Prince Edward Island
CANADA

Education and Early Childhood Development
English Programs

Science Curriculum

CURRICULUM

Physics

Physics 621A

2010

Prince Edward Island Department of Education
and Early Childhood Development
P.O. Box 2000, Charlottetown
Prince Edward Island
Canada, C1A 7N8
Tel. (902) 368-4600
Fax. (902) 368-4622
http://www.gov.pe.ca/eecd/

Acknowledgments

The Atlantic Provinces Education Foundation and the P.E.I. Department of Education and Early Childhood Development express their indebtedness to members of regional physics committees for their professional expertise and insights in developing this regional Physics 621A curriculum guide. In addition, the local physics committee and pilot teachers who contributed comments and suggestions are to be commended for their commitment to developing exemplary science programs.

The Prince Edward Island Physics Curriculum Committee members and Pilot Teachers

Bluefield High School	Jeff Carragher
Charlottetown Rural High School	Elizabeth MacAulay
Colonel Gray Senior High	Shirlee Curtis
Kensington Intermediate SeniorHigh	Richard Younker
Kinkora Regional High School	Brendan Kelly
Montague Regional High School	Randy Harper
Morell Regional High School	Steven Wynne
Souris Regional Senior High	Karen Power
Three Oaks Senior High	Gerald Maccormack
Westisle Composite High School	Lynn Thomson
	Andrew MacDougald
University of P.E.I.	Dr. Derek Lawther Dr. Ron MacDonald
Department of Education and Early Childhood Development	Jonathan Hayes

Contents

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).

This guide is intended to provide teachers with the overview of the outcomes framework for Physics 621A. It also includes some suggestions to assist teachers in designing learning experiences and assessment tasks.

Introduction

Background

The curriculum described in *Foundation for the Atlantic Canada Science Curriculum* and in *Physics 621A* 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 science 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.

Communicating 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 by 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 class. To adapt instructional strategies, assessment practices, and learning resources to the needs of all learners, teachers must create opportunities that will permit them 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.

Science for EAL Learners

The Prince Edward Island science curriculum is committed to the principle that learners of English as an additional language (EAL) should be full participants in all aspects of science education. English deficiencies and cultural differences must not be barriers to full participation. All students should study a comprehensive science curriculum with high-quality instruction and co-ordinated assessment.

To this end,

- schools should provide EAL learners with support in their dominant language and English language while learning science;
- teachers, counsellors, and other professionals should consider the English-language proficiency level of EAL learners as well as their prior course work in science;
- the science proficiency level of EAL learners should be solely based on their prior academic record and not on other factors;
- science teaching, curriculum, and assessment strategies should be based on best practices and build on the prior knowledge and experiences of students and on their cultural heritage;
- the importance of science and the nature of the science program should be communicated with appropriate language support to both students and parents;
- to verify that barriers have been removed, educators should monitor enrolment and achievement data to determine whether EAL learners have gained access to, and are succeeding in, science courses.

Education for Sustainable Development

Education for sustainable development (ESD) involves incorporating the key themes of sustainable development - such as poverty alleviation, human rights, health, environmental protection, and climate change - into the education system. ESD is a complex and evolving concept and requires learning about these key themes from a social, cultural, environmental, and economic perspective, and exploring how those factors are interrelated and interdependent.

With this in mind, it is important that all teachers, including science teachers, attempt to incorporate these key themes in their subject areas. One tool that can be used is the searchable on-line database *Resources for Rethinking*, found at **http://r4r.ca/en**. It provides teachers with access to materials that integrate ecological, social, and economic spheres through active, relevant, interdisciplinary learning.

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 assessing 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.

Assessment Techniques

Assessment techniques should match the style of learning and instruction employed. Several options are suggested in this curriculum guide from which teachers may choose, depending on the curriculum outcomes, class, and school/district policies. It is important that students know the purpose of an assessment, the method used, and the marking scheme being used. In order that formative assessment support learning, the results, when reported to students, should indicate the improvements expected.

Assessment Techniques *Continued...*

Observation (formal or informal)

This technique provides a way of gathering information fairly quickly while a lesson is in progress. When used formally, the student(s) would be made aware of the observation and the criteria being assessed. Informally, it could be a frequent, but brief, check on a given criterion. Observation may offer information about the participation level of a student for a given task, use of a piece of equipment, or application of a given process. The results may be recorded in the form of checklists, rating scales, or brief written notes. It is important to plan in order that specific criteria are identified, suitable recording forms are ready, and that all students are observed in a reasonable period time.

Performance

This curriculum encourages learning through active participation. Many of the curriculum outcomes found in the guide promote skills and their application. There is a balance between scientific processes and content. In order that students appreciate the importance of skill development, it is important that assessment provide feedback on the various skills. These may be the correct manner in which to use a piece of equipment, an experimental technique, the ability to interpret and follow instructions, or to research, organize and present information. Assessing performance is most often achieved through observing the process.

Journal

Although not assessed in a formal manner, journals provide an opportunity for students to express thoughts and ideas in a reflective way. By recording feelings, perceptions of success, and responses to new concepts, a student may be helped to identify his or her most effective learning style.

Knowing how to learn in an effective way is powerful information. Journal entries also give indicators of developing attitudes to science concepts, processes, and skills, and how these may be applied in the context of society. Self-assessment, through a journal, permits a student to consider strengths and weaknesses, attitudes, interests, and new ideas. Developing patterns may help in career decisions and choices of further study.

Interview

This curriculum promotes understanding and applying scientific concepts. Interviewing a student allows the teacher to confirm that learning has taken place beyond simply factual recall. Discussion allows a student to display an ability to use information and clarify understanding. Interviews may be brief discussions between teacher and student, or they may be more extensive and include student, parent, and teacher. Such conferences allow a student to be pro-active in displaying understanding. It is helpful for students to know which criteria will be used to assess formal interviews. The assessment technique provides an opportunity for students whose verbal presentation skills are stronger than their written skills.

Assessment Techniques *Continued...*

Paper and Pencil (assignment or test)

These techniques can be formative or summative. Several curriculum outcomes call for displaying ideas, data, conclusions, and the results of practical or literature research. These can be in written form for display or for direct teacher assessment. Whether it is a part of learning, or a final statement, students should know the expectations for the exercise and the rubric by which it will be assessed. Written assignments and tests can be used to assess knowledge, understanding, and application concepts. They are less successful assessing skills, processes, and attitudes. The purpose of the assessment should determine what form of paper and pencil exercise is used.

Presentation

The curriculum includes outcomes that require students to analyze and interpret information; to identify relationships between science, technology, society, and environment; to be able to work in teams; and to communicate information. Although it can be time consuming, these activities are best displayed and assessed through presentations. These can be given orally, in written/pictorial form, by project summary (science fair), or by using electronic systems such as video or computer software. Whatever the level of complexity or format used, it is important to consider the curriculum outcomes as a guide to assessing the presentation. The outcomes indicate the process, concepts, and context for which and about which a presentation is made.

Portfolio

Portfolios offer another option for assessing student progress in meeting curriculum outcomes over a more extended period of time. This form of assessment allows the student to be central in the process. Decisions about the portfolio and its contents can be made by the student. What is placed in the portfolio, the criteria for selection, how the portfolio is used, how and where it is stored, and how it is evaluated are some of the questions to consider when planning to collect and display student work in this way. The portfolio should provide a long-term record of growth in learning and skills. This record of growth is important for individual reflection and self-assessment, but it is also important to share with others. For many students it is exciting to review a portfolio and see the record of development over time.

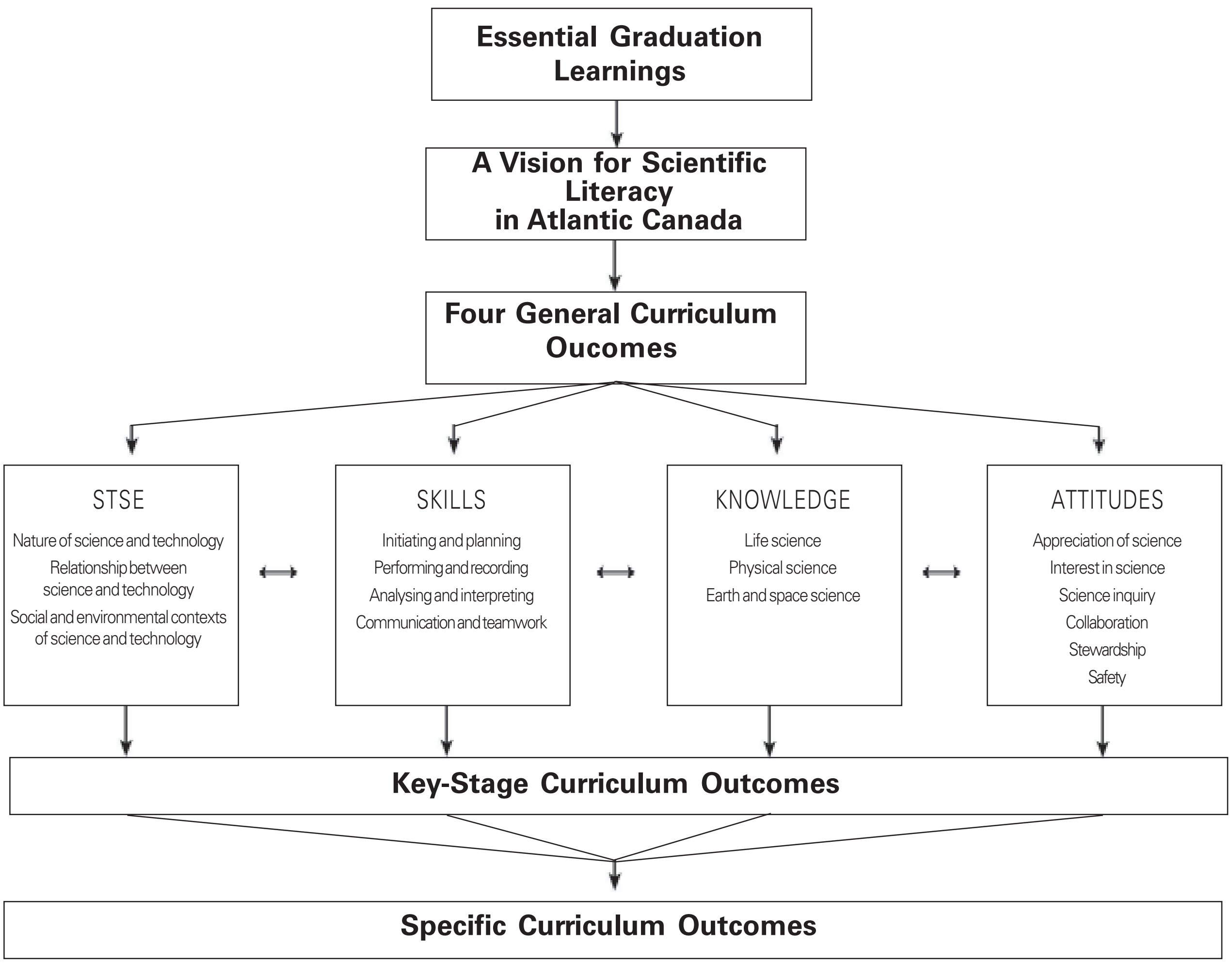
Curriculum Outcomes Framework

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

FIGURE 1



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. The essential graduation learnings are the following:

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 to 12*.

Specific 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 units for each grade level.

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, outcomes 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.

Common Framework of Science Learning Outcomes K to 12 Attitude Outcome Statements

By the end of grade 12, it is expected that students will be encouraged 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 explore where further 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 between 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 opinion 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

Common Framework of Science Learning Outcomes K to 12

Attitude Outcome Statements *(continued)*

By the end of grade 12, it is expected that students will be encouraged 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. Suggested times for each topic are also provided. Although Physics 621A is 110 hours in duration, the cummulative topic instructional time allocated is 92 hours, or 46 hours per term. The remaining 9 hours each term allows for summative assessment considerations.

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. 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 16–18)

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

Within each unit, the pan-Canadian outcomes are written in the context of Prince Edward Island's Physics 621A curriculum.

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

Page One		Page Two	
Topic			
Outcomes	Elaborations—Strategies for Learning and Teaching	Tasks for Instruction and/or Assessment	Resources/Notes
Students will be expected to • Specific curriculum outcome based on the pan-Canadian outcomes (outcome number) • Specific curriculum outcome based on the pan-Canadian outcomes (outcome number)	elaboration of outcome and strategies for learning and teaching elaboration of outcome and strategies for learning and teaching	*Informal/Formal Observation* *Performance* *Journal* *Interview* *Paper and Pencil* *Presentation* *Portfolio*	Provincial responsibility

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 appear(s) 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.

Some STSE, Skills, and Knowledge outcomes that appear after the assessment item may not appear in the first column. Although these outcomes are not the key outcome(s) for this section, the assessment item provides an opportunity to address these outcomes in a different context.

Column Four: Resources/Notes

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

Application of Vectors *(~27 Classes)*

Introduction

From the first intelligent musings of the human species came questions which 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.

The Renaissance and the Galilean method of doing science 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 421A, and was expanded in Physics 521A 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	Skills	Knowledge
Students will be expected to	*Students will be expected to* **Analysing and Interpreting** **214-14** construct and test a prototype of a device or system and troubleshoot problems as they arise **214-16** evaluate a personally designed and constructed device on the basis of criteria they have developed themselves	*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 **325-6** analyse quantitatively the horizontal and vertical motion of a projectile

Dynamics Extension
~ 16 Classes

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)
  - use analytical methods, including vector resolution, to determine vector sums and differences

Elaborations—Strategies for Learning and Teaching

In Physics 521A, students experienced adding and subtracting parallel and perpendicular vectors algebraically, and all vectors graphically.

In Physics 621A, it is expected that students be able to resolve a vector into its right-angled components, add vectors at any angle, and add multiple vectors using the sum of the components method. As an opening discussion, 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.

This list may include the following:

- 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 like the seesaw and bridge supports

As an extension, students may be engaged in the sine law/cosine law method of vector analysis. An extension would also include problems involving relative velocity where the direction of the velocities are not parallel or perpendicular AND the angle of the velocity and time are unknown (e.g., MHR, p. 463, #5; p. 460, model problem).

Dynamics Extension
~ 16 Classes

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)
- 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 resultant velocity of the canoe? At what angle, relative to the river bank, should Nadia point her canoe if she wants to reach a point directly across the river? (ACP-1)
- An airplane pointing $E25^0N$ is travelling at a speed of 250 km/h through the air (relative to air). A wind is blowing at 30.0 km/h at 45^0 North of East. What is the airplane's velocity relative to the ground? (ACP-1)

Resources/Notes

MHR *Physics,* pp. 454-463

Omit Model Problem, p. 460
Problem #5, p. 463

Dynamics Extension *continued...*

~ 16 Classes

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)
  - use analytical methods, including vector resolution, to calculate the net force acting on an object that is hanging or on a horizontal or inclined plane

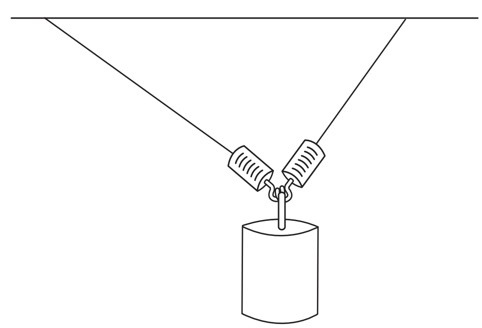
Elaborations—Strategies for Learning and Teaching

Students are expected to use analytical methods of vector addition and subtraction to

- calculate net force, frictional force, or any of the components thereof involving an object (at rest or in motion) being acted upon by one or more applied forces acting horizontally or at any angle with the horizontal;
- calculate net force, frictional force, or any of the components thereof involving an object (at rest, or in motion) on an inclined plane.

Problems resulting in a non-zero net force provide an excellent opportunity for students to incorporate Newton's laws along with the kinematics and dynamics equations from previous courses. It is encouraged that students apply free-body analysis using thumbnail sketches in all problems.

Students should have laboratory experience with static equilibrium. A hanging mass apparatus can be constructed using two force sensors (or spring scales as illustrated below) supporting an unknown mass. Each force sensor (or spring scale) should be attached by a string (unequal lengths) to a horizontal support rod. By measuring appropriate angles and performing vector calculations, the unknown mass can be determined.



Dynamics Extension *continued...*

~ 16 Classes

Tasks for Instruction and/or Assessment

Journal

- Keep a journal throughout this course. Write personal reflections as you progress, and 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)

Performance

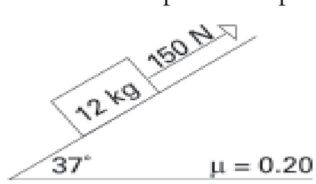
- Perform an experiment to determine the coefficient of kinetic friction of a mass moving on an incline plane. Prepare a written report of your experiment. (ACP-1)
- Perform an experiment involving a mass held in static equilibrium by two cables of different lengths suspended at different angles. Prepare a written report of your experiment. (ACP-1)

Presentation

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

Paper and Pencil

- 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 9×10^2 N at an angle of 20° from the centre line, and the other dog pulls with a 6×10^2 N force at 30° from the centre line. What is the net force pulling on the sled? Use a scaled vector diagram AND the sum of components algebraic method to solve. (ACP-1)
- A 45 kg sign is suspended using two wires that each make a 76^0 angle with the vertical surface where they are attached. Calculate the tension in the wires. (ACP-1)
- A 100 kg sled is being pulled with a 200 N force applied at an angle of 30° with the horizontal. If the coefficient of kinetic friction between the sled and ground is 0.10 calculate the acceleration of the sled. (ACP-1)
- Examine the diagram below 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 up the ramp? (ACP-1)



Resources/Notes

MHR *Physics,* pp. 463-475

Quick Lab: "Maintaining Equilibrium," MHR *Physics,* p. 468

Dynamics Extension *continued...*
~ 16 Classes

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)
  - use analytical methods, including vector resolution, for calculations involving connected masses

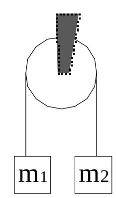
Elaborations—Strategies for Learning and Teaching

Students are expected to perform calculations involving connected masses. Adequate time is required for students to conceptualize and illustrate connected mass problems. Furthermore, these problems provide students with an opportunity to reflect upon and incorporate prior knowledge of dynamics and kinematics.

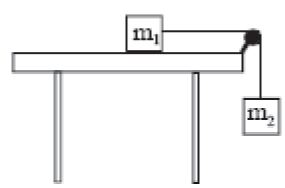
Students may find it difficult to make the transition to problems involving connected masses as a result of the possibility of objects not moving in the same plane. It may be helpful to illustrate how one plane can be rotated such that the objects can be perceived as moving in the same direction. Positive and negative directions on the "adjusted" plane can then be assigned. Students are expected to solve for tension and acceleration in each of the following situations.

The following situations illustrate and describe the depth of treatment:

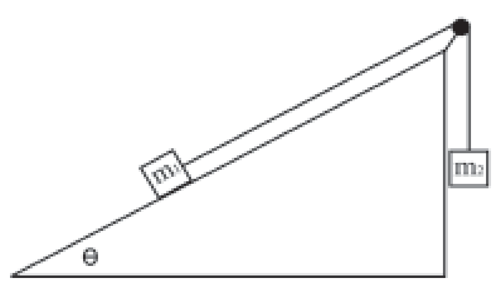
1. Calculations involving an Atwood machine - two connected hanging masses (with and without non-conservative forces)



2. Calculations involving a hanging mass and a connected mass pulled horizontally (with and without non-conservative forces)



3. Calculations involving a hanging mass and a connected mass on an inclined plane (with and without non-conservative forces)



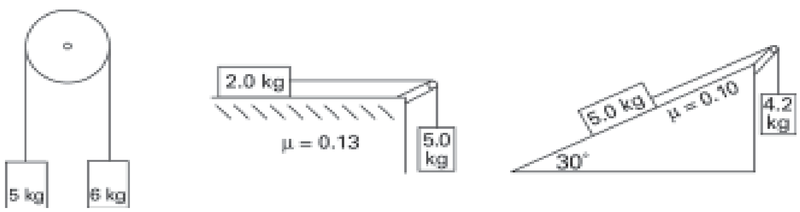
Dynamics Extension *continued...*

~ 16 classes

Tasks for Instruction and/or Assessment

Paper and Pencil

- An elevator filled with people has a total mass of 1825 kg. What is the tension on the cable when the elevator is stationary? Accelerating up at 0.25 m/s^2? Accelerating down at 0.25 m/s^2? Draw the free-body diagram for each. (ACP-1)
- Determine the acceleration of the 5.0 kg mass in each of the following situations. (ACP-1)



Performance

- Perform an experiment involving an Atwood machine with two hanging masses. Analyse the effect of (1) adding mass to each side of the pulley (keeping the difference in mass constant), and (2) transferring mass from one side of the pulley to the other (keeping total mass constant). In each case, predict what you expect will happen to the acceleration of the system, and use probeware to obtain experimental values for acceleration. (ACP-1)
- Perform an experiment to calculate the coefficient of kinetic friction as a wooden block accelerates up an inclined plane. The wooden block is connected at an angle to a hanging mass as shown in the diagram above right (mass on an inclined plane with a mass attached over a pulley at the top). Using a motion sensor, a wooden block with string, a pulley, and a hanging mass (200 g), determine the coefficient of kinetic friction. (ACP-1)

Resources/Notes

MHR *Physics,* pp. 476-489

Investigation 10-A: "Atwood's Machine," MHR *Physics,* pp. 480-481

Omit Problem #26, p. 489

Torque
~ 3 Classes

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)
  - use analytical methods, including vector resolution, for calculations involving static torque

Elaborations—Strategies for Learning and Teaching

Students have analysed situations involving equilibrant and resultant forces acting on point masses in static and dynamic translational equilibrum. Students will now have the opportunity to qualitatively and quantitatively analyse situations involving changes in rotational or angular motion. Students should recognize that rotational equilibrium occurs when the sum of the quantities that cause an object to rotate is zero.

Torque can be introduced qualitatively by having student identify various objects that rotate and describe the factors they believe affect the rotational movement. Common examples include closing a door, lifting a wheel barrow, or forearm motion. From this inquiry, students should establish that torque, or change in circular motion, involves two quantities (perpendicularly applied force, and lever arm length). To establish the concept of static torque, students could be invited to create a mobile for a younger sibling or relative.

Quantitatively, students are expected to calculate torque involving a force applied perpendicular, or at any angle, to the lever arm. Given a situation involving several forces acting on a lever arm of an object in rotational (angular) equilibrium, students are expected to calculate any quantity involved in any of the individual torques applied to the equilibrium system. Furthermore, students should be expected to calculate net torque.

Torque

~ 3 Classes

Tasks for Instruction and/or Assessment

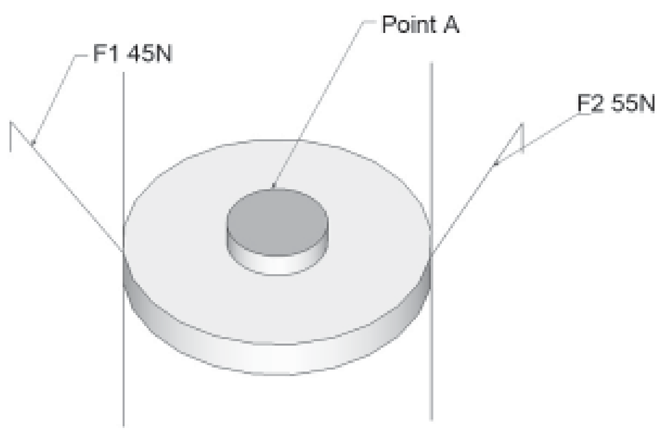
Performance

- Using your knowledge of static torque, design a decorative mobile for an infant's room. Construct the mobile and comment on the ability of the mobile to balance. Explain potential sources of error in unbalanced torques. (ACP-1)

Paper and Pencil

- Calculate the torque when a 55 N force is applied 50.0 cm from the fulcrum of a lever if the force is applied
  - perpendicular to the lever
  - at a 30.0° angle to the lever
  - at a 45.0° angle to the lever
  - at a 60.0° angle to the lever (ACP-1)

- Determine the position on a see-saw on which a 25.0 kg mass must be placed if a 20.0 kg and 30.0 kg mass are located 0.75 m and 1.10 m from the opposite side of the fulcrum, respectively. (ACP-1)



- In the graphic above, F1 and F2 are applied at 45° and 43° angles to the tangent line of the outer circle, respectively. If the radius of the larger circle is 57 cm and the smaller 28 cm, calculate the following:
  a. Net torque caused by F1 and F2
  b. Force experienced tangent to the inner circle at point A (ACP-1)

Resources/Notes

MHR *Physics,* pp. 490-495

Quick Lab: "Build a Mobile," MHR *Physics,* p.502

Omit Static Equilibrium, pp. 496-501

Projectiles
~ 8 Classes

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

As an introductory activity students could be asked to walk at a steady pace and drop small objects into a cup. They could explore how changing walking speed affects release time. This will give students a sense of the independence of vertical and horizontal motion. If one is available, teachers could use a projectile launcher to demonstrate that a dropped object and a horizontally projected object land at the same time. Once a conceptual understanding of the independence of vertical and horizontal motion is realized, students would be expected to quantitatively analyse projectile motion by separating motion into independent x and y components. They could draw the position of a horizontally projected point mass at 0.1 s intervals illustrating component velocity vectors drawn to scale.

Students should be expected to solve problems that involve objects

1. projected horizontally;
2. projected at any angle and landing at a point above, below, and at the same vertical launch position.

In both of the situations above it is expected that students calculate one or more of the following: range, time in air (hang time), maximum height, launch and impact angles, launch and impact velocities.

- **construct, test, and evaluate a device or system on the basis of developed criteria (214-14, 214-16)**

Students should conduct an investigation of projectile motion using a suitable apparatus in which they predict the path of a horizontal projectile using independent horizontal and vertical calculations. A ramp (curtain track) can be used to accelerate a metal ball that will be projected horizontally. The students can measure the height from which the object is to be launched and investigate the initial horizontal velocity and ultimately the location on the floor where the ball will land. A cup can also be used to add further complexity. When using a cup the students must include the cup height in their calculations in order to determine where it must be placed to “catch” the ball.

Students could be asked to construct a projectile launcher (metre stick, elastic, washer). By attempting vertical and/or horizontal trials to obtain the launch velocity of their device they can engage in a class competition to determine the launch angle required to hit a target at a given distance.

Projectiles
~ 8 Classes

Tasks for Instruction and/or Assessment

Performance

- Using a projectile launcher, demonstrate that the maximum range for a given muzzle velocity will occur at a launch angle of 45°. Prove this is true with calculations. (325-6, 214-14, 214-16)
- Perform an experiment to confirm the calculated landing position of a horizontally launched projectile. (325-6, 214-14, 214-16)
- Your task is to determine the necessary angle and stretch to launch a projectile from a fixed launch point to a target which will be 5.00 m away (horizontally) from the launch point. You are given a metre stick, elastic, and washer to create a launcher. You will need to determine the launch velocity of your washer when the elastic is stretched to a certain length. The only permitted trials before your launch to the target are either straight up with a certain stretch or horizontally with a certain stretch.

  Once you have what you believe to be the proper angle and stretch you will be given three trials in order to hit the target.

  Write up the method used to determine the initial velocity of the washer and show the calculations that support the angle and the stretch, that you decided to use for your actual trials. (325-6)

Paper and Pencil

- A projectile is launched with a muzzle velocity of 20.0 m/s at an angle of 57° from the horizontal. Determine its 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)? (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 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 an adjacent building. If the buildings are 8 m apart, can you help her determine what speed she must have as she reaches the edge of the higher roof? (325-6)

Resources/Notes

MHR *Physics,* pp. 530-549

www.gov.pe.ca/go/science

Projectile Hoop Lab

Projectile Landing Lab

Circular and Planetary Motion *(~13 Classes)*

Introduction

From the first intelligent musings of the human species came questions which 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 421A, and was expanded in Physics 521A 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 which *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	Skills	Knowledge
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 **Relationship 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** **117-11** analyse examples of Canadian contributions to science and technology	*Students will be expected to* **Initiating and Planning** **212-3** design an experiment, identifying and controlling major 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 **213-5** compile and organize data, using data tables and graphs to facilitate interpretation of the 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 **Communication and Teamwork** **215-2** select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results	*Students will be expected to* **325-12** describe uniform circular motion, using algebraic and vector analysis **325-13** explain quantitatively circular motion, using Newton's laws **327-3** explain qualitatively the relationship among displacement, velocity, time, and acceleration for simple harmonic motion **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

Circular Motion
~ 4 Classes

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. Their familiarity with playground carousels, bicycle wheels, and 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 sharp turn very fast? (Does the car pull into the passengers, or do they slam into the side of the car?)

Students should move from a discussion of familiar experiences to a more analytical examination. Teachers should point out to students that a progression in concept development has occurred. First, linear motions, in which a force changes only the magnitude of an object's velocity, were studied. 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 being difficult to accept that a force can result in a change in direction only.

Students should be expected to distinguish between centripetal and "centrifugal" forces. They should explain, and illustrate using velocity vectors, the direction of centripetal acceleration and centripetal force. Given the formula for centripetal acceleration, Newton's second law, the period-frequency relationship, and the speed of an object in circular motion $\left(a_c = \frac{v^2}{r};\ F_c = ma_c;\ T = \frac{1}{f};\ v = \frac{2\pi r}{T}\right)$

students are expected to synthesize the following formulas for centripetal force:

$$F_c = ma_c = \frac{mv^2}{r} = \frac{4\pi^2 r}{T^2}$$

- **carry out procedures controlling the major variables and adapting or extending procedures where required (213-2)**
- **use instruments effectively and accurately for collecting data (213-3)**
- **interpret patterns and trends in data, and infer linear and non-linear relationships among variables (214-5)**

Students are expected to quantitatively analyse problem situations involving circular motion (excluding banked curves) using the above formulas.

A centripetal force experiment involving masses being swung in circular motion while held in place by a force sensor should be performed. Students should analyse the centripetal force acting on a rotating mass by controlling variables (radius, mass, frequency) during trials. From this experiment the students should be able to verify the following proportional relationships:

$$F_c \alpha m,\ F_c \alpha v^2,\ F_c \alpha \frac{1}{r}$$

Circular Motion
~ 4 Classes

Tasks for Instruction and/or Assessment

Performance

- Perform an experiment to determine or to verify the relationship between centripetal force and an object's mass, velocity, and radius of revolution. (213-2, 213-3, 214-5, 325-12, 325-13)

Journal

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

Paper and Pencil

- 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 half a revolution? (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? (325-13)
- Due to the shape of the earth, an object has less apparent weight at the equator than at the North Pole. Explain this qualitatively in consideration of Earth's radius at the poles and equator. (325-13)
- Research the value of gravitational acceleration at the poles and equator to answer the following questions:
  - 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

MHR *Physics,* pp. 551-562

Omit Banked Curve Problems

Investigation 11-B: "Verifying the Circular Motion Equation," MHR *Physics,* pp. 561-562

Universal Gravitation
~ 5 Classes

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students should investigate the elliptical properties of orbital motion. They could perform an investigation of orbital motion using two push pins, a piece of string, a sheet of paper, and a cardboard sheet as a punch board to create an elliptical pattern. Students could draw in a 1.0 cm long vector to represent the gravitational force on the planet at the furthest point on the orbit from the central body (one of the elliptical focusses). They can then be asked to draw the proportional force vector at the closest point on the orbit to the central body, as well as at other positions. This will provide students with the opportunity to answer questions such as, At which position do you think the planet will be moving at its fastest speed? Slowest 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 to confirm Kepler's third law. Students should be expected to solve problems using the relationship $T_a^2/T_b^2 = r_a^3/r_b^3$. Similarly, Newton's version (formula) of Kepler's third law should be derived by the students. Students should use this formula to solve problems involving orbital period and radius, and mass of the central body (focus mass, m_f). Astronomical unit should be defined.

Newton's version (formula) of Kepler's third law: $\frac{r^3}{T^2}=\frac{Gm_f}{4\pi^2}=3.35\text{x}10^{18}\,\frac{m^3}{s^2}=1\frac{AU^3}{yr^2}$

Students should be led through Newton's Cannon thought experiment. Students should make the connection that orbital motion will occur when centripetal force equals gravitational force.

Students should describe the proportionalities in the equation for universal gravitation. The proportionalities will reapply in

Coulomb's law: $F \propto m_1, F \propto m_2, F \propto \frac{1}{r^2}$, and $F_t = G\frac{m_1 m_2}{r^2}$.

Students should be asked to write an algebraic equation for orbital velocity and period by combining the gravitational force (Newton's law of universal gravitation) with centripetal force equations to obtain

$$v=\sqrt{\frac{Gm_f}{r}};\qquad T= 2\pi\sqrt{\frac{r^3}{Gm_f}}\ .$$

Students should be asked questions such as, 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)?

Universal Gravitation
~ 5 Classes

Tasks for Instruction and/or Assessment

Performance

- The following data represents the force of attraction (F) 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	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 for communication, remote-sensing, and weather observation. Write a journal entry which presents a specific contribution. Do you think Canada played a leadership role in developing this technology? (115,1, 116-4, 117-11)

Paper and Pencil

- The period of the moon's orbit is 27.3 days. If the mean radius of moon's orbit is 3.84×10^8 m, calculate the mass of Earth. (ACP-2)
- Calculate the mass of the sun using orbital period and radius data from Mercury, Venus, and Earth. (ACP-2)
- The orbital period and radius for Jupiter is 4332.62 days and 5.200 AU, respectively. Calculate Saturn's orbital radius if the orbital period for Saturn is 10 759.20 days. (ACP-2)
- 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 attraction force between them? (215-2)
- What is the mass of an object which 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)
- 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

MHR *Physics,* pp. 572-586

MHR *Physics,* pp. 587-594

Simple Harmonic Motion (SHM)
~ 4 Classes

Outcomes

Students will be expected to

- **identify questions, and 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 among displacement, velocity, time, and acceleration for simple harmonic motion** (327-3)
- **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 can relate in their exploration of simple harmonic motion. 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 Narrows bridge is still an impressive sight. From this viewing, students should be asked to discuss experiences with water beds, pendulums, skyscraper damper floors, automobile suspensions, or other related objects/technologies.

Students have recently completed a study circular motion. 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.

The energy changes of a mass oscillating on a string was examined in Physics 521A. Students also studied conservation of mechanical energy in the absence of elastic potential. In Physics 621A students should qualitatively explore the relationships among position, velocity, and acceleration (force) during the oscillation of a mass on a spring. Furthermore, they should be expected to study Hooke's law and perform calculations involving conservation of mechanical energy involving elastic potential.

Students should conduct an energy analysis of either a spring system (horizontal frictionless surface only) or a pendulum. At this time, there is no need to consider damped or coupled situations. Students should solve problems relating to the period of harmonic motion using the following formulas (formula derivation is not expected):

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

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

Please Note: Calculations involving spring systems should be restricted to elastic potential energy and kinetic energy (springs on horizontal, frictionless surfaces).

Simple Harmonic Motion (SHM)
~ 4 Classes

Tasks for Instruction and/or Assessment

Journal

- "Restoring 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 spring of spring constant 40.0 N/m on a horizontal, frictionless surface.
  - If the mass is displaced 6.0 cm from the rest position, what period of oscillation will result?
  - Determine the spring potential energy and the kinetic energy at the centre of oscillation (rest position) if the mass is released from a position described above.
  - How fast is the mass moving at the rest position? (327-3, 327-4)
- A 0.60 kg mass is vibrating at the end of a 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? (327-3, 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? (327-3, 327-4)
- An astronaut exploring Mars wants to find the mass of an object. She finds a metal strip which she knows has a spring 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? (327-3, 327-4)
- What is the period of a 0.80 m long pendulum? (327-3, 327-4)
- What length must a pendulum be to have a period of 1.0 s? (327-3, 327-4)

Presentation

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

Resources/Notes

MHR *Physics,* pp. 254-261

MHR *Physics,* pp. 600-614

Omit Section 13.2 (pp.615-621)

MHR *Physics,* p. 255

Investigation 6-A: Force and Spring Extension

MHR *Physics,* p. 609

Investigation 13-B: The Period of a Mass on a Spring

Electricity and Magnetism *(~35 Classes)*

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 which 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 dinners with radio waves. Plasma displays for computers have found 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 which 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 Physics 521A. 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	**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 **213-8** 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	**308-13** explain the production of static electric charges in some common material **308-14** identify properties of static electric charges **308-15** compare qualitatively static electricity and electric current **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 direction 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 with 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

Coulomb's Law
~ 6 Classes

Outcomes

Students will be expected to

- **explain the production of static electric charges in some common material (308-13)**
- **identify properties of static electric charges (308-14)**
- **compare qualitatively static electricity and electric current (308-15)**

- **explain the roles of evidence, theories, 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

All specific curriculum outcomes on this page can be addressed, in part, by having students perform the recommended investigation Static Electricity.

Prior to the explicit study of Coulomb's law, electric fields, and field intensity, static electric charge should be explored in the lab and in historical context.

Students should conduct a lab investigation using an electroscope to examine temporary charges produced by induction, and permanent charges produced by conduction, induction, and friction. Teachers might explain that only electrons are being moved, and that electrons are not created or destroyed. 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. Students should understand the three ways (conduction, induction, friction) of producing a static charge, and the properties of static electric charges, and be able to qualitatively compare static electricity to electric current.

Throughout this laboratory investigation students will be able to experience and better describe the field around various charged objects. Students should be able to explain, using evidence from their experiment, the various ways that objects can become charged. Furthermore, it is expected that students understand and be able to explain why neutral objects are attracted to charged objects. Students should use proper terminology (e.g., insulator, conductor, conduct, induce, temporary dipole) in their explanations.

During experimentation, students should have the autonomy to test their ideas and discuss/debate with their peers. The nature of science and the importance of scientific inquiry is best addressed by engaging students in these sorts of authentic discussions and evidence gathering investigations.

Coulomb's Law
~ 6 Classes

Tasks for Instruction and/or Assessment

Performance

- Perform an experiment to identify the three ways (conduction, induction, friction) of producing a static charge, and demonstrate the properties of static electric charges. (114-2, 114-5, 115-3, 215-1, 308-13, 308-14)

Presentation

- Write a report, including diagrams, that indicates in steps how various charges can be placed on an electroscope. (308-13)

Resources/Notes

P.E.I. Department of Education and Early Childhood Development Web site:

http://www.gov.pe.ca/eecd/

Investigation: Static Electricity

Coulomb's Law *continued...*
~ 6 Classes

Outcomes

Students will be expected to

- **compare Newton's law of universal gravitation with Coulomb's law, and apply both laws quantitatively** (328-4)
- **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)

Elaborations—Strategies for Learning and Teaching

Although it is possible to conduct a laboratory investigation of Coulomb's law using pith balls on a torsion balance, 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?

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

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

Student should compare the relationship between Coulomb's law and Newton's law of universal gravitation. 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™* (www.design-simulation.com/ip/index.php) can be used to simulate the collection of data.

Coulomb's Law *continued...*

~ 6 Classes

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 took 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 each 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 which 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. Give students the charge of an electron (-1.602×10^{-19} C/electron).

  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 $+2.0 \times 10^{-6}$ 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

MHR *Physics,* pp. 630-642

Electric and Gravitational Fields
~ 5 Classes

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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 which show the lines of force related to a positive test charge around single objects and between two objects.

For single objects it might be useful to map the field using electric field lines which indicate the inverse square nature of the field. It is important to remind students of the convention for determining the direction of the electric field as being the direction a test charge would move if placed in the field (test charge being universally defined as an infinitely small positive charge).

It is expected that students 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. Students should be able to describe how a uniform electric field can be created using two parallel plates. R.A. Millikan won the Nobel Prize in Physics (1923) by discovering the elementary charge (charge of one electron). His famous oil drop experiment used a uniform electric field generated from parallel plates placed at an appropriate distance apart. Teachers should describe the Millikan oil drop experiment to illustrate how knowledge and the use of electric and gravitational fields were required for the experiment.

Student should be able to compare the electric field to the gravitational field qualitatively. They should be able to perform calculations of the electric field intensity at any position about a point charge. Furthermore, students should be able to calculate the electric field intensity generated by two or more point charges anywhere in a two dimensional plane.

Electric Field Intensity

$$\vec{E} = \frac{\vec{F}_Q}{q_t}; \quad \vec{E} = \frac{k\frac{q\,q_t}{r^2}}{q_t}; \quad \vec{E} = k\frac{q}{r^2}$$

Gravitational Field Intensity

$$\vec{g} = \frac{\vec{F}g}{m}; \quad \vec{g} = \frac{G\frac{Mm}{r^2}}{m}; \quad \vec{g} = G\frac{M}{r^2}$$

Electric and Gravitational Fields
~ 5 Classes

Tasks for Instruction and/or Assessment

Journal

- What is your understanding of electric and gravitational fields? How are these related? (328-1a, 328-2a, 328-3a)

Paper and Pencil

- 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. (328-1a, 328-2a, 328-3a)
- Suppose that a friend has missed class for several days and was not present when electric field and electric field intensity were discussed. Write a complete explanation of this concept and how to use it to solve problems. (328-1a, 328-2a, 328-3a, 328-4)
- Two +2.0 x 10^{-6} C charges are placed at opposite corners of a square with 5.00 cm sides. A third charge (-2.0 x 10^{-6} C) is placed at a vacant corner. What is the magnetic field intensity felt by a test charge if placed at the unoccupied corner? (328-1a, 328-2a, 328-3a, 328-4)
- If they are 70.0 cm apart, what is the electric field at the midpoint between the following charged objects: -3.2 x 10^{-6} C and +4.6 x 10^{-6} C? (328-1a, 328-2a, 328-3a, 328-4)
- At what point between a -0.20 x 10^{-6} C and a -0.50 x 10^{-6} C point charge would the electric field intensity be zero, given that the charges are 1.0m apart? (328-1a, 328-2a, 328-3a, 328-4)

Resources/Notes

MHR *Physics,* pp. 643-661

MHR *Physics,* p. 698
(Description of Millikan's Oil Drop Experiment)

Omit Magnetic Fields
(addressed later)

Electric Circuits
~ 14 Classes

Outcomes

Students will be expected to

- **apply Ohm's law to series, parallel, and combination circuits (ACP-3)**
  - 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

Elaborations—Strategies for Learning and Teaching

Students should be asked, based on their prior experience with electricity in the grade 9 curriculum, to create operational definitions for current, potential difference, resistance, and power. Using their operational definitions, they could predict how these quantities are interrelated. Through class discussion they can add to, or refine, their definitions. For instance, the term "power" is often used in place of the scientifically correct term "energy". This mistake can be compounded by the fact that the energy unit used (kWh) contains the term "Watt" (a unit of power).

The operational definitions for potential difference, current, and resistance should be qualitatively correlated with the fundamental units associated with each quantity. Students must quantitatively analyse electrical potential difference, current, and resistance using their fundamental units.

Electric Potential Difference (V)

$$V = \frac{\Delta E_Q}{q}; \text{ units: } 1\ V = \frac{J}{C}$$

Electric Current (A)

$$I = \frac{q}{\Delta t}; \text{ units: } 1A = \frac{C}{s}$$

Resistance (Ω) of a Conductor

$$R = \rho\frac{L}{A}; \text{ units: } \rho = \Omega \cdot m;\ L = m;\ A = m^2$$

- **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)**

Students should perform an investigation to determine the effect of potential difference and resistance on current. This will require students to control major variables (e.g., maintain constant resistance when testing the effect of potential difference on current). Students should analyse the data graphically to identify proportional relationships. Furthermore, for linear relationships, students should be asked to identify the numerical value of the slope and the electrical quantity it represents. This experiment would provide an excellent lead into Ohm's law.

- **apply Ohm's law to series, parallel, and combination circuits (ACP-3)**
  - apply Ohm's Law qualitatively and quantitatively to single resistors

From the investigation of current, resistance, and voltage, students should determine the relationship between voltage and current in a circuit with a single resistance (Ohm's law). Students should realize that Ohm's law applies only in certain cases. Students should also consider a qualitative view of the factors that influence resistance, namely length, diameter, type of metal, and temperature in the wire.

Electric Circuits
~ 14 Classes

Tasks for Instruction and/or Assessment

Performance

- Perform an experiment to investigate the relationship between current, voltage, and resistance using resistors that obey Ohm's law and others that do not. (213-2, 213-3, 213-8, ACP-3)

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)

Pencil and Paper

- A light bulb has a resistance of 32 Ohms. If the bulb draws 160 mA, what is the operating potential difference?
- A 6.0 Ohm flashlight bulb operates on 12 V. If it operates for 6.0 minutes, calculate
  - a. the current that the bulb draws
  - b. the quantity of charge that passes through the bulb during operation. (ACP-3)

Resources/Notes

MHR *Physics,* pp. 686-709

MHR *Physics,* pp. 709-711

Investigation 15-B: "Current, Resistance, and Potential Difference"

MHR *Physics,* pp. 712-714

P.E.I. Department of Education and Early Childhood Development Web site: http://www.gov.pe.ca/eecd/

Investigation: Ohm's Law

Electric Circuits *continued...*
~ 14 Classes

Outcomes

Students will be expected to

- **apply Ohm's law to series, parallel, and combination circuits** (ACP-3)
  - draw a schematic diagram for series, parallel, and simple combination circuits
  - apply the characteristics of series and parallel connections to series, parallel, and combined circuits
  - investigate the relationship between voltage rises and voltage drops across circuit elements
  - describe the energy transformations
- **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

Given the characteristics of series and parallel circuit connections, 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 characteristics for series and parallel circuit connections are as follows:

Series	Parallel
$V_t = V_1 + V_2 + V_3 \ldots$	$V_t = V_1 = V_2 = V_3 \ldots$
$I_t = I_1 = I_2 = I_3 \ldots$	$I_t = I_1 + I_2 + I_3 \ldots$
$R_t = R_1 + R_2 + R_3 \ldots$	$\frac{1}{R_t} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} \ldots$

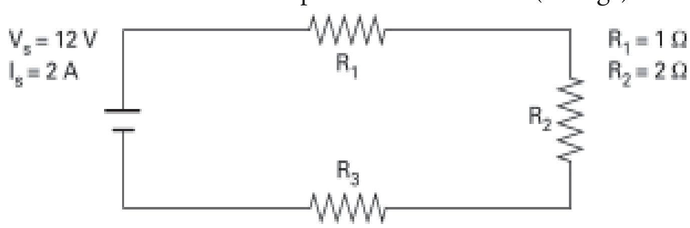
Teachers should limit circuit analysis problems to simple combinations of no more than four resistors. Internal resistance should not be considered in these calculations. Current flow convention must be given consideration. Current is assumed to be electron flow. At this point teachers may want to make the distinction between current (flow of electrons) and conventional current (the hypothetical flow of positive charges). Conventional current will be used later to identify the direction of the magnetic field using right-hand rules.

Electric Circuits *continued...*
~ 14 Classes

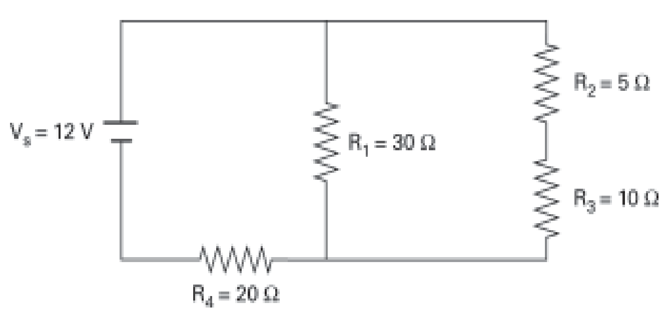
Tasks for Instruction and/or Assessment

Paper and Pencil

- Prepare a written report based on your lab investigation. (ACP-3)
- Two resistors are connected in series across a 30 V source. Draw a diagram of the circuit. Solve problems such as the following:
  - 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 18 Ohms, 9 Ohms, and 6 Ohms 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 6 Ohm resistor, and then splits between two branches, one of which has a 2 Ohm resistor and the other a 4 Ohm 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 2 A 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? (ACP-3)

Resources/Notes

MHR *Physics,* pp. 715-728

P.E.I. Department of Education and Early Childhood Development Web site: http://www.gov.pe.ca/eecd/

Investigation: Series Circuits

Investigation: Series and Parallel Circuits

Electric Circuits *continued...*

~ 14 Classes

Outcomes

Students will be expected to

- **apply Ohm's law to series, parallel, and combination circuits (ACP-3)**
  - describe electrical energy and electrical power qualitatively and quantitatively

- **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

Students should perform calculations involving power rating and electrical consumption using any one of the following three equations: $P = IV$; $P = V^2/R$; and $P = I^2R$.

Prior to the use of P=IV, students should be shown how this formula is derived from the fundamental units of electric potential difference (V) and current (I). It is expected that student can derive $P = V^2/R$ and $P = I^2R$ using Ohm's law and P=IV.

Students could perform an experiment to quantify the transfer of electrical energy to mechanical or thermal energy.

Electrical Energy to Thermal Energy

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 (or any temperature between 20^0C and 100^0C). 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. Again, voltage, current, and time should be recorded, and the efficiency calculated. In class, the results could be collected in a table on the board or overhead, and compared. Students would require the formula to calculate energy absorbed by the water ($E=mc(T_2-T_1)$; c=4.184 Jg/˚C).

Electrical Energy to Mechanical Energy

Students could 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 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), 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.

Electric Circuits *continued...*
~ 14 Classes

Tasks for Instruction and/or Assessment

Performance

- Perform an experiment to determine the efficiency of energy transfer between electrical energy and thermal energy, or electrical energy and mechanical energy. Calculate the efficiency of the transfer and account for differences. Students can research energy cost and calculate the cost of the energy transfer. (ACP-3, 212-4, 212-6, 213-2, 213-3, 213-8)

Paper and Pencil

- A heater has a resistance of 12 Ohms. What is the power output if it draws 6.5 A? If the current was reduced to a third of the original value, what would happen to the power output? (ACP-3)

- An electric kettle that operates on a 120 V supply is used to bring water to a boil. If it takes the 15.0 Ohm heating element 4.2 minutes to boil the water, and the cost of energy is 15.15 cents per kWh, calculate

  a. the power rating of the kettle

  b. the cost to boil the water. (ACP-3)

Resources/Notes

MHR *Physics,* pp. 734-746

Magnetic Fields, Electromagnetism, and Electromagnetic Induction
~ 6 Classes

Outcomes

Students will be expected to

- **describe magnetic fields as regions of space that affect mass and charge (328-1b)**
- **describe magnetic fields by illustrating the source and direction of the lines of force (328-2b)**
- **describe magnetic fields in terms of poles (328-3b)**

Elaborations—Strategies for Learning and Teaching

Although students will have studied magnetism in earlier grades, it is appropriate to look again at magnetic fields by using iron filings and bar magnets.

Students should describe a magnet as having two poles (north and south), and magnetic forces as being attractive (opposite poles) or repulsive (same poles). They should recognize the similarity between magnetic fields and electric or gravitational fields in terms of the force of attraction (or repulsion) being proportional to the inverse square of the distance between them.

Students should sketch the field around a single magnet, the field between two like poles, and the field between unlike poles. The concept of a north-seeking pole should be reviewed.

The concept of magnetic domain should be introduced to explain the structure and behaviour of magnets. A magnetic domain is a region in a magnet where the magnetic fields of atoms are aligned. When magnetic domains are not aligned, the magnetic fields will cancel and the result is a material that is either very weakly magnetic or not magnetized. Teachers should use the concept of magnetic domain to explain how a magnetic field can be induced in non-magnetized material.

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

Students should be introduced to electromagnetism through the study of magnetic fields produced by current in a long, straight conductor and in a solenoid.

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. They should describe the way that the magnetic field exists in space in these cases, explore the interaction between two current-carrying wires placed close to each other.

Note: When using the right-hand rules, it is important to remember that the rules assume motion of conventional current (the hypthetical flow of positive charges).

Right-Hand Rule#1
If the right thumb points in the direction of conventional current, the fingers of the right hand curl around the wire in the direction of the magnetic field.

Right-Hand Rule#2
If the fingers of the right hand curl around the wire in the direction of conventional current, the right thumb will point in the direction of the magnetic field to indicate the N-pole of the coil.

Magnetic Fields, Electromagnetism, and Electromagnetic Induction
~ 6 Classes

Tasks for Instruction and/or Assessment

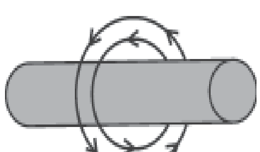
Paper and Pencil

- Magnets have poles and electric fields have charges. Explain this similarity to a group of grade nine students. (328-3)
- 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. (328-2b, 328-3b)

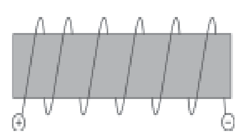
Performance

- 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)
- In groups, research and discuss changes in the orientation of Earth's magnetic field over geological periods of time. (328-3)
- Research an application of an electromagnet and explain how the device functions. Examples of devices containing electromagnets include relays, lifting electromagnets, and electric bells. (328-6)
- Using right-hand rules, find the

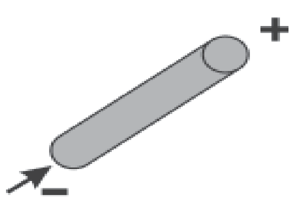
  a. direction of current

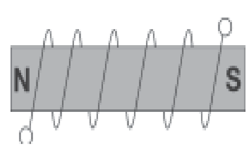
  b. polarity of the magnet

  c. magnetic field direction

  d. direction of current.

  (328-6)

Resources/Notes

MHR *Physics,* pp. 660-661, pp. 752-755

MHR *Physics,* pp. 755-767

Investigation 16A: "Magnetic Field around a Straight Conductor," MHR *Physics,* pp. 757-759

Investigation 16B: "Magnetic Field around a Helix," MHR *Physics,* pp. 762-763

Magnetic Fields, Electromagnetism, and Electromagnetic Induction
~ 6 Classes **_continued..._**

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students should build on their understanding of the relationship among force (F), magnetic field strength (B), and the length of conductor in a magnetic field (L) to understand the factors for the force on a charge moving in a uniform magnetic field. Furthermore, students should quantitatively analyse the above relationship using the formula $F = BIL$.

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 on a current carrying wire (motor effect). Students should try to devise a hand rule which takes into account the direction of the field, the direction of the current, and the direction of force (movement of the wire loop). This is sometimes called the third right-hand rule, or the thumb-and-two-fingers rule. Students should be able to describe how a galvanometer works on this principle.

Right-Hand Rule #3

If the right thumb points in the direction of conventional current and the fingers of the right hand point in the direction of the magnetic field, then a vector perpendicular to the palm of the right hand indicates the direction of the force on the conducting wire

Students should perform 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 which turns the heaviest rotor. Students should appreciate that an operating motor produces a back EMF which is responsible for, in part, the result of the motor obtaining a constant speed.

Magnetic Fields, Electromagnetism, and Electromagnetic Induction
~ 6 Classes **_continued..._**

Tasks for Instruction and/or Assessment

Performance

- Perform an experiment to investigate the motor effect and to predict the direction of the force on a current-carrying wire in a magnetic field. (328-5)
- Create an electric motor using two paper clips, a 1.5V dry cell, cellophane tape, and 50 cm of wire. Create a coil with the wire, leaving about 2 cm of straight wire on both ends of the coil. Remove the coating from the top side of the wire only. Explain how the motor functions. Describe the purpose of the commutator in commercially prepared electric motors. (328-5)

Presentation

- In groups, prepare a multimedia presentation on the history of the development of the modern electric motor. (328-5)
- Using observations from your investigation of the motor effect, present to the class how the direction of the force on a current-carrying wire is determined when exposed to a magnetic field. (328-5)

Resources/Notes

MHR *Physics*, pp. 768-780

Investigation 16C: "The Motor Effect," MHR *Physics*, pp. 771-772

Generators and Motors

~ 4 Classes

Outcomes

Students will be expected to

- **analyse qualitatively electromagnetic induction by both a changing magnetic flux and a moving conductor** (328-7)
  - use Faraday's "generator effect" and Lenz's law to predict the directions of induced current
  - describe the construction and operation of step-up and step-down transformers
- **compare and contrast the ways a motor and generator function, using the principles of electromagnetism** (328-9)

Elaborations—Strategies for Learning and Teaching

Students should develop an understanding that an electric current can result (electromagnetic induction) from the motion of a conductor past a magnetic field, or the motion of a magnetic field past a conductor - a phenomenon known as "the generator effect", was discovered by Faraday. Students should be able to determine the direction of conventional current in a conductor using Faraday's version of the right-hand rule.

Faraday's Version of the Right-Hand Rule (Generator Effect)

If the right thumb points in the direction of motion of the wire, the fingers of the right hand point in the direction of the magnetic field, then a vector perpendicular to the palm of the right hand indicates the direction of the force on the positive charged particles, and therefore the direction of conventional current.
Lenz's law also predicts the direction of the current in a coil produced by a changing magnetic flux. Lenz's law states that when a conductor interacts with a magnetic field, there must be an induced current that opposes the interaction.

Lenz's Version of the Right-Hand Rule (Generator Effect)

Point your fingers in the direction of the magnetic field and orient the palm of your hand to exert a force to oppose the motion of the conductor. Your thumb will point in the direction of the induced current (conventional current).

A good example of applying the theory of Lenz's law without Lenz's version of the right-hand rule above is using the right-hand rule #2 to explain the flow of conventional current in a coil when approached by a permanent magnet. Lenz would claim that the electrons will flow in the coil so as to create a magnetic field that will oppose the approaching field. This explanation is also consistent with Newton's third law of motion.

Students should use Lenz's law to explain back EMF, and magnetic dampening resulting from eddy currents.

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 understand that a AC 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. Students should be able to explain why an alternator (AC) is used in automobiles considering that automobiles run on DC circuitry.

Generators and Motors
~ 4 Classes

Tasks for Instruction and/or Assessment

Journal

- Write an entry in your journal that summarizes your understanding of Lenz's law and the right-hand rule for conductors. This could take the form of a series of diagrams and explanatory notes. (328-7)
- 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)

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. (328-7)

Resources/Notes

MHR *Physics,* pp. 781-796

Appendix

Instructional Planning (Term 1)

Unit 1: Application of Vectors (~27 Classes)			
Unit/Section Title	# Classes	Text Section/Pages	Suggested Core Investigations
Dynamics Extension	16	Sections 10.1, 10.2 pp. 454-489	Maintaining Equilibrium Atwood Machine
Torque	3	Section 10.3 pp. 490-495, 502	Build a Mobile
Projectiles	8	Section 11.1 pp. 530-549	Projectile Hoop Projectile Landing
Unit 2: Circular and Planetary Motion (~13 Classes)			
Unit/Section Title	# Classes	Text Section/Pages	Suggested Core Investigations
Circular Motion	4	Section 11.2 pp. 551-562	Verifying the Circular Motion Equations
Universal Gravitation	5	Sections 12.1, 12.2 pp. 572-594	
Simple Harmonic Motion	4	Sections 13.1, 6.3 pp. 600-614, 254-261	Force and Spring Extension The Period of a Mass on a Spring
~ Mid-Term			

Instructional Planning (Term 2)

Unit 3: Electricity and Magnetism (~35 Classes)			
Unit/Section Title	# Classes	Text Section/Pages	Suggested Core Investigations
Coulomb's Law	6	Section 14.1 pp. 630-642	Static Electricity
Electric and Gravitational Fields	5	Section 14.2 pp. 643-661, 698	
Electric Circuits	14	Sections 15.1, 15.2, 15.3, 15.4, 15.5 pp. 686-728, 734-746	Current, Resistance, and Potential Difference Ohm's Law Series Circuits Series and Parallel Circuits
Magnetic Fields, Electromagnetism, and Electromagnetic Induction	6	Sections 16.1, 16.2 pp. 660-661, 752-780	Magnetic Field around a Straight Conductor Magnetic Field around a Helix The Motor Effect
Generators and Motors	4	Section 16.3 pp. 781-796	