

Resources/Notes

(329-4, 214-2)

Textbook resources, and activities for these outcomes can be found in Appendix C.

Videos

- *Properties of Becquerel Rays* (Media Services, Learning Resources and Technology) V9471; 10 minutes
- *Natural Transmutations* (Media Services, Learning Resources and Technology) V9472; 10 minutes
- *Energy from the Nucleus* (Media Services, Learning Resources and Technology) V9473; 10 minutes

Fission and Fusion

4 hours

Outcomes

Students will be expected to

- compare and contrast fission and fusion (329-6)
- analyse examples of Canadian contribution to a particular development of science and technology (115-5, 117-11)
- identify, develop, present, and defend a position or course of action based on identifying multiple perspectives that influence the issue, and on interpreting data and the relationship among variables (214-15, 215-4, 215-5)
- analyse and evaluate, from a variety of perspectives, using a variety of criteria, the risks and benefits to society and the environment of a particular application of scientific knowledge and technology (118-2, 118-4)

Elaborations—Strategies for Learning and Teaching

Students could approach these outcomes in an integrated research/presentation activity that is focussed on the STSE implications of using nuclear technology as a power source for electricity generation. They can begin by researching the nature of existing fission reactors and the state of the research into fusion reactors.

Students should look for answers to questions such as the following: What technological challenges have led society to question the practicality of fission reactors? How is the Candu reactor different from other reactor designs? What factors make fusion reactors seem to be an attractive alternative to fission reactors? What problems need to be solved before fusion reactors become a reality?

Fission and Fusion

4 hours

Tasks for Instruction and/or Assessment

Journal

- Reflect and comment on the statement that all nuclear reactions are detrimental to human life. (Hint: Do not forget our sun.) (118-2, 118-4)

Presentation

- Research and prepare for a panel discussion on the topic: Canada should abandon the fission technology currently in use at the end of its productive life and devote national resources to the development of fusion reactors. Panel members could include members of the community with relevant expertise. Presentation topics could include economic viability, long-term reliability, and risk/benefit analysis. (329-6, 115-5, 117-11, 214-15, 215-4, 215-5, 118-2, 118-4)

Resources/Notes

(329-6)

Textbook resources and activities for this outcome can be found in Appendix C.

Videos

- *Electrical Energy from Fission* (Media Services, Learning Resources and Technology) V9474; 10 minutes
- *Nuclear By-Products* (Media Services, Learning Resources and Technology) V9475; 10 minutes
- *Nuclear Fusion* (Media Services, Learning Resources and Technology) V0851; 25 minutes
- *Fusion: A Work in Progress* (Media Services, Learning Resources and Technology) V20899; 25 minutes

Appendices

Appendix A: Equipment Lists

The apparatus listed will supply one laboratory for 32 students. It is recommended that student lab groups be no larger than four. It goes without saying that the established high school will already have much of the equipment listed.

This list is, of course, a minimal inventory. We hope that schools will have on hand or be able to budget for a few pieces of apparatus for demonstration and motivational purposes.

Supply List	Quantity
air table	1
airball, 20–30 cm (a volleyball is an ideal size)	8
balance, double pan	8
balls, 2.5 cm metal	
ballistic pendulum	8
C-clamp, 7.5 cm (3 inches)	16
carpenter's level	1
chalkboard protractor	1
circular motion apparatus	8
clamp, right angle	8
collision apparatus	1
Coulomb's law chimney apparatus	8
D-cells, 1.5 V	16
defraction gratings, approximately 500 lines per mL	32
dynamics cart	16
fire extinguisher	1
first aid kit	1
graduated cylinder, polypropylene, 2000 mL	8
Hall's carriage	8
helium-neon laser	1
hooked weights, set of 50 g, 100 g, 200 g	16
large timer	1
magnet, small disk	8

mass hanger	8
metre stick	16
motion sensor	1
protractor	32
radioactivity kit	1
ramp, incline plane	8
refraction block glass, 9 mm thick	8
refraction prism equilateral glass, 9 mm thick	8
refraction tanks, semi-circular, plastic, disposable	24
right-angled triangled glass, 9 mm thick	8
ring stand	16
ripple tank assembly consisting of tank and supports, high-power light source, wave generator, and power supply	8
rod, metal, 30 cm	8
rolling ball two-dimensional collision apparatus	8
ruler, 30 cm	16
ScienceWorkshop Interface ±50 Newton Force Sensor, software	1
selection of masses	16
small conducting charged sphere	16
spring (force constant between 20 and 40 N/m two kinds, 8 low constant, 8 high constant)	16
spring scales	16
stop watch	8
table clamp pulley	8
ticker timers	8
toy vehicles, battery operated, various speeds	2
tuning forks, C2 (512 Hz)	8
tuning forks, set of C1 and C2	1
wave demonstrators, large coil (Slinky)	8
wave demonstrators, small, heavy coil (helix)	8
wire, enamelled armature, 28 gauge	8

Recyclables and Collectables List	
dressmaker pins	8
penny	N/A
Consumables List	
alligator clips or paper clips	N/A
carbon paper	N/A
cardboard	N/A
duct tape	N/A
elastic band	N/A
fine nylon thread	N/A
fly-fishing line	N/A
masking tape	N/A
paper	N/A
paraffin blocks, package	8
plastic bag	N/A
plastic strip or sheet of overhead transparency	N/A
rubber hose	N/A
sandpaper	N/A
shampoo, 1000 mL	1
silk or paper	N/A
string	N/A
tape	N/A
vegetable oil, 1000 mL	1

Appendix B: Video Resources

Teacher Resource

Safety videos from driver's training programs or personal development and relationships course video list

Media Services, Learning Resources and Technology

Outcomes	Title	Description
Dynamics: Newton's Laws		
325-8, 115-3	*Inertia* Call Number 22660 30 minutes	Copernicus conjectured that the Earth spins on its axis and orbits the sun. A dangerous assumption that prompted risky questions: "Why do objects fall to Earth rather than hurtle off into space?" and "In this heretical scheme of things, where was God?" Risking more than his favoured status in Rome, Galileo helped to answer such questions with the law of inertia.
325-8	*The Fundamental Forces* Call Number 22658 30 minutes	All physical phenomena of nature are explained by four forces. Two nuclear forces, strong and weak, dwell within the atomic nucleus. The fundamental force of gravity ranges across the universe at large. So does electricity, which bind the atoms of all matter.
115-3	*Galileo: The Challenge of Reason* Call Number V2486 26 minutes	Galileo's experiments led him to support Copernicus' view that the sun was the centre of the universe. For these beliefs, Galileo was brought before the Inquisition. After showing Galileo's experiments, the film dramatizes the conflict between Galileo's new scientific thinking and the Church's authority, based on faith alone. Although in the end Galileo recanted, it was his view that was to dominate the West in succeeding centuries.
Force, Motion, Work, and Energy: Collisions in Two Dimensions		
326-3, 326-4	*Conservation of Momentum* Call Number 22656 30 minutes	If the mechanical universe is a perpetual clock, what keeps it ticking? Taking a clue from Descartes' momentum, the product of mass and velocity is always conserved. Newton's laws embody the concept of conservation of momentum.

Outcomes	Title	Description
Force, Motion, Work, and Energy: Projectiles		
214-14, 214-16, 325-6	*Motion: Newton's 3 Laws* Call Number V2210 18 minutes	Newton revolutionized physics by developing the three laws of motion and this program revolutionizes the study of Newton's three laws of motion with exciting footage of top fuel dragsters, fighter jets, bungee jumpers, and rockets. These examples are used to explain the motion of falling bodies and projectiles, circular motion, and how the motion of an object is relative to the observer's frame of reference. Concepts critical to understanding Newton's three laws of motion are also explained.
Force, Motion, Work, and Energy: Simple Harmonic Motion (SHM)		
327-2, 327-4	*Harmonic Motion* Call Number 22659 30 minutes	The music and mathematics of nature—the restoring force and inertia of any stable mechanical system causes objects to execute simple harmonic motion, a phenomenon that repeats itself in perfect time.
Force, Motion, Work, and Energy: Universal Gravitation		
ACP-2, 215-2	*From Kepler to Einstein* Call Number 22657 30 minutes	The orbiting planets, the ebbing and flowing tides, the falling body as it accelerates, these phenomena are consequences of the law of gravity. Why that is so leads to Einstein's general theory of relativity, and into the black hole, but not back out again.
ACP-2, 215-2	*Moving in Circles* Call Number 22664 30 minutes	The video explores sharing and features young children showing how to listen, explain, mediate, and negotiate calmly. The program presents a realistic story line with humour, imagination, and sincerity. The program uses song, dance, animation and role playing to demonstrate conflict resolution strategies.
ACP-2, 215-2	*The Kepler Problem* Call Number 22661 30 minutes	The combination of Newton's law of gravity and $F=ma$. The task of deducing all three of Kepler's laws from Newton's universal law of gravitation is known as the Kepler problem. Its solution is one of the crowning achievements of Western thought.
Fields: Magnetic, Electric, and Gravitational Fields		
114-2, 114-5, 115-3, 215-1, 328-1, 328-2, 328-3	*The Electric Field* Call Number 22669 30 minutes	Faraday's vision of lines of constant force in space laid the foundation of the modern idea of the force field. This program explores electric fields of static charges, Gauss' law and the consideration of flux.

Outcomes	Title	Description
Fields: Electric Circuits		
ACP-3	*Charging and Discharging* Call Number V9477 10 minutes	This program explains why two dissimilar objects, initially neutral, can acquire equal and opposite charges when they come in contact. The metal-leaf electroscope is introduced. Includes teacher's guide.
ACP-3	*Charging by Induction* Call Number V9478 10 minutes	This program illustrates how an object can become charged without coming into contact with a charged object (charging by induction). The program explains how lightning is an example of charging by induction and Ben Franklin's experiments are discussed.
ACP-3	*Conductors and Insulators* Call Number V9476 10 minutes	This program introduces the concept of conductors and insulators by reviewing the atomic model of matter to observe the distinction at the atomic and nuclear levels. Includes teacher's guide.
ACP-3	*Current Electricity* Call Number V9479 10 minutes	When an electrostatically charged object is grounded, charge is set in motion. The program opens by showing how this motion of charge can be used as a source of energy. This source of energy is short term, but a more durable and reliable source, such as a battery, can be produced. "Charge in motion" or current electricity needs a path or circuit to travel: if in one direction only, it is called direct current; if it vibrates back and forth, it is called alternating current. The unit of charge, or coulomb, is defined in terms of a quantity of electrons. Includes teacher's guide.
ACP-3	*Potential Difference* Call Number V9480 10 minutes	The program first points out that two light bulbs with the same current passing through them may not have the same brightness. This example illustrates that current is not the only determining factor in an electrical circuit. The coulombs of charge moving in an electrical circuit are compared to skiers on a ski lift. This concept lead to the definition of the volt in terms of energy and charge.
ACP-3	*Resistance* Call Number V9481 10 minutes	This program includes the third variable in electric circuits—resistance. It does so by asking why it is that the wire leads remain cool while heating elements get hot. This introduces the idea of different materials having different properties

Outcomes	Title	Description
	Resistance (continued)	because of the manner in which electrons are bound at the atomic level. The production of heat is explained in terms of vibration. The ohm is defined in terms of voltage and current. Includes teacher's guide.
Fields: Electromagnetism and Electromagnetic Induction		
328-6, 328-5, 328-7	*Electromagnetism* Call Number V0663 60 minutes	Another mini-series in the Concepts in Science series. Both magnetic and electrical forces were observed in ancient times, but it was not until the nineteenth century that scientists came to see these two seemingly unrelated phenomena as manifestations of the same force. This recognition of electromagnetic force represented the first step towards seeing the fundamental forces of nature as unified. At the beginning of the twenty-first century, we know now that electromagnetism is all around us. We learn how compasses, electromagnets, electric motors, generators, and transformers employ magnetic fields. "Electromagnetism," in six ten-minute segments, discusses the basic properties of magnetic fields and poles; describes Earth's magnetic field; demonstrates the relationship between electric charge flow and magnetic fields; explains the source of magnetic fields in ferromagnetic metals; describes how electromagnetism is employed in devices such as electric motors, generators, and transformers.
328-6, 328-5, 328-7	*Electromagnetism* Call Number 22538 29 minutes	This video shows how harnessing the principles of electromagnetism is central to our modern way of life. The video also examines the historical experiments, explains the concepts, and illustrates their application in a wide range of inventions. Topics covered include electrostatic or electric fields, electromagnetic fields, the solenoid, atomic magnets, deflection of moving charges, core materials, magnetic field strength, interacting fields and torque on a coil. Includes brief teacher's notes.
Fields: Generators and Motors		
328-9, ACP-4	*Magnetism and Electricity* Call Number V9642 21 minutes	This black and white filmstrip transfer explains the theory and operation of magnets and electromagnets, and outlines the application of electromagnets to the starter motors, generators, solenoids, and relays of an automobile.

Outcomes	Title	Description
328-9, ACP-4	*Electromagnetism* Call Number V0663 6 10-minute videos	Relevant topic for this outcome is *The Motor Principle*.
Waves and Modern Physics: Quantum Physics		
326-9, 327-9, 327-10	*The Earliest Models* Call Number V9446 10 minutes	Who were the first scientists to ask “How big is small, and can things be divided in half forever?” This program examines the developments in the study of the atom throughout the ages. From the Greek atomist, Democritus, through Roger Bacon, William Gilbert, Niccolo Cabeo, Benjamin Franklin, Charles Augustin Coulomb, Antoine Lavoisier, and Joseph Proust, two thousand years of experiment have led up to the modern atomic model.
326-9, 327-9, 327-10	*Smaller than the Smallest* Call Number V9447 10 minutes	This videotape is an exploration of Dalton’s chemical atomic theory, and the support it lent to; previous observations such as Proust’s law of definite proportions. Experiments using electricity and devices such as the cathode ray tube by physicists Michael Faraday, William Crookes, Thomson (his “raisin bun” theory), and R.A. Millikan are demonstrated.
326-9, 327-9, 327-10	*Rutherford Model* Call Number V9448 10 minutes	Rutherford’s contribution to atomic theory is examined, beginning with his use of radioactivity to probe the atom. He concluded that it was mainly empty space. Rutherford also proposed that the nucleus of the atom was positively charged, and he created a model of the atom that imitated the structure of the solar system.
Waves and Modern Physics: Compton and de Broglie		
329-1	*Wave Mechanical Model* Call Number V9451 10 minutes	Speculation on the wave nature of matter led physicist Louis Victor de Broglie to predict the allowable orbits and radii of atoms. This discovery was the key to explaining the behaviour of multi-electron atoms and multi-atom compounds by establishing the wave-mechanical model, the still accepted model.

Outcomes	Title	Description
Waves and Modern Physics: Particles and Waves		
327-11	*The Particle Model* Call Number V8987 10 minutes	This program offers a look at the early explanations of the source and behaviour of light, from the ancient Greeks to Isaac Newton's development of the particle model. The program illustrates how this model explained geometric reflection, refraction, and dispersion.
327-11	*The Wave Model* Call Number V8988 10 minutes	This program is an examination of the development of Christian Huygens' wave model of light behaviour, which eventually superseded Newton's particle model. The program illustrates how energy is transmitted through a medium, and demonstrates Thomas Young's theory of light interference, as well as Jean Foucault's observations on the speed of light.
327-11	*The Electromagnetic Model* Call Number V8989 10 minutes	This program illustrates James Maxwell's prediction of the existence of electromagnetic waves and Heinrich Hertz's verification of their existence. At this point in time, the wave model of light behaviour was accepted totally, and the particle model was abandoned.
Waves and Modern Physics: Bohr Atoms and Quantum Atoms		
329-2, 329-3, 329-7	*The Quantum Idea* Call Number V8990 10 minutes	This is a look at Max Planck's theory of energy emissions as bundles, which he called quanta, and Albert Einstein's explanation of the photoelectric effect. The program describes how these discoveries led scientists to use both the particle and the wave models to describe the behaviour of light.
329-2, 329-3, 329-7	*Photons* Call Number V8991 10 minutes	This program illustrates the roles of both the particle and the wave models in explaining the behaviour of light. Demonstrations show how the work of Arthur Compton and Geoffrey Taylor reinforced each of these models.
329-2, 329-3, 329-7	*Matter Waves* Call Number V8992 10 minutes	This videotape is a look at Louis de Broglie's prediction that particles sometimes behave like waves, and the conditions under which this occurs. The program shows the differences between photons and electrons, and illustrates the need of both the wave and particle models to explain the behaviour of electromagnetic radiation.

Outcomes	Title	Description
329-2, 329-3, 329-7	*Spectra* Call Number V9450 10 minutes	This is an examination of Bohr's revolutionary proposals, which, brought atomic structure into the realm of quantum physics. Using spectroanalysis, Bohr was able to predict all frequencies of radiation for the hydrogen atom, but his model could not predict the behavior of more complex atoms.
329-2, 329-3, 329-7	*Bohr Model* Call Number V9449 10 minutes	Neil Bohr was able to salvage Rutherford's model of the atom, in spite of its shortcomings. Bohr studied quantized energies, orbit radii, and electron velocities and concluded that electrons may occupy only certain precise orb orbits, or energy levels. He was then able to predict the speed and energy of the electron in each orbit, using the simplest atom—hydrogen.
Radioactivity: Natural and Artificial Sources of Radiation		
329-5, 326-9	*Discovery of Radioactivity* Call Number V9470 10 minutes	This introductory program explores the nature of radioactivity and presents an historical overview of the scientific developments that led to its discovery. The research of Faraday, Röntgen, and the Curies is examined, and Becquerel's discovery of radioactivity is highlighted.
329-5, 326-9	*Too Hot to Handle: The Nature of Radioactivity* Call Number V0798 17 minutes	The program examines the forty-plus years between Hiroshima and Chernobyl, from the glowing promises made for nuclear power to anti-nuclear pickets. It shows how the simpler elements are constituted and why some heavier ones are unstable; the four kinds of radiation and how they work; where they appear in nature; and why radon gas poses such danger. Humans have evolved on a radioactive planet, eat radioactive food, and live in radioactive houses. What are the realistic dangers of nuclear power plant emissions? The program provides an outline answer.
Radioactivity: Radioactive Decay		
329-4, 214-2	*Properties of Becquerel Rays* Call Number V9471 10 minutes	The discovery of Becquerel rays and their properties and the Curies' experiments with radioactive sources are recreated. Experiments conducted by Rutherford illustrate the properties of the three types of radiation—alpha, beta, and gamma.

Outcomes	Title	Description
329-4, 214-2	*Natural Transmutations* Call Number V9472 10 minutes	Demonstrations at the atomic level show how elements are transformed into new elements, or isotopes, through the process of decay. Three types of radioactive decay are explained and the concept of half-life is discussed.
329-4, 214-2	*Energy from the Nucleus* Call Number V9473 10 minutes	This program examines the process of radioactive decay, and how Einstein's special theory of relativity applies. The conversion of mass to energy is recreated in various simulations such as nuclear fission and nuclear fusion.
Radioactivity: Fission and Fusion		
329-6	*Electrical Energy from Fission* Call Number V9474 10 minutes	A review of nuclear fission demonstrates how the process can lead to chain reactions, controlled and harnessed in nuclear reactors. Outlining the functioning of a nuclear reactor step by step, the program shows how energy is produced and transmitted as electricity.
329-6	*Nuclear By-Products* Call Number V9475 10 minutes	The fission process in the core of a nuclear reactor is illustrated, with emphasis on the dual nature of the by-products. A discussion of the long life of the nuclear waste produced, the difficulty of disposal, and the drawbacks of nuclear reactors as sources of energy occurs.
329-6	*Nuclear Fusion* Call Number V0851 25 minutes	Paul Hewitt graphically explores $E=mc^2$ to explain nuclear fusion.
329-6	*Fusion: A Work in Progress* Call Number 20899 25 minutes	A successfully operating fusion power plant would have the capacity to provide the world with almost unlimited energy. We meet Nobel Prize winner Hans Bethe, who discovered how the fusion process generates the power of the sun; Lyman Spitzer Jr., who pioneered fusion technology research, and other notable scientists. Animation reveals the natural fusion process in the sun and explains the difference between the two main energy-releasing nuclear processes, fission and fusion. The magnetic confinement and inertial confinement methods employed by fusion researchers are explained. Teacher's guide included.

Appendix C: Resources

Legend

1. *Conceptual Physics, Third Edition*, Hewitt (1997)
2. *Conceptual Physics, Laboratory Manual*, Hewitt (1992)
3. *Fundamentals of Physics, A Senior Course*, Martindale, Heath, Eastman (1986)
4. *Fundamentals of Physics, Combined Edition*, Martindale, Heath, Eastman (1992)
5. *Physics, Fifth Edition*, Giancoli (1998)
6. *Physics, Fourth Edition*, Giancoli (1995)
7. *Physics, Principles and Problems*, Merrill (1992)
8. *Physics, Principles and Problems, Laboratory Manual*, Merrill (1992)
9. *Physics Labs with Computers for ScienceWorkshop and DataStudio*, Pasco Scientific (1999)
10. *Physics with CBL*, Vernier (1998)

Outcome	Resource	Topic	Reference
Kinematics: Presenting Vectors			
Text References			
325-7	1	Frames of Reference	p. 10 (Chapter 2.1)
325-7	3	Frames of Reference	p. 103 (Chapter 3.7)
325-7	4	Frames of Reference	p. 104 (Chapter 3.7)
325-7	6	Frames of Reference	p. 20 (Chapter 2.1)
325-7	5	Frames of Reference	p. 20 (Chapter 2.1)
Lab Reference			
325-7	7	Frames of Reference	p. 114 (Chapter 6)
Kinematics: Vector Analysis			
Text References			
325-5	1	Vector Basics	pp. 28–31 (Chapters 3.1–3.2)
325-5	3	Vector Basics	pp. 42–45 (Chapter 2.1) pp. 94–97 (Chapter 3.4)
325-5	4	Vector Basics	pp. 42–45 (Chapter 2.1) pp. 95–98 (Chapter 3.4)
325-5	6	Vector Basics	pp. 23–24 (Chapter 2.6)
325-5	5	Vector Basics	pp. 48–51 (Chapters 3.1–3.2)

Outcome	Resource	Topic	Reference
Lab References			
325-5	9	Acceleration Due to Gravity	Experiment P06
325-5	8	Acceleration Due to Gravity	p. 19 (Experiment 4.2)
325-5	10	Acceleration Due to Gravity	Experiments 5 and 6
Kinematics: Algebraic Problem Solving			
Text References			
325-2	3	Graphing Motion	pp. 47–74 (Chapters 2.3–2.13)
325-2	4	Graphing Motion	pp. 47–74 (Chapters 2.3–2.13)
325-2	7	Graphing Motion	pp. 48–56 (Chapters 3.1–3.2) pp. 64–69 (Chapter 4.1)
325-2	6	Problem-Solving Techniques	p. 29 (Chapter 2.9)
325-2	5	Problem-Solving Techniques	p. 29 (Chapter 2.6)
325-2	7	Algebraic Problem Solving	pp. 71–80 (Chapter 4.2)
325-2	3	Algebraic Problem Solving (SIN)	pp. 80–87 (Chapter 2.15)
325-2	4	Algebraic Problem Solving (SIN)	pp. 80–88 (Chapter 2.15)
Dynamics: Dynamics Introduction			
Text References			
116-6, 116-7	4	Natural and Technological Systems	p. 79 (Chapter 2) p. 134 (Chapter 4)
116-6, 116-7	7	Natural and Technological Systems	p. 211 (Chapter 10.2) p. 277 (Chapter 13.1)
325-5	3	Free-Body Diagrams	pp. 134–135 (Chapter 4.4)
325-5	4	Free-Body Diagrams	pp. 136–137 (Chapter 4.4)
325-5	6	Free-Body Diagrams	p. 87 (Chapter 4.7)
325-5	5	Free-Body Diagrams	p. 91 (Chapter 4.7)
Lab Reference			
325-5	7	Spring Scale	p. 98 (Chapter 5)
Dynamics: Newton's Laws			
Text References			
325-8	1	Newton's First Law	pp. 43–55 (Chapter 4)
325-8	3	Newton's First Law	pp. 130–132 (Chapter 4.3)

Outcome	Resource	Topic	Reference
325-8	4	Newton's First Law	pp. 132–134 (Chapter 4.3)
325-8	6	Newton's First Law	pp. 75–77 (Chapters 4.2–4.3)
325-8	5	Newton's First Law	pp. 78–80 (Chapters 4.2–4.3)
325-8	1	Newton's Second Law	pp. 59–70 (Chapter 5)
325-8	3	Newton's Second Law	pp. 132–138 (Chapter 4.4)
325-8	4	Newton's Second Law	pp. 134–140 (Chapter 4.4)
325-8	6	Newton's Second Law	pp. 77–80 (Chapter 4.4)
325-8	5	Newton's Second Law	pp. 80–82 (Chapter 4.4)
325-8	1	Newton's Third Law	pp. 74–82 (Chapter 6)
325-8	3	Newton's Third Law	pp. 144–147 (Chapter 4.6)
325-8	4	Newton's Third Law	pp. 146–149 (Chapter 4.6)
325-8	6	Newton's Third Law	pp. 80–83 (Chapter 4.5)
325-8	5	Newton's Third Law	pp. 83–86 (Chapter 4.5)
325-8	3	Gravitational Force	pp. 154–161 (Chapters 5.1–5.3) pp. 166–171 (Chapters 5.5–5.7)
325-8	4	Gravitational Force	pp. 158–165 (Chapters 5.1–5.3) pp. 170–175 (Chapters 5.5–5.7)
325-8	6	Gravitational Force	pp. 83–85 (Chapter 4.6)
325-8	5	Gravitational Force	pp. 87–89 (Chapter 4.6)
325-8	1	Friction	pp. 63–64 (Chapter 5.4)
325-8	3	Friction	pp. 162–166 (Chapter 5.4)
325-8	4	Friction	pp. 166–170 (Chapter 5.4)
325-8	6	Friction	pp. 92–94 (Chapter 4.8)
325-8	5	Friction	pp. 96–98 (Chapter 4.8)
115-3	3	Theories of the Universe	pp. 264–275 (Chapters 7.1–7.6)
115-3	4	Theories of the Universe	pp. 208–219 (Chapters 6.1–6.6)
Activity References			
325-8	1	Newton's First Law	p. 25 (Activity 7) p. 27 (Activity 8)
325-8	1	Newton's Second Law	p. 61 (Chapter 5.3)
325-8	2	Newton's Second Law	p. 29 (Activity 9)
325-8	2	Newton's Third Law	p. 45 (Activity 13)
325-8	7	Friction	p. 100 (Chapter 5.2)

Outcome	Resource	Topic	Reference
Lab References			
325-8	2	Newton's Second Law	p. 33 (Experiment 10) p. 37 (Experiment 11)
325-8	3	Newton's Second Law	p. 148 (Chapter 4.7)
325-8	4	Newton's Second Law	p. 150 (Chapter 4.7)
325-8	9	Newton's Second Law	Experiments P08 and P09
325-8	8	Newton's Second Law	p. 25 (Experiment 5.1)
325-8	10	Newton's Second Law	Experiment 9
325-8	2	Newton's Third Law	p. 47 (Experiment 14) p. 51 (Experiment 15)
325-8	10	Newton's Third Law	Experiment 11
325-8	7	Gravitational Force	p. 98 (Chapter 5.2)
325-8	2	Friction	p. 95 (Experiment 29)
325-8	9	Friction	Experiment P21
325-8	8	Friction	p. 29 (Experiment 5.2)
325-8	10	Friction	Experiment 12
Dynamics: Momentum Introduction			
Text References			
116-5	1	Momentum and Impulse	pp. 86–92 (Chapters 7.1–7.3)
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328-4	1	Coulomb's Law	pp. 504–507 (Chapter 32.3)
328-4	3	Coulomb's Law	pp. 579–587 (Chapter 15.3)
328-4	4	Coulomb's Law	pp. 585– 593 (Chapter 15.3)
328-4	6	Coulomb's Law	pp. 459–464 (Chapters 16.5–16.6)
328-4	5	Coulomb's Law	pp. 481–485 (Chapters 16.5–16.6)

Outcome	Resource	Topic	Reference
Fields: Electric Circuits			
Text References			
ACP-3	1	Current, Resistance, Potential Difference, and Power	pp. 531–538 (Chapters 34.1–34.6)
ACP-3	3	Current, Resistance, Potential Difference, and Power	pp. 593–597 (Chapter 15.5)
ACP-3	4	Current, Resistance, Potential Difference, and Power	pp. 625–637 (Chapters 16.1–16.4)
ACP-3	6	Current, Resistance, Potential Difference, and Power	pp. 503–509 (Chapters 18.1–18.3) pp. 512–515 (Chapter 18.6)
ACP-3	5	Current, Resistance, Potential Difference, and Power	pp. 527–534 (Chapters 18.1–18.3) pp. 538–541 (Chapters 18.6–18.7)
ACP-3	1	Series and Parallel Circuits	pp. 548–558 (Chapters 35.1–35.7)
ACP-3	4	Series and Parallel Circuits	pp. 640–666 (Chapters 17.1–17.6)
ACP-3	6	Series and Parallel Circuits	pp. 528–534 (Chapter 19.1) pp. 535–539 (Chapters 19.3–19.4) pp. 546–548 (Chapter 19.10)
ACP-3	5	Series and Parallel Circuits	pp. 555–561 (Chapter 19.1) pp. 564–567 (Chapters 19.3–19.4) pp. 575–577 (Chapter 19.10)
Activity Reference			
ACP-3	2	Electric Circuits	p. 277 (Activity 87) p. 287 (Activity 90)
Lab References			
ACP-3	1	Electric Circuits	p. 514 (Chapter 32.7)
ACP-3	2	Electric Circuits	p. 283 (Experiment 89) p. 291 (Experiment 91)
ACP-3	4	Electric Circuits	pp. 667–671 (Chapter 17.7)
ACP-3	8	Electric Circuits	p. 149 (Experiment 22.1) p. 157 (Experiment 23.1) p. 161 (Experiment 23.2)
ACP-3	10	Electric Circuits	Experiments 25, 26, and 30
Fields: Electromagnetism and Electromagnetic Induction			
Text References			
328-6, 328-5, 328-7	1	Electromagnetism	p. 571 (Chapter 36.7)
328-6, 328-5, 328-7	3	Electromagnetism	pp. 623–626 (Chapter 16.2)

Outcome	Resource	Topic	Reference
328-6, 328-5, 328-7	4	Electromagnetism	pp. 681–686 (Chapters 18.2–18.3)
328-6, 328-5, 328-7	1	Electromagnetic Induction	pp. 577–579 (Chapters 37.1–37.2)
328-6, 328-5, 328-7	4	Electromagnetic Induction	pp. 738–744 (Chapters 19.1–19.4)
328-6, 328-5, 328-7	6	Electromagnetic Induction	pp. 589–595 (Chapters 21.1–21.4)
328-6, 328-5, 328-7	5	Electromagnetic Induction	pp. 622–628 (Chapters 21.1–21.4)
Activity Reference			
328-6, 328-5, 328-7	2	Electromagnetism	p. 299 (Activity 94) p. 303 (Activity 95)
Lab References			
328-6, 328-5, 328-7	8	Electromagnetism	p. 171 (Experiment 24.2) p. 175 (Experiment 24.3)
328-6, 328-5, 328-7	10	Electromagnetism	Experiments 28 and 29
328-6, 328-5, 328-7	4	Electromagnetic Induction	pp. 761–763 (Chapter 19.8)
328-6, 328-5, 328-7	9	Electromagnetic Induction	Experiment P30
328-6, 328-5, 328-7	8	Electromagnetic Induction	p. 179 (Experiment 25.1) p. 183 (Experiment 25.2)
Fields: Generators and Motors			
Text References			
328-9, ACP-4	1	Transformers	pp. 583–586 (Chapter 37.5)
328-9, ACP-4	4	Transformers	pp. 752–759 (Chapters 19.6–19.7)
328-9, ACP-4	6	Transformers	pp. 600–602 (Chapter 21.7)
328-9, ACP-4	5	Transformers	pp. 633–637 (Chapter 21.7)
328-9, ACP-4	1	Generators	pp. 580–582 (Chapter 37.3)
328-9, ACP-4	4	Generators	pp. 745–752 (Chapter 19.5)
328-9, ACP-4	6	Generators	pp. 595–598 (Chapter 21.5)

Outcome	Resource	Topic	Reference
328-9, ACP-4	5	Generators	pp. 629–631 (Chapter 21.5)
328-9, ACP-4	1	Motors	pp. 582–583 (Chapter 37.4)
328-9, ACP-4	4	Motors	pp. 695–698 (Chapter 18.5)
328-9, ACP-4	6	Motors	pp. 573–574 (Chapter 20.9)
328-9, ACP-4	5	Motors	pp. 604–605 (Chapter 20.10)
Lab Reference			
328-9, ACP-4	4	Generators and Motors	pp. 728–730 (Chapter 18.12)
Waves and Modern Physics: Quantum Physics			
Text References			
326-9, 327-9, 327-10	1	Quantum Physics	pp. 636–639 (Chapter 40.5)
326-9, 327-9, 327-10	3	Quantum Physics	pp. 694–705 (Chapters 18.1–18.2) pp. 686–688 (Chapter 17.6)
326-9, 327-9, 327-10	4	Quantum Physics	pp. 768–779 (Chapters 20.1–20.2) pp. 906–907 (Chapter 24.1)
326-9, 327-9, 327-10	6	Quantum Physics	pp. 774–779 (Chapters 27.2–27.3)
326-9, 327-9, 327-10	5	Quantum Physics	pp. 826–832 (Chapters 27.2–27.3)
Activity Reference			
326-9, 327-9, 327-10	2	Quantum Physics	p. 305 (Activity 96)
Waves and Modern Physics: Compton and de Broglie			
Text References			
329-1	1	Compton and de Broglie	pp. 600–601 (Chapter 38.5)
329-1	3	Compton and de Broglie	pp. 705–708 (Chapter 18.3) pp. 713–717 (Chapter 18.5)
329-1	4	Compton and de Broglie	pp. 779–782 (Chapter 20.3) pp. 787–791 (Chapter 20.5)
329-1	6	Compton and de Broglie	pp. 780–784 (Chapters 27.4–27.6) pp. 796–798 (Chapter 27.11)
329-1	5	Compton and de Broglie	pp. 833–838 (Chapters 27.4–27.6) pp. 851–852 (Chapter 27.11)

Outcome	Resource	Topic	Reference
Waves and Modern Physics: Particles and Waves			
Text References			
327-11	1	Particles and Waves	pp. 600–601 (Chapter 38.5)
327-11	3	Particles and Waves	pp. 709–713 (Chapter 18.4)
327-11	4	Particles and Waves	pp. 783–787 (Chapter 20.4)
Waves and Modern Physics: Bohr Atoms and Quantum Atoms			
Text References			
329-2, 329-3, 329-7	1	Bohr Atoms and Quantum Atoms	pp. 601–603 (Chapter 38.6)
329-2, 329-3, 329-7	3	Bohr Atoms and Quantum Atoms	pp. 730–737 (Chapters 19.1–19.2) pp. 750–761 (Chapters 19.6–19.8)
329-2, 329-3, 329-7	4	Bohr Atoms and Quantum Atoms	pp. 828–835 (Chapters 22.1–22.2) pp. 848–859 (Chapters 22.6–22.8)
329-2, 329-3, 329-7	6	Bohr Atoms and Quantum Atoms	pp. 786–796 (Chapters 27.8–27.10)
329-2, 329-3, 329-7	5	Bohr Atoms and Quantum Atoms	pp. 840–850 (Chapters 27.8–27.10)
Radioactivity: Natural and Artificial Sources of Radiation			
Text References			
329-5, 326-9	4	Natural and Artificial Sources of Radiation	pp. 816–818 (Chapter 21.6)
329-5, 326-9	6	Natural and Artificial Sources of Radiation	pp. 863–864 (Chapter 30.3)
329-5, 326-9	5	Natural and Artificial Sources of Radiation	pp. 922–923 (Chapter 30.3)
Radioactivity: Radioactive Decay			
Text References			
329-4, 214-2	1	Radioactive Decay	pp. 610–625 (Chapters 39.2–39.11)
329-4, 214-2	3	Radioactive Decay	pp. 770–780 (Chapters 20.1–20.3)
329-4, 214-2	4	Radioactive Decay	pp. 870–889 (Chapters 23.1–23.9)
329-4, 214-2	6	Radioactive Decay	pp. 864–875 (Chapters 30.4–30.11)
329-4, 214-2	5	Radioactive Decay	pp. 923–935 (Chapters 30.4–30.11)
Activity Reference			
329-4, 214-2	2	Radioactive Decay	p. 313 (Activity 98)

Outcome	Resource	Topic	Reference
Radioactivity: Fission and Fusion			
Text References			
329-6	1	Fission	pp. 630–639 (Chapters 40.1–40.5)
329-6	4	Fission	pp. 908–921 (Chapters 24.2–24.6)
329-6	6	Fission	pp. 885–891 (Chapter 31.2)
329-6	5	Fission	pp. 947–952 (Chapter 31.2)
329-6	1	Fusion	pp. 639–642 (Chapters 40.6–40.7)
329-6	4	Fusion	pp. 922–925 (Chapters 24.7–24.8)
329-6	6	Fusion	pp. 891–895 (Chapter 31.3)
329-6	5	Fusion	pp. 953–958 (Chapter 31.3)
Activity Reference			
329-6	2	Fission and Fusion	p. 315 (Activity 99)

Appendix D: The Research Process

The research process involves many different skills and strategies grouped within phases or stages. The process is cumulative in nature, each stage laying the groundwork for the next. The phases or stages are commonly identified as

- planning (or pre-research)
- accessing and gathering information (or information retrieval)
- evaluating and interacting with information
- organizing information
- creating new information
- preparing, sharing, and presenting information
- evaluating the research process

Students' use of the information process is not linear or purely sequential. A new piece of information, artifact, or conversation with a resource person may lead a student to revise a question under consideration, determine a perspective or point of view from which to examine critically the information available, or develop an alternative plan.

Planning

During the introductory stage of the research process, students usually

- identify the topic or question—decide on a general area of interest that warrants further investigation, then clarify or narrow the area of focus to make it manageable
- formulate broad and specific questions to guide their research
- identify a variety of potential sources of information
- decide what strategies they will use to record information and keep track of the materials they use

Accessing and Gathering Information

Students access appropriate resources (print, non-print, information technology, human, community). The actual resource is located, and the information is found within the resource. Students will need to learn and apply several important skills:

- search (with direction) a card catalogue, electronic catalogue, the World Wide Web to identify potential information resources such as books, journals, newspapers, videos, audios, databases, or other media
- locate resources (e.g., community, text, magazines, artifacts from home, World Wide Web sites) and determine appropriate ways of gaining access to them
- select appropriate resources in a range of media

- use organizational tools and features within a resource (e.g., table of contents, index, glossary, captions, menu prompts, knowledge tree for searching electronically, VCR counter to identify video clips for specific relevance)
- skim, scan, view, and listen to information to determine the point of view or perspective from which the content is organized/presented
- determine whether the content is relevant to the research question
- determine whether the information can be effectively shaped and communicated in the medium the student will use to complete the project

Teachers should help students realize that fewer appropriate resources are better than a multitude of inappropriate resources.

Interacting with Information

Students continue critical evaluation of the information they find to determine if it will be useful in answering their questions. Students apply reading, viewing, listening, and critical thinking skills to

- question, skim, read (QSR)
- use text features such as key words, bold headings, and captions
- use navigation features or software
- use pause points or topic shift points in video
- read and interpret charts, graphs, maps, and pictures
- listen for relevant information
- scan videos, bookmark and highlight Web sites
- compare and evaluate content from multiple sources and media
- determine accuracy, relevance, and completeness of information

Teachers should help students develop a range of strategies for recording the information they need to explore their topic and answer their guiding questions. Simple point form notes (facts, key words, phrases) should be written or recorded symbolically (pictures, numerical data) in an appropriate format, such as a concept map, Web site, matrix sheet, chart, computer database, or spreadsheet. Teachers may also need to assist students in citing sources of information accurately and obtaining appropriate copyright clearances for images, data, sounds, and text they intend to reference or include in their work.

Organizing Information

Students may use a variety of strategies to organize the information they have collected while exploring their topics and answering their guiding questions:

- numbering
- sequencing
- colouring, highlighting notes according to questions or categories
- establishing directories of files
- creating a Web page of annotated links to relevant Internet sources

- archiving e-mail collaborations using subject lines and correspondents' names
- creating a database of images and sound files using software such as ClarisWorks

Students should review their information with regard to their guiding questions and the stated requirements of the activity to determine whether they need additional information or further clarification before creating their products, planning their performances or presentations, or exhibiting their work. They may need to re-frame the research in light of information and sources gathered.

Sharing Information

Students review and reflect on the information they have collected, connecting new ideas with their prior knowledge and evaluating new information that may not fit with their previous understandings. As they integrate new information into their current knowledge, students develop new understandings and draw conclusions. Teachers may need to assist students in deciding how best to convey the results of their research process to the intended audience. Students should have many opportunities to share with a variety of audiences what they have learned, discovered, and created, and opportunities to examine carefully the responses of those audiences to their work.

Evaluating the Research Process

Students should reflect on the skills and learning strategies they are using throughout activities and examine and discuss their learning processes. Teachers and library professionals can help students with evaluation by

- providing time and encouragement for reflection and metacognition to occur (e.g., What did we/you learn about gathering information?)
- creating a climate of trust for self-assessment and peer-assessment of process, creation, or performance (students tend to be realistic and have high expectations for their own work)
- asking questions, making observations, and guiding discussions throughout the process
- conferencing
- monitoring and providing feedback on student progress (e.g., demonstrated ability to organize notes)

Media Analysis

The development of media analysis skills is an important component of Physics 11 and Physics 12. Media studies can be integrated into the curriculum as a source of current information, as a means to stimulate student interest and discussion, and as a vehicle to present real-world issues and situations to students. It is important for students to be able to evaluate media critically. Students should be able to distinguish fact from opinion and propaganda from responsible, objective reporting. Analysis of media products requires students to consider the following:

- the purpose and qualification of the author(s)
- the type of source and how that source is monitored (e.g., an established newspaper as opposed to an article appearing on an interest group's site on the Internet)
- the type of audience that the information is directed toward
- the reasons a particular target audience was chosen
- the ways the author(s) chose to reach that audience
- identification of inaccuracies, contradictions, or illogical reasoning
- the presentation of opinions
- evidence of bias in the work
- the source(s) of information and the interpretation of that information by the author
- the presentation of unsupported ideas and/or conclusions

When analysing advertising, students should focus their attention on the use of unsupported conclusions, testimonials by unknown or unqualified people, and the use of unsubstantiated events or quotes to draw conclusions.

Evaluation of Media Analysis

The evaluation process for a media assignment in Physics 11 and Physics 12 will depend on the nature of the assignment and the criteria established by both the teacher and students. Criteria might include the following:

- the inclusion of appropriate physics-related materials
- the use of a wide variety of relevant sources
- sources properly identified
- appropriate physics concepts identified
- purpose(s) of material properly identified
- target audience identified
- point of view identified
- open, unbiased approach to analysis

Appendix E: Communication Tools

Photography: Individual students might create a photo documentary of a theme, concept, person, place, or event and with it also show consideration for how this documentary can affect its audience through various ways in which can be presented.

Photoshop or Corel Photopaint: pairs of students might walk through the tutorials that accompany one of these programs. They might also follow tutorials created by their teacher or from quality publications. Such tutorials could be designed so that by the end of this tutorial students have significantly altered the text of an image exhibiting thoughtful consideration for the elements and principles of design.

Adobe Illustrator or Corel Draw: Pairs of students might walk through tutorials that accompany one of these programs. They might also follow tutorials created by their teacher or from quality publications. Such tutorials could be designed so that, by the end of a tutorial, students have

- created a series of drawings that render a form in a variety of finishes
- developed a complex rendering of a form where a combination of graphic tools and filters has been used
- created a range of non-representational forms that illustrate the essential character of various principles of design

PageMaker or Quark Express: Pairs of students might walk through the tutorials that accompany one of these programs. They might also follow tutorials created by their teacher or from quality publications. Such tutorials could be designed so that by the end of this tutorial, through the incorporation of several devices unique to layout computer applications, students have

- created a pamphlet promoting an event or place
- designed a poster which promotes an event, idea, business, or place
- produced a mock magazine layout that could be convincingly inserted into an existing publication

HTML editors: Pairs of students might walk through the tutorials that accompany one of these programs. They might also follow tutorials created by their teacher or from quality publications. Such tutorials could be designed so that, by the end of this tutorial, students have

- created a personal Web page
- developed a Web page for a local business
- significantly and convincingly altered existing Web pages

PowerPoint or Director: Pairs of students might walk through the tutorials that accompany one of these programs. They might also follow tutorials created by their teacher or from quality publications. Such tutorials could be designed so that, by the end of a tutorial, students have

- created a slide show that illustrates interests particular to the student
- created a small interactive game
- incorporated video tools to produce a small video project

Video: Teams of students could write, star in, and produce a short video that focusses on one or more basic video styles.

Avid Cinema: Pairs of students might walk through the tutorials that accompany one of these programs. They might also follow tutorials created by their teacher. Such tutorials could be designed so that, by the end of a tutorial, students have

- recorded, edited, and arranged a short video
- manipulated found video and sound footage to create a coherent production

Printmaking: individual students could use a conventional hands-on printmaking tool to create a consistent edition of ten prints using one or more colours or plates.

Sculpture: individual students could create text in a three-dimensional form through

- an additive sculpture made out of wire, clay, or Plasticine
- a subtractive sculpture from a block of plaster, soapstone, clay, or Styrofoam
- the alteration of existing three-dimensional forms to create new coherent texts

Performance Art: Individual or teams of students could observe and identify the essential elements of existing examples of quality performance art work and create their own short performance piece.

Drawing: Individual students might

- examine great examples of portraiture (e.g., Albrecht Dürer, Leonardo da Vinci, Michelangelo Buonarroti) and execute his or her own series of portrait works
- create a journal of marks. Students could investigate various mediums and marks used to construct texts in drawing, from which students might create their own drawings in the visual languages they have observed and made their own.

Painting: Students might use professional-quality paints to

- create a painting that convincingly makes use of a style mastered by another artist for a specific purpose
- interpret, through paint, the text of a musical work
- represent objects, people, or places in an interpretive way or with coherent aesthetic likeness

- create a series of paintings that permit students to investigate how paints and colours relate (e.g., students could create a painting in purely analogous hues, another in complementary hues, one in earth tones, and perhaps one using a high key or low key palette)

Notes: Using layout software may provide a good opportunity for students to extend their learning beyond the classroom by undertaking projects for other classes, school clubs and organizations, or local businesses and community groups.

Considering potential time, safety, and economic restrictions, screen printing or block printing are recommended for printmaking activities.

A good subject for sculpture can be the human form or simple physical objects. Students could also design a formalist sculpture that clearly illustrates one or more of the elements or principles of design.

Good examples of performance art can be found in the works of Joseph Beuys, the General Idea, Suzy Lake, happenings from the1960s and 1970s, Russian constructivist performances, Holly Hughes, Michael Snow, Laurie Anderson, etc.

Other great examples of drawing through a variety of mark making styles can be found among the works of: traditional English landscape artists, Egon Schiele, Giorgio Morandi, Alberto Giacometti, Claes Oldenburg, Vincent Van Gogh, traditional Japanese artists, Jean-Michel Basquiat, Anselm Kiefer, Betty Goodwin, etc.

Though paints do tend to place stress on classroom finances, it is suggested that teachers do not resolve this by providing poor-quality paints. Painting can be very frustrating, especially to those engaging in it for the first time. Poor-quality paints tend to compound the negative aspects of painting for the student. Good and inexpensive paints are available from many suppliers, though often not in famous brand names. Consult suppliers who specialize in providing artists with materials.

There are many user-friendly HTML editors available for purchasing and as shareware. Netscape Communicator, for instance, provides a good, though basic, composer.

Students can experiment in one or a combination of the following video styles: expository, personification, dramatic, and documentary formats.

Appendix F: Journals and Logbooks

Logbooks and journals are a part of many occupations and as such are highly reflective of the world of work. Many highly successful people keep a daily journal as a habit that helps them develop insights into their work. A journal can include sketches, diagrams, notes, quotes, questions, excerpts, and drafts.

The logbook or journal may be used to develop a final product, such as a report, design, profile, fictional text or dramatization, or it may be a way of tracking progress and developing ideas and insights.

Student need to see the value of their journal writing, not only through frequent responses from the teacher, including assessments that "count," but also through assignments that provide linkages to previous and subsequent learning or that meet specific learning and/or personal needs for the student.

Since the logbook or journal can contain very personal thoughts and ideas stimulated by thought-provoking questions, the teacher must make provisions to honour the confidentiality of students' work, except where legally required to do otherwise.

Elements of the following journal assessment rubrics can be used in various combinations.

Journal Comment Rubric	
Name	Comments
Ideas • interprets and analyses issues • describes new insight(s)	
Critical Thinking • identifies assumptions underlying an issue, problem, or point of view • probes beneath the surface for layers of significance • explains an issue from multiple perspectives	
Ethical Reasoning • uses rules or standards of right/wrong or good/bad to guide debate/reflection	
Personal Experience • connects insights/thoughts to personal experience	
Development • content thoroughly developed	

Journal Scoring Rubric					
	1	2	3	Assessment Student/Teacher	
Ideas	states facts	interprets and/or analyses an issue	interprets, analyses, and describes a new insight(s)		
Critical Thinking	responds to a stated issue, problem, or point of view	identifies assumptions underlying an issue, problem, or point of view	questions assumptions underlying an issue, problem, or point of view		
Critical Thinking	responds to a stated issue, problem, or point of view	identifies more than one layer of significance	probes beneath the surface for multiple layers of significance		
Critical Thinking	describes a single response to a situation or problem	describes several responses to a situation or problem	sees implications of alternative responses to a situation or problem		
Critical Thinking	explains an issue from one perspective	explains an issue from more than one perspective	explains an issue from multiple perspectives		
Ethical Reasoning	does not consider ethical aspects of issues	recognizes and often applies standards/rules	uses rules or standards of right/wrong or good/bad to guide debate/reflection		
Personal Experience	does not personalize journal	makes some connection to personal experience	connects insights and thoughts to personal experience		
Development	minimal development	content adequately developed	content thoroughly developed		
NAME:			SCORE:		

Appendix G: Examples of Instructional Strategies and Approaches

Teachers recognize that an effective learning environment is one in which students interact with each other co-operatively, construct meaning, and confirm understanding through conversation. Such a learning environment is dynamic. It is one in which teachers guide students in searching for meaning, acknowledging and valuing uncertainty, and assuming a large measure of responsibility for their own learning. Particular strategies and approaches have been developed that foster such a climate. Brief descriptions of a number of these follow.

Group Discussion

Turn to Your Partner and (TTYPA)

This strategy is used frequently in interactive classrooms. As a concept or idea is presented to the class, students are asked to turn to a partner and talk about it. Students explore personal connections to the topic under discussion. By articulating ideas to each other, students enhance their learning. These short interactions are followed by a transition to a small-group or full-group discussion.

Think/Pair/Share

In the think/pair/share design of co-operative interaction, a teacher's question is deliberately followed by 3–10 seconds of silence, called "wait time" by its original researcher, Mary Budd Rowe. After giving students sufficient wait time to think through a question and make some personal connections, the teacher asks the members of the pairs to share their thinking with each other. As students share their ideas, each partner can benefit from the other's perspective. Partners examine their statements, searching for examples and clarifying their thinking. The teacher may ask the partners to synthesize their ideas into one.

Triads: Observer Feedback

In this strategy, partner work is complemented by a third role, that of an observer. While partners engage in the learning task, the observer outside the interaction records observable behaviours and later provides feedback to the pair.

Triads: Three-Step Interview

Students work in triads. Each group member assumes, in turn, one of three different roles: interviewer, interviewee, or recorder. Usually the teacher provides a number of open-ended interview questions and a form for recording responses. Though the initial questions are pre-established, interviewers are encouraged to use their own questions to prompt and probe.

Triads: Carousel Activity

In this activity, students have the opportunity to develop a collective knowledge base and respond to one another's ideas and opinions. Open-ended questions are written on pieces of chart paper. The questions are placed in accessible locations around the classroom, and student triads move in rotation to these sites. They record their knowledge and/or viewpoints and respond to the ideas of prior groups. Triads may prepare for this activity in a variety of ways (e.g., by reading related material or watching a video). Through full-class critical dialogue, students review their ideas and opinions.

Co-operative Learning in Groups

Co-operative learning occurs when students work together in groups of three to five to accomplish shared goals. The co-operative groups work on a particular task. Participants work over a period of days or weeks on a shared assignment. The co-operative "base group," heterogeneous in nature, may be in place for a long term, possibly the duration of the course. Its members help, encourage, and support one another over the long term. Formal co-operative learning groups may work together for several weeks to complete specific tasks and assignments. Informal co-operative learning groups are temporary, ad hoc groups that work together for a few minutes or a single class period to process information through, for example, three-to five-minute focussed discussions or two- to three-minute turn-to-your-partner discussions. Key elements for co-operative groups include positive independence, individual accountability, group processing, social skills, and face-to-face interactions. Assigned roles may include timekeeper and recorder.

Jigsaw Activity

This activity involves students in learning and teaching. In essence, individual students become familiar with a portion of an assigned task and "teach" the selected material or skill to a small group of their peers. Two types of groupings are involved: base and expert. Each member of the base group selects or is assigned a different portion of the task (e.g., one aspect of curriculum content). Students with the same materials meet as an expert group, review their task, and decide what to teach and how to teach it. Students then return to their base groups and provide a series of mini-lessons as each student shares his/her information and knowledge. To perform the jigsaw effectively, students need explicit instructions on how to select and share information.

Red Tag Technique

This technique is designed to encourage some level of participation from all students and to ensure that individual students do not monopolize group discussions. Each member of the group is given four red tags (the teacher may vary this number). Each time a member makes a contribution, he/she must discard one tag. The group cannot finish the discussions until all the participants have used up their red tags. A student asking a question for clarification does not have to discard a tag. Teachers may wish to have students practise this technique on a topic that generates vigorous discussion such as “gender issues in the hospitality sector.”

Community Circle

A circle provides a supportive setting for a sharing of ideas. In the circle, one person is the speaker. All other group members should listen carefully and respectfully to the speaker. When finished, the speaker turns to the student beside him/her and that student becomes the speaker. This procedure is followed until all students have had an opportunity to speak. Students may pass if they do not wish to speak at that time. This activity is effective in allowing students to share their feelings and ideas. Initially, the teacher may have to take an active role to ensure that individual students in the circle speak in turn and that other students listen carefully. Often a decorated talking stick or South American rain stick is helpful in focussing both speakers and listeners.

Other Strategies

Oral Presentation

Oral presentations are a means by which students communicate ideas, concepts, stories, and research findings to their peers. Oral presentations are important in this course as they allow students to practice and enhance communication skills. Students need to understand the importance of body language (showing confidence and making eye contact with the audience), voice and projection (clear and strong voice), and organization (use of interesting visuals, involving the audience by inviting and answering questions, and keeping within the time frame) in conducting a successful presentation. This process is easier for some students than others, and sensitivity, especially to cultural differences, is required in modelling and coaching.

Dramatic Representation

Drama is a powerful learning tool. It may take many forms and is a particularly important means by which we acknowledge and strengthen varying learning styles and intelligences. In all modules of Physics 11 and 12, opportunities exist for students to represent their understandings through this medium. Many recommended strategies are available in the Drama 10 and 11 curriculum guide. A few follow.

Role-playing is an activity in which students assume a character role in a simulated situation. Role-playing allows students to build on and apply prior knowledge and skills while developing their communication, co-operative, and interpersonal skills.

Readers Theatre is a forum in which students read aloud from scripts (commercial or adapted versions from literature) with no special costumes, sets, props, or music. The whole class or partners can participate in this strategy, which encourages students to reflect on the story, the characters, the author's intent, or the theme.

Dance drama is expressive movement through which ideas, stories, sounds, and music can be interpreted.

A *tableau* is a still image, a frozen moment, or a photograph created by posing still bodies. It communicates a living representation of an event, idea, or feeling and can be a powerful statement to initiate discussion or reflection.

Flash-backs and flash-forwards can be used effectively to help build belief, challenge the students to consider the consequences of their decisions, and support periods of reflection.

Visual Arts, Dance, and Music

Many students have strengths in art, dance, and music that can enhance learning in any subject area. These students can be encouraged to share their expertise and invited to express their understandings through these media.

Debate

A debate is a formal discussion that begins with a statement of one point of view on a particular issue.

Participation in debates allows students to explore different points of view and to respond critically to a range of issues.

The three standard forms of formal debate are

- *Cross examination*—modelled after courtroom procedures; in addition to presenting various points, debaters question or cross-examine their opponents.
- *Academic*—the most basic form, where two teams of two or three members each debate the resolution point by point; emphasis is placed on the debating skills of each team.

Parliamentary—modelled after parliamentary procedure; after the prime minister and the leader of the opposition have spoken, members of the government and the loyal opposition take turns debating various points of the bill before the House.

Choose an interesting, two-sided topic that is relevant to the interests and abilities of the students. Avoid broad or complicated questions or propositions that can never be proved or disproved.

Field Study

Field studies provide the opportunity for students to gain a first-hand impression of an ocean site. The local community often provides an excellent forum for students to investigate a range of experiences. Field studies can be teacher-directed, student-directed, or expert-led experiences. Examples of field studies are

- a walking tour of a local historic area
- a field trip to a museum, attraction, celebration, or cultural site
- a travel experience that focusses on a particular cultural experience such as a milling frolic or a local dance
- a project that includes data gathering, observation, and analysis such as the interviewing of industry professionals

Case Studies

Case studies are written narrative scenarios that typically relay a particular problem or dilemma centred around a set of issues or concerns. Case studies are useful in the study of physics as they allow students to consider situations that they would not normally encounter in class, and they provide a forum for students to practise the skills and knowledge they have gained through classroom instruction.

Students can work individually, in small groups, or as a class to analyse, interpret, and respond to the material. Students should be encouraged to utilize and expand on their knowledge base and skills as they formulate their responses.

Interviewing

The process of preparing and participating in an interview provides a range of learning opportunities and experiences for students to apply and develop their reading, writing, speaking, listening, and critical-thinking skills. Interviews help students gain a better understanding of concepts developed in the classroom setting as well as helping them to build important links among themselves, their community, and their school.

Planning for an interview is crucial for its success and usefulness. Students should research their topic in advance and prepare a list of questions to review with their teacher before the interview. Decisions on the date, time, place, and method of recording should be confirmed well in advance of the interview. A well-prepared and confident student will gain from most interviews a wealth of information and an important connection to their community.

Journal Writing

The use of personal or interactive journals provides an effective means by which students can reflect upon most classroom proceedings and activities. Reflective journals assist students in articulating what they have learned, how they have learned it, and what they want to learn next. The form and content of journals can be tailored to suit the particular activity and the needs of the individual student. It is important that the journal be an interactive means by which teachers can respond to students' questions, concerns, and ideas.

Appendix H: Portfolios

A portfolio is a selection of work samples and other items that demonstrate students' interests, talents, skills, and achievements. The purpose of a portfolio is to show others teachers, counselors, parents, peers, and possible employers what students have learned, accomplished, and/or produced. Students should frequently update their portfolios and reflect on their progress and growth. Reflective writing is a key component of portfolios.

Portfolios at the high school level can be used to display and summarize a range of achievements and can serve to help students

- identify and acknowledge personal growth and achievement
- demonstrate their achievements to families, potential employers, and others
- apply to post-secondary institutions
- apply for scholarships and bursaries
- obtain a volunteer position
- make decisions concerning career path choices

Creating Portfolios

Four basic types of portfolios are the following:

Student Portfolios demonstrate the skills, accomplishments, and achievements of a student's academic career over a specific time period. The portfolio can represent one area of study, or it can encompass a broad range of disciplines. Students are often encouraged to include materials that represent accomplishments and interests outside of the classroom.

Project Portfolios are designed to outline the steps or progress of a specific project or independent study. Students are required to record and comment on the process and outcome of their efforts.

Expert and Professional/Employability Portfolios identify students' skills and accomplishments related to their career interests. This type of portfolio is becoming popular as a useful addition to the standard résumé.

A *Personal Portfolio* is designed in a format similar to a scrapbook or a personal journal. It reflects the personal interests, ideas, and aspirations of the student. The most important factors for a successful portfolio format are durability, accessibility, and presentability. Whether a portfolio is in a binder, scrapbook, or folder, on computer disks, multimedia CD-ROMs, videotapes or audiotapes, it must be easy to transport, showcase, and understand.

Students must be able to organize and maintain their portfolios effectively. The decision of what to include in a portfolio entirely depends on the purpose of the portfolio. Following are some of the materials that could be included:

- essays, position papers
- reflective writing
- awards
- evaluations/reviews
- articles, newspaper clippings
- rubrics, test results, assessment information
- photographs
- letters of invitation, thanks
- art and design work
- poems, tunes, stories
- certificates

Assessing Portfolios

The assessment of portfolios should be discussed and negotiated with students before the process of their creation is initiated. Assessment criteria often reflect the design and purpose of the portfolio. The most important form of feedback to students may be in the form of dialoguing and conferencing. General qualities that students should be aiming to achieve include the following:

- clean format—easy to read and understand
- creativity
- thoughtful organization
- thoughtful self-evaluation
- clear representation of learning goals and achievements