Atlantic Canada Science Curriculum

New Brunswick
Department of Education
Educational Programs & Services Branch

New Brunswick / Nouveau Brunswick

Physics 12

CURRICULUM

2003

Additional copies of this document (*Physics 12*) may be obtained from the Instructional Resources Branch.
Title Code (840620)

Acknowledgements

The Atlantic Provinces Education Foundation expresses its indebtedness to members of the regional physics committee for their professional expertise and insights in developing this regional Physics 11 curriculum guide. In addition, pilot teachers and others who contributed comments and suggestions are to be commended for their commitment to developing exemplary science programs.

The New Brunswick Department of Education would like to thank the following people for their contribution:

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Contents

Foreword

The pan-Canadian Common Framework of Science Learning Outcomes K to 12, released in October 1997, assists provinces in developing a common science curriculum framework.

New science curriculum for the Atlantic Provinces is described in Foundation for the Atlantic Canada Science Curriculum (1998).

This Physics 12 guide provides teachers with the overview of the outcomes framework for the course. It also includes suggestions to assist teachers in designing learning experiences and assessment tasks.

Introduction

Background

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

Aim

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

Scientific literacy is an evolving combination of the science-related attitudes, skills, and knowledge students need to develop inquiry, problem-solving, and decision-making abilities; to become life-long learners; and to maintain a sense of wonder about the world around them.

To develop scientific literacy, students require diverse learning experiences that provide opportunities to explore, analyse, evaluate, synthesize, appreciate, and understand the interrelationships among science, technology, society, and the environment.

Program Design and Components

Learning and Teaching Science

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

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

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

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

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

Writing in Science

Learning experiences should provide opportunities for students to use writing and other forms of representation as ways to learning. Students, at all grade levels, should be encouraged to use writing to speculate, theorize, summarize, discover connections, describe processes, express understandings, raise questions, and make sense of new information using their own language as a step to the language of science. Science logs are useful for such expressive and reflective writing. Purposeful note taking 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 teacher demonstrations of the strategies they need to develop and apply in selecting, constructing, and using various forms for communicating in science.

The Three Processes of Scientific Literacy

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

Inquiry

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

Problem Solving

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

Decision Making

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

Meeting the Needs of All Learners

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

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. Examples of these are illustrated in the following lists:

Inquiry

- define questions related to a topic
- refine descriptors/factors that focus practical and theoretical
- select an appropriate way to find information
- make direct observations
- perform experiments, record and interpret data, and draw conclusions
- design an experiment which tests relationships and variables
- write lab reports that meet a variety of needs (limit the production of “formal” reports) and place emphasis on recorded data
- recongnize that the quality of both the process and the product are important

Problem Solving

- clearly define a problem
- produce a range of potential solutions for the problem
- appreciate that several solutions should be considered
- plan and design a product or device intended to solve a problem, construct a variety of acceptable prototypes, pilot test, evaluate, and refine to meet a need
- present the refined process/product/device and support why it is "preferred"
- recognize that the quality of both the process and the product are important

Decision Making

- gather information from a variety of sources
- evaluate the validity of the information source
- evaluate which information is relevant
- identify the different perspectives that influence a decision
- present information in a balanced manner
- use information to support a given perspective
- recommend a decision and provide supporting evidence
- communicate a decision and provide a "best" solution

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, the 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 fomative assesssment support learning, the results, when reported to students, should indicate the improvements expected.

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 of a given task, use of a piece of equipmetn or application of a given process. The results may be recorded in the form of checklist, 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 of 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 for students to 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, perception of success, reponses 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 a brief discussion between teacher and student or they may be more extensive and include student, parent and teacher. Such conferences allow a student to know which criteria will be used to assess formal interviews. This assessment technique provides an opportunity to students whose verbal presentation skills are stronger than their written skills.

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 dispaly or direct teacher assessment. Whether as 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 of concepts. They are less successful at assessing skills, processes and attitudes. The purpose of the assessment should determine what form of pencil and paper exercise is used.

Presentation

The curriculum includes outcomes that require students to analyse 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 activites are best displayed and assessed through presentations. These can be given orally, in written/pictoral 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

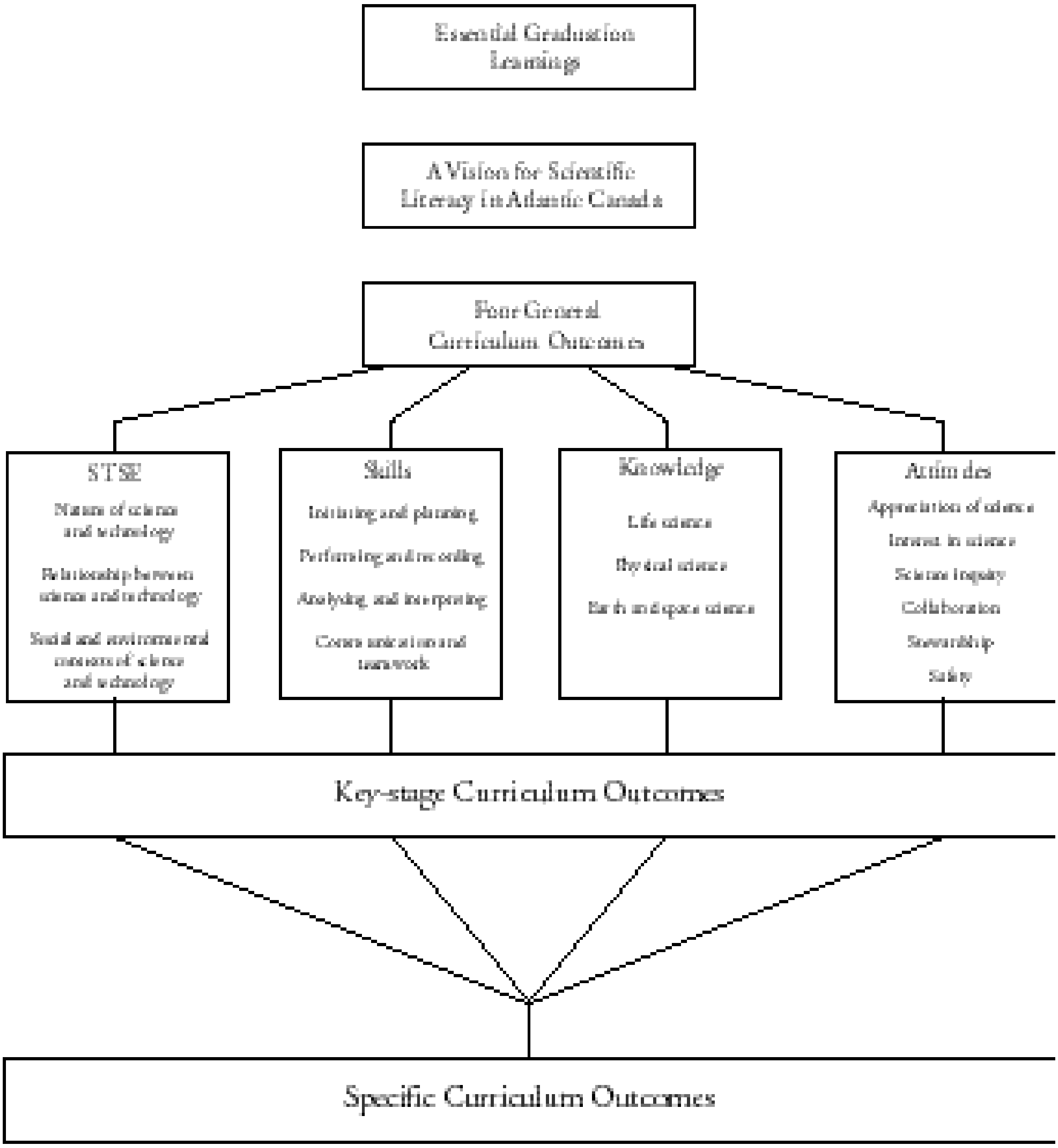
Portfolios offer another option for assessing student progress in meeting curriculum outcomes over a more extended period of time. This form of assessment allows the students to be central to the process. There are decision about the portfolio, and its contents, which can be made by the students. What is placed in the portfolio, the criteria for selection, how the the portfolio is used, how and where it is stored, 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 to share with others. For all students, but particularly younger 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 Common Framework of Science Learning Outcomes K to 12. The diagram below provides the blueprint of the outcomes framework.

Outcomes Framework



Essential Graduation Learnings

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

Aesthetic Expression

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

Citizenship

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

Communication

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

Personal Development

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

Problem Solving

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

Technological Competence

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

General Curriculum Outcomes

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

Science, Technology, Society, and the Environment

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

Skills

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

Knowledge

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

Attitudes

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

Key-Stage Curriculum Outcomes

Key-stage curriculum outcomes are statements that identify what students are expected to know, be able to do, and value by the end of grades 2, 5, 8, 10, and 12 as a result of their cumulative learning experiences in science. The key-stage curriculum outcomes are from the Common Framework for Science Learning Outcomes K to12.

Specific Curriculum Outcomes

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, outcome statements for attitudes are written as key-stage curriculum outcomes for the end of grades 2, 5, 8, 10, 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 outcome statements 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	439 show a continuing and more informed curiosity and interest in science and science-related issues 440 acquire, with interest and confidence, additional science knowledge and skills using a variety of resources and methods, including formal research 441 consider further studies and careers in science- and technology-related fields	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, • 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	Evident when students, for example, • conduct research to answer their own questions • recognize that part-time jobs require science- and technology-related knowledge and skills • maintain interest in or pursue further studies in science • recognize the importance of making connections among various science disciplines • explore and use a variety of methods and resources to increase their own knowledge and skills • are interested in science and technology topics not directly related to their formal studies • explore where further science- and technology-related studies can be pursued • are critical and constructive when considering new theories and techniques • use scientific vocabulary and principles in everyday discussions • readily investigate STSE issues	Evident when students, for example, • insist on evidence before accepting a new idea or explanation; ask questions and conduct research to confirm and extend their understanding • criticize arguments based on the faulty, incomplete, or misleading use of numbers • recognize the importance of reviewing the basic assumptions from which a line of inquiry has arisen • expend the effort and time needed to make valid inferences • critically evaluate inferences and conclusions, cognizant of the many variables involved in experimentation • critically assess their opinions of the value of science and its applications • criticize arguments in which evidence, explanations, or positions do not reflect the diversity of perspectives that exist • insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged • seek new models, explanations, and theories when confronted with discrepant events or evidence

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	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	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, • 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	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	Evident when students, for example, • read the label on materials before using them, interpret the WHMIS symbols, and consult a reference document if safety symbols are not understood • criticize a procedure, a design, or materials that are not safe or that could have a negative impact on the environment • consider safety a positive limiting factor in scientific and technological endeavours • carefully manipulate materials, cognizant of the risks and potential consequences of their actions • write into a laboratory procedure safety and waste-disposal concerns • evaluate the long-term impact of safety and waste disposal on the environment and the quality of life of living organisms • use safety and waste disposal as criteria for evaluating an experiment • assume responsibility for the safety of all those who share a common working environment by cleaning up after an activity and disposing of materials in a safe place • seek assistance immediately for any first aid concerns like cuts, burns, or unusual reactions • keep the work station uncluttered, with only appropriate lab materials present

Curriculum Guide Organization

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

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

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

Unit Organization

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

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

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

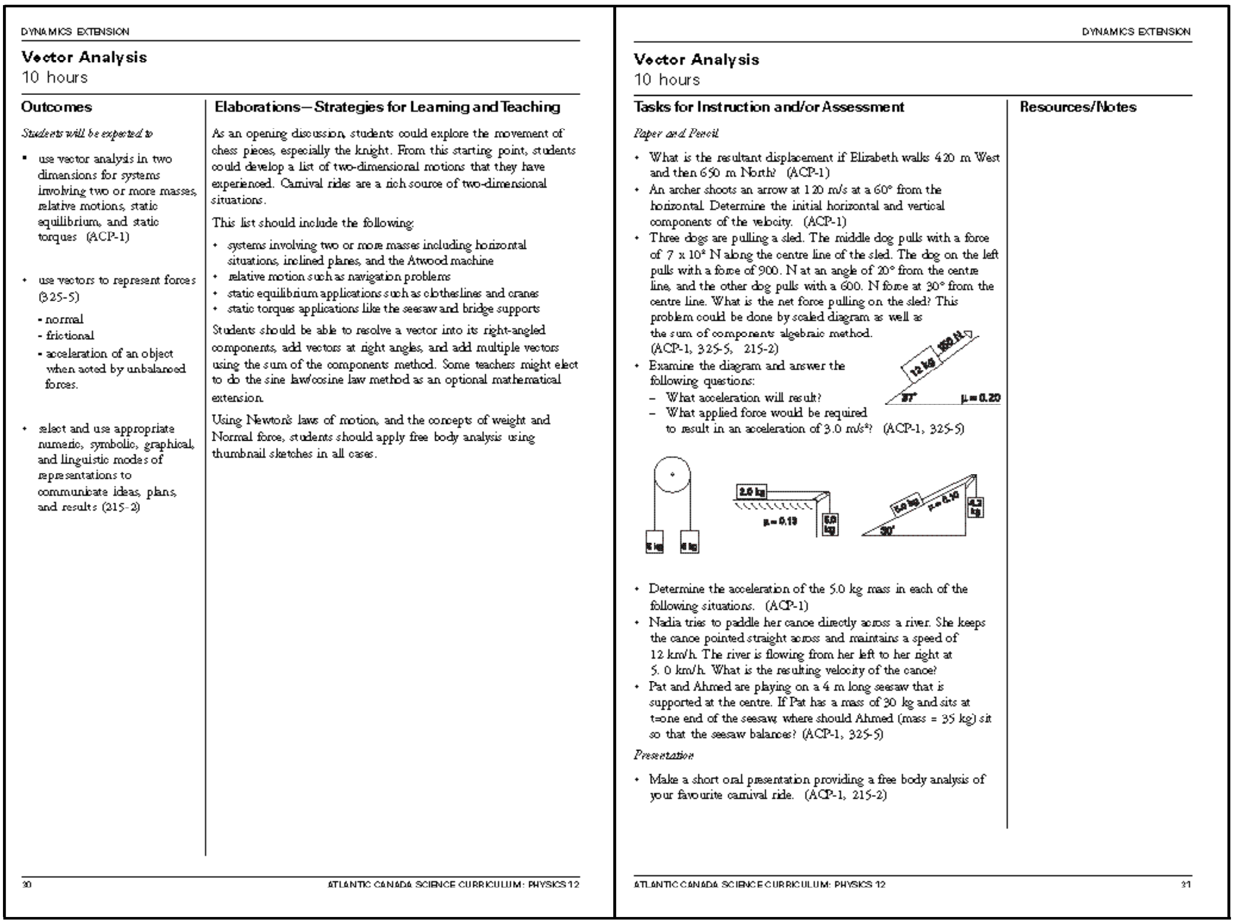
These code numbers appear in brackets after each specific curriculum outcome (SCO).

The Four-Column Spread

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

Two-Page,

Four-Column Spread



DYNAMICS EXTENSION

Vector Analysis
10 hours

Outcomes

Students will be expected to

- use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques (ACP-1)
- use vectors to represent forces (325-5)
  - normal
  - frictional
  - acceleration of an object when acted by unbalanced forces.
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representations to communicate ideas, plans, and results (215-2)

Elaborations—Strategies for Learning and Teaching

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 should 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

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

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

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DYNAMICS EXTENSION

Vector Analysis
10 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- What is the resultant displacement if Elizabeth walks 420 m West and then 650 m North? (ACP-1)
- An archer shoots an arrow at 120 m/s at a 60° from the horizontal. Determine the initial horizontal and vertical components of the velocity. (ACP-1)
- Three dogs are pulling a sled. The middle dog pulls with a force of 7 x 10² N along the centre line of the sled. The dog on the left pulls with a force of 900. N at an angle of 20° from the centre line, and the other dog pulls with a 600. N force at 30° from the centre line. What is the net force pulling on the sled? This problem could be done by scaled diagram as well as the sum of components algebraic method. (ACP-1, 325-5, 215-2)
- Examine the diagram and answer the following questions:
  - What acceleration will result?
  - What applied force would be required to result in an acceleration of 3.0 m/s²? (ACP-1, 325-5)

- Determine the acceleration of the 5.0 kg mass in each of the following situations. (ACP-1)
- Nadia tries to paddle her canoe directly across a river. She keeps the canoe pointed straight across and maintains a speed of 12 km/h. The river is flowing from her left to her right at 5. 0 km/h. What is the resulting velocity of the canoe?
- Pat and Ahmed are playing on a 4 m long seesaw that is supported at the centre. If Pat has a mass of 30 kg and sits at t=one end of the seesaw, where should Ahmed (mass = 35 kg) sit so that the seesaw balances? (ACP-1, 325-5)

Presentation

- Make a short oral presentation providing a free body analysis of your favourite carnival ride. (ACP-1, 215-2)

Resources/Notes

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Column One: Outcomes

The first column provides the specific curriculum outcomes. These are based on the pan-Canadian Common Framework of Science Learning Outcomes K to 12. The statements involve the Science-Technology-Society-Environment (STSE), skills, and knowledge outcomes indicated by the outcome number(s) that appears in parenthesis 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.

ColumnThree: 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 outcomes. The assessment item identifies the outcome(s) addressed by the outcome number in brackets after the item.

Column Four: Resources/Notes

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

Level 1:

As well, curriculum extensions intended for students in the Level 1 course are indicated with the *** * ** ** * *** symbol.

This symbol not only brackets text discussing differentiation for students in the Level 1 course, but also appears at the top of each page on which such text is located.

Unit 1

Dynamics Extension

Suggested Time: 25 Hours

Dynamics Extension

Introduction

From real life experiences, students know that objects speed up, slow down, and change direction, and they accept this as a matter of course. Dynamics is the study of the factors that cause such changes, that is, why an object moves the way it does. It is a logical extension of kinematics, and this unit should pick up with questions arising naturally from the motion of objects studied in the previous course. Students could begin by investigation the effects of one-dimensional forces on themselves and on objects, and, through the application of Newton's laws, move on to an analysis of systems using their knowledge of dynamics. At the end of this unit students are introduced to situations where two or more objects are considered at once (a system is involved). These situations are dealt with using the concept of momentum and collisions.

Focus and Context

As in the kinematics unit in Physics 11, students should draw on their own experiences in attempting to describe and analyze forces. Familiar forces students feel acting on themselves in cars, on amusement park rides, and during sports activities should be discussed and analyzed. A simple activity such as measuring with a spring scale the force needed to start and continue to pull a student along the floor in a wagon or freight dolly can lead to discussion of the outcomes of applied force: acceleration and overcoming friction. Activities with dynamics carts would then allow students to investigate, measure, manipulate, and predict relationships among force, mass, and acceleration. This could lead to many opportunities for individual study and research projects involving the design and operation of such devices as seat belts, airbags, helmets, and sports equipment – all with a view to making connections among the design, principles of physics, and society's concern and influence (an STSE connection.)

Science Curriculum Links

This unit completes the study of motion begun in Science 10. It leads students to the more sophisticated concepts of momentum and energy that are necessary for the study of interactions between masses. The concepts developed in the study of dynamics will be further developed in unit 2 with the treatment of two dimensional situations, uniform circular motion, and Kepler's Laws.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Nature of Science and Technology** 114-9 explain the importance of using appropriate language 115-5 analyse why and how a particular technology was developed and improved over time **Relationships Between Science and Technology** 116-4 analyse and describe examples where technologies were developed based on scientific understanding 116-6 describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum	Students will be expected to **Initiating and Planning** 212-3 design an experiment identifying and controlling major variables 212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring and decision making **Performing and Recording** 213-2 carry out procedures controlling major variables and adapting or extending prodecures where required **Analysing and Interpreting** 214-3 compile and display evidence, by hand or computer, in a variety of formats, including diagrams, charts, tables, graphs and scatter plots **Communication and Teamwork** 215-2 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representations to communicate ideas, plans, and results 215-4 identify multiple perspectives that influence a science related decision or issue 215-6 work cooperatively with team members to develop and carryout a plan, and troubleshoot problems as they arise	Students will be expected to ACP-1 use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques 326-3 apply quantitatively the laws of conservation of momentum to one- and two-dimensional collisions and explosions 326-4 determine which laws of conservation of energy or momentum are best used to solve particular real-life situations involving elastic and inelastic collisions 325-5 use vectors to represent force

Vectors to Analyze: Force and Motion
15 hours

Outcomes

Students will be expected to

- use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques (ACP-1)
- use vectors to represent forces (325-5)
  - normal
  - frictional
  - acceleration of an object when acted by unbalanced forces.
- select and use appropriate numeric, symbolic, graphical, and linguistic modes of representations to communicate ideas, plans, and results (215-2)

Elaborations—Strategies for Learning and Teaching

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 should 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

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

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

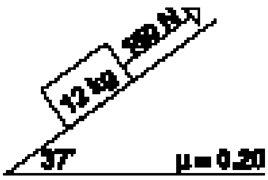
Most of the work on objects and structures in equilibrium should be part of the level 1 program, especially static torques.

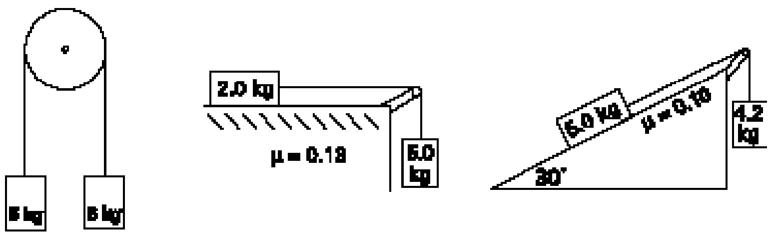
Vectors to Analyze: Force and Motion
15 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- What is the resultant displacement if Elizabeth walks 420 m West and then 650 m North? (ACP-1) 773.9 m W[57.1°]N
- An archer shoots an arrow at 120 m/s at a 60° from the horizontal. Determine the initial horizontal and vertical components of the velocity. (ACP-1) 60m/s horizontal 103.9 m/s vertical
- Three dogs are pulling a sled. The middle dog pulls with a force of 7 x 10^2 N along the centre line of the sled. The dog on the left pulls with a force of 900. N at an angle of 20° from the centre line, and the other dog pulls with a 600. N force at 30° from the centre line. What is the net force pulling on the sled? This problem could be done by scaled diagram as well as the sum of components algebraic method. (ACP-1, 325-5, 215-2) 2064.42N (0.31° to the left)
- Examine the diagram and answer the following questions:
  - What acceleration will result? 8.2 m/s^2 up ramp
  - What applied force would be required to result in an acceleration of 3.0 m/s^2? (ACP-1, 325-5) 126.6 N up the ramp





- Determine the acceleration of the 5.0 kg mass in each of the above situations. (ACP-1) 2.96 m/s^2 23.3 m/s^2 2.5 m/s^2
- Nadia tries to paddle her canoe directly across a river. She keeps the canoe pointed straight across and maintains a speed of 12 km/h. The river is flowing from her left to her right at 5. 0 km/h. What is the resulting velocity of the canoe? 13 km/h 67.4° to the current

Presentation

- Make a short oral presentation providing a free body analysis of your favourite carnival ride. (ACP-1, 215-2)

Resources/Notes

Vectors to Analyze: Force and Motion (continued)
15 hours

Outcomes

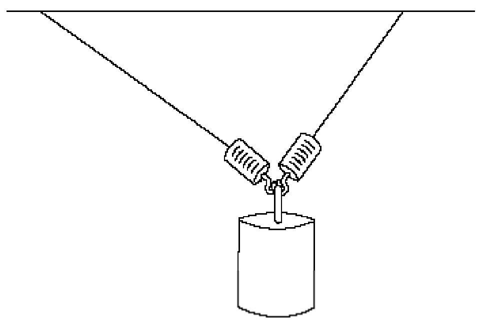
Students will be expected to

- use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and torques (ACP-1)
- design an experiment identifying and controlling major variables (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring and decision making (212-8)
- carry out procedures controlling major variables and adapting or extending prodecures where required (213-2)
- compile and display evidence, by hand or computer, in a variety of formats, including diagrams, charts, tables, graphs and scatter plots (214-3)

Elaborations—Strategies for Learning and Teaching

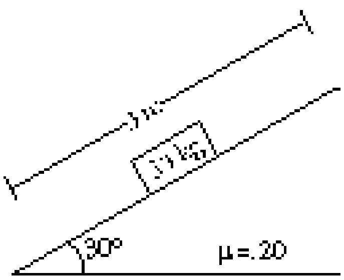
Students should have a laboratory experience with static equilibrium using a force board or other suitable apparatus.

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



Teachers should continue to reinforce work-energy concepts from grade 11 Physics.

For example:



- calculate work needed to push box up incline
- what is potential energy of box once it is up to the incline
- what would be velocity of box at bottom of incline if allowed to slide
- what energy is lost to friction

Vectors to Analyze: Force and Motion (continued)
15 hours

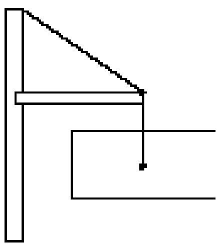
Tasks for Instruction and/or Assessment

Journal

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

Paper and Pencil

- Prepare a written report of your experiment about static equilibrium. (ACP-1, 212-3, 212-8, 213-3, 214-3)
  - A 1.5×10^3 kg car is crossing a 120 m long flat bridge which is supported at both ends. When the car is 32 m from one end, what force must each end support be able to provide? (ACP-1) 10780 N, 3920 N
  - Determine the tension in the cable and the compression force in the boom to support the 1.0×10^1 kg sign. The angle between the boom and the supporting cable is 30° C. (ACP-1) Cable tension 196 N; Boom 170 N



Resources/Notes

Conservation of Momentum
5 hours

Outcomes

Students will be expected to

- apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions (326-3)
- design an experiment identifying and controlling major variables (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring and decision making (212-8)
- carry out procedures controlling major variables and adapting or extending prodecures where required (213-2)
- compile and display evidence, by hand or computer, in a variety of formats, including diagrams, charts, tables, graphs and scatter plots (214-3)

Elaborations—Strategies for Learning and Teaching

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

The following situations could be set up:

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

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

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

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

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

Conservation of Momentum
5 hours

Tasks for Instruction and/or Assessment

Performance
- Conduct a collision analysis lab. (212-3, 212-8, 213-3, 214-3, 326-3)

Journal
- Write down your observations and questions that you have regarding the use of dynamics carts. Organize them. How does writing your observations help your understanding of your collision lab? (212-3, 212-8, 213-3, 214-3, 326-3)

Paper and Pencil
- Write a report of your collision analysis lab. You are expected to look for patterns in your raw data. For example, you can investigate how $\triangle V$ is related to mass ratio. Account for the difference in total momentum from trial to trial. You should describe, in detail, the nature of the interaction during the collision as the plunger compresses and rebounds and relate this observation to other interactions such as billiard balls and automobiles. Some discussion of error (less than 100% conservation of momentum) is expected. (212-3, 212-8, 213-3, 214-3, 326-3)
- What condition(s) must be met for the total momentum of a system to be conserved? (326-3) No outside influence on system.
- A 45-kg student stands on a stationary 33-kg raft. The student then walks with a velocity of 1.9 m/s [E] relative to the water. What is the resulting velocity of the raft, relative to the water, if fluid friction is negligible? (326-3) 2.6 m/s [w]
- Two ice skaters, initially stationary, push each other so that they move in opposite directions. One skater of mass of 56.9 kg has a speed of 3.28 m/s. What is the mass of the other skater if her speed is 3.69 m/s? Neglect friction. (326-3) 50.6 kg
- A stationary 35-kg artillery shell accidentally explodes, sending two fragments of mass 11 kg and 24 kg in opposite directions. The speed of the 11-kg fragment is 95 m/s. What is the speed of the other fragment? (326-3) 44 m/s
- A railway car of mass 1.37×10^4 kg, rolling at 20.0 km/hr [N], collides with another railway car of mass 1.12×10^4 kg, also initially rolling north, but moving more slowly. After the collision, the coupled cars have a velocity of 18.3 km/h [N]. What is the initial velocity of the second car? (326-3) 162 km/hr [N]

Resources/Notes

Technological Implications
2 hours

Outcomes

Students will be expected to

- analyse and describe examples where energy- and momentum-related technologies were developed and improved over time (115-5, 116-4)
- describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum (116-6)
- explain the importance of using appropriate language and conventions when describing events related to momentum and energy (114-9)
- identify multiple perspectives that influence a science related decision or issue (215-4)

Elaborations—Strategies for Learning and Teaching

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

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

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

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

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

Technological Implications
2 hours

Tasks for Instruction and/or Assessment

Performance

- Research the application of technology in a specific sport, then debate how to enhance performance by modifying the equipment. Apply relevant physics concepts in your debate. An example might be as follows:
  - Be it resolved that aluminium baseball bats should be permitted in professional baseball. (115-5, 116-4, 116-6, 114-9, 215-4)

Journal

- "One billiard ball collides with a stationary ball. The first ball stops while the second moves away with the same velocity as the original ball." Explain what happens in this interaction using the concepts of momentum and energy. (115-5, 116-6, 215-4) Both momentum and energy is fully transfered to second ball. Thus, first ball stops moving and second moves.

Presentation

- The Parent Teacher Organization (PTO) of your local elementary school has asked your team of three members to participate in a safety assessment of their playground. Select one piece of playground apparatus. Do a momentum and energy analysis and make recommendations as to what modifications should be made to the apparatus. As a consultants' group, you must prepare an audio-visual presentation to the PTO. (114-9, 116-6, 115-5, 116-4, 215-4)

Resources/Notes

Collisions in Two Dimensions
3 hours

Outcomes

Students will be expected to

- apply quantitatively the laws of conservation of momentum to one and two dimensional collisions and explosions (326-3)
- determine in which real-life situations involving elastic and inelastic interactions the laws of conservation of momentum and energy are best used (326-4)
- design an experiment identifying and controlling major variables (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring and decision making (212-8)
- carry out procedures controlling major variables and adapting or extending prodecures where required (213-2)
- compile and display evidence, by hand or computer, in a variety of formats, including diagrams, charts, tables, graphs and scatter plots (214-3)
- work cooperatively with team members to develop and carryout a plan, and troubleshoot problems as they arise (215-6)

Elaborations—Strategies for Learning and Teaching

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

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

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

Collisions in Two Dimensions
3 hours

Tasks for Instruction and/or Assessment

Performance

- Students should perform a two-dimensional elastic and/or inelastic collision lab investigation. The use of software (e.g., Interactive Physics) is encouraged. (212-3, 212-8, 213-2, 214-3, 215-6, 326-3)
- Go to the website www.glenbrook.K12.il.us/gbssci/phys/mmedia/ index.html and write about the different types of collisions.

Pencil and Paper

- Prepare a written report for the investigation. (326-3)
- A collision between two vehicles occurs at a right-angled intersection. Vehicle A is a car of mass 1800 kg, travelling at 65 km/h north. Vehicle B is a delivery truck of mass 3500 kg, initially travelling east at 45 km/h. If the two vehicles remain stuck together after the impact, what will be the velocity (speed and direction) of the combined mass after impact? (326-4)
  37 km/hr E [36.6°] N
- A 5.0 kg bomb at rest explodes into three pieces, each of which travels parallel to the ground. The first piece, with a mass of 1.2 kg, travels at 5.5 m/s at an angle of 20° south of east. The second piece has a mass of 2.5 kg and travels 4.1 m/s at an angle of 25° north of east. Determine the velocity of the third piece.
  12 m/s [W 7.6° S]

Resources/Notes

Unit 2

Projectiles, Circular Motion and Universal Gravitaion

Suggested Time: 25 hours

Projectiles, Circular Motion and Universal Gravitation

Introduction

From the first intelligent musings of the human species came a variety of questions on why and how objects moved. Why does a rock fall down? When thrown, why does a rock take a curved path? How do the sun, stars and moon move about the universe? 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 during the Renaissance, with the Galilean approach to practical experimentation, that began the classical period in physical science. Concepts of force, momentum, and energy; precise observations of orbital motions; and a mathematical system to represent rates of change led to explanations that satisfy all ordinary experiences.

Focus and Context

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

Science Curriculum Links

The study of motion was begun in Science 10, and expanded in Physics 11 to include wave motion as well as the movement of solid objects. Students will use their ability to describe motion to complete 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

Students will be expected to

Relationship between Science and Technology

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

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

Nature of Science and Technology

115-5 distinguish between scientific questions and technological problems

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

Skills

Students will be expected to

Initiating and Planning

212-3 design and experiment identifying and controlling major variables

Analysing and Interpreting

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

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

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

Communication and Teamwork

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

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

Knowledge

Students will be expected to

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

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

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

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

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

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

Projectiles
8 hours

Outcomes

Students will be expected to

- analyse and describe examples where technologies were developed based on scientific understanding (116-4)
  - rocket launcher
  - skeet shooter
- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- construct, test and evaluate a device or system on the basis of developed criteria (214-14, 214-16)
- analyse quantitatively the horizontal and vertical motion of a projectile (325-6)

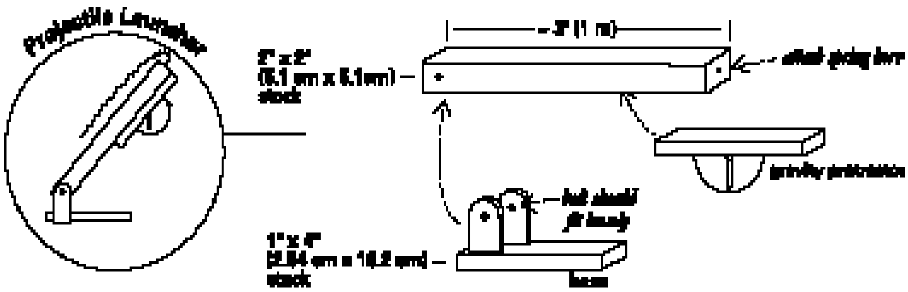
Elaborations—Strategies for Learning and Teaching

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

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

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

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



Projectiles
8 hours

Tasks for Instruction and/or Assessment

Teacher Observation

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

Paper and Pencil

- A written lab report should be presented on the investigation of projectile motion. (325-6)
- A projectile is launched at a muzzle velocity of 20.0 m/s at an angle of 57° from the horizontal. Determine the position, horizontally and vertically, from the launch point at 1.5 s. Horizontally - 16.4 m; Vertically - 14.2 m
- A trained dog can jump forward at an angle of 37° to the horizontal and with a speed of 3.5 m/s. Where should the trainer hold a hoop so the dog passes through it at his highest point (how far horizontally from the dog's initial position, and how high)? What would be different if the dog jumped from one platform to another each 2.0 m high? (325-6) Top of hoop at least .23 m above ground and bottom of hoop not more than .23 m above ground and 0.6 m from dog's initial jump point. Height of hoop only: 2.23 above, 0.6 m from initial jump point.
- 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 if cannon opening is 1.3 m above ground? (325-6) 20.5 m/s
- A daredevil stunt driver is planning a scene for a movie. She must drive a car horizontally off the roof of a tall building and crash into a window 8.0 m lower in the next building, which is a horizontal distance of 15 m away. Can you help her determine what speed she must have as she reaches the edge of the higher roof? (325-6) 41.5 km/h
- Write a report describing the features of any projectile launcher. (116-4, 116-6)

Resources/Notes

Projectiles (continued)
8 hours

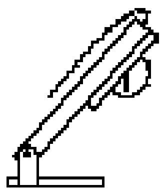
Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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



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

Vertical: $d_2 = d_1 + v_y t + ½at^2$

$d_2 = 2\text{ m} + 0 = ½\,(–9.8\text{m/s}^2)(0.3\text{s})^2$

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

Horizontal: $d_2 = d_1 + v_x t + ½at^2$

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

$d_2 = 1.5\text{ m}$

Projectiles (continued)
8 hours

Tasks for Instruction and/or Assessment

Performance

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

  It is the range that we are concerned with today. Your group will be given the following: one metre stick, one large elastic band, one large metal washer (projectile), and a 10 metre measuring tape.

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

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

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

Resources/Notes

Projectiles (continued)
8 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

A similar approach can be taken with launches at any angle. The launcher can be modified as shown in the diagram (on pages 46 and 47) by adding a gravity protractor, or attaching a protractor scale to the rear of the base so it is visible from the front.

Students should also draw in velocity vectors to scale at each 0.1 s and show the graphical addition of the components. If the instantaneous velocities at two different times are subtracted, a Δv value can be determined which is directed vertically down.

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

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

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

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

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

Projectiles (continued)
8 hours

Tasks for Instruction and/or Assessment

Performance

- Describe how you would build and test a device made of simple, inexpensive materials to demonstrate that two coins launched simultaneously from the same level, one launched horizontally and the other dropped vertically, land at the same instant. (325-6)

- A garden hose is held with its nozzle horizontally above the ground. The flowing water follows projectile motion. Given a metre stick and a calculator, describe how you would determine the speed of the water coming out of the nozzle. (325-6)

Extension

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

- Derive a formula for the range of a level to level projective (325-6) Answer:

$$R = \frac{V^2 \sin 2\theta}{g}$$

- Use your formula to prove that the maximum range for a given muzzle velocity will occur at a launch angle of 45° (325-6) Answer: Maximum value of sin θ occurs at 90°, thus $\sin\theta \Rightarrow \sin 2(45) \Rightarrow \sin 90^\circ$

Resources/Notes

Circular Motion
8 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

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

The traditional centripetal force experiment involving weights being swung in circular motion while held in place by a suspended mass can be done at this point. It is recommended that this be done as a teacher demonstration with student help in the interest of safety and to ensure that the technique required to operate the sling apparatus smoothly is consistent. Through discussion, students could suggest ways to control variables during trials. The relationship of frequency to velocity should be developed. The students should be able to verify that

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

As an extension, the concept of banked curves as a centripetal force must be covered.

Circular Motion
8 hours

Tasks for Instruction and/or Assessment

Journal

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

Paper and Pencil

- Prepare a written lab report on the centripetal force experiment/demonstration. (325-12)
- In a Celtic field event called the hammer throw, a 12 kg ball is whirled in a circle of radius 2.0 m with a frequency of 1.5 Hz. What is the velocity when it is released? 18.84 m/s What is the centripetal force? (325-13) 21.30 N
- How can a motion with constant speed be an accelerated motion? (325-13) Because constant circular speed needs a force action on it, thus it is accelerated.
- Suppose a plane flies in a circular path of circumference 20.0 km at a speed of 200.0 km/h. What is the change in velocity in one quarter of a revolution? What is the change in velocity in half a revolution? (325-13) 200 km/h 90° from start for quarter turn and 180° from start at half turn
- If the speed of an object in circular motion is doubled, what effect will this have on the centripetal force? (325-13) Four times more
- 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) 140 m/s or 504 km/h
- A car with a mass of 2135 kg is rounding a curve on a level road. If the radius of curvature of the road is 52 m and the coefficient of friction between the tires and the road is 0.70, what is the maximum speed at which the car can make the curve without skidding? 19 m/s (68.4 km/h)
- Paul Tracy set the speed record for time trials at the Michigan International Speedway in 2000. Tracy averaged 378.11 km/h in the time trials. The oval track is banked at 18° with a radius of curvature of 382 m.
  - (a) What speed can cars round the curve without the need for friction to provide a centripetal force? 126 km/h
  - (b) Did Paul rely on friction? (325-13)

Resources/Notes

Simple Harmonic Motion (SHM)
4 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

There are numerous life experiences to which students could relate in the exploration of simple harmonic motion. 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 build up in the Tacoma bridge is still an impressive sight. From this viewing, students should be asked to pose related experiences such as water beds, pendulums, skyscraper damper floors, automobile suspension, or other topics.

Students have recently completed 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.

A laboratory investigation of energy changes of a mass oscillating on a string was done conducting in Physics 11. For a new investigation, students should explore the relationships among position, velocity, and acceleration (force) during the oscillation. This could be accomplished if students generate graphs for each variable against time. New data could be generated or data from a previous experiment could be used. Physics simulation software allows students to manipulate masses and spring force constants to explore how the variables relate.

Students should conduct an energy analysis of either a spring system 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 formulae:

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

T = period (s)
m = mass (kg)
k = force constant of spring (N/m)

and for pendulums using the formulae:

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

T = period (s)
l = length (m)
g = gravity (m/s)

Simple Harmonic Motion (SHM)
4 hours

Tasks for Instruction and/or Assessment

Journal

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

Paper and Pencil

- A 0.45 kg mass is attached to a spring with a force constant of 1.4×10^2 N/m. The mass spring system is placed horizontally, with the mass resting on a surface with neglible friction. The mass is displaced 15 cm, and then is released. Determine period and frequency of the SHM. (327-2, 327-4)
  Period = 0.36 s; Frequency = 2.8 Hz
- A 0.60 kg mass is vibrating at the end of spring on a frictionless horizontal surface. If the spring constant is 26 N/m and the maximum displacement (end to end) of the mass is 0.15 m, what is the speed of the object at its equilibrium position? (327-2, 327-4) 0.5 m/s
- Explain why the total energy of a mass spring system is

$$E_T = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$

  (327-2, 327-4)

- What is the period of a 0.80 m long pendulum? (327-2, 327-4) 1.8 s
- What length must a pendulum be to have a period of 1.0 seconds? (327-2, 327-4) .24 m

Presentation

- Develop and present a research paper on the design history of a particular bridge, for example, the famous Tacoma Bridge. Alternatively, you can research on how SHM or pendulums measure gravity of the mass of an object. (212-3, 214-3, 115-5)

Resources/Notes

Universal Gravitation
5 hours

Outcomes

Students will be expected to

- explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law (ACP-2)
- 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. This a good example of scientists' efforts is to find patterns in data which may lead to a more general understanding.

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

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

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

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

Universal Gravitation
5 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Write a summary report for the investigation of Kepler's Laws. (ACP-2)
- Two masses, 4.0 kg and 8.0 kg, are located 2.0 m apart. What is the gravitational interaction force between them? (215-2)

$$5.3 \times 10^{-10} \Rightarrow 5.3 \times 10^{-10} N$$

- What is the mass of an object which experiences a pull of 10.0 N at the earth's surface? (215-2) 1.0 kg
- At what height above the earth's surface would an object's weight be one half the value at the surface? (215-2) 2620 km above
- At what height will a satellite moving in the plane of the equator stay over the same location on the earth? (215-2) 3.58×10^7 m above
- Calculate the force of attraction between a 100 kg rugby player and Earth of mass 5.98×10^{24} kg if she (he) is sitting on the surface of Earth. Is there a simpler way to calculate? (215-5) 980 N -- Yes by using w = m . g
- If rugby player went to planet X and now only had a weight of 250 N, can you calculate mass of planet X? If so, what mass does it have? If not, why not? (215-2)
  Need distance between object centers. Teacher can provide one and students can now answer questions.
- The Hubble telescope is in orbit 600 km above Earth's surface. At what speed is the telescope travelling? (325-13, 215-2)
  7.57×10^3 m/s

Journal

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

Resources/Notes

Unit 3
Fields

Suggested Time: 30 hours

Fields

Introduction

Students have had experience with contact forces. Forces that exert influence through space without contact are more difficult to visualize. Historically, the notion of a field of influence 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 dinner with radio waves. Plasma displays for computers are finding their way onto our walls as large, thin television screens. A space probe has been recently placed in orbit around an asteroid.

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

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

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

Field theory has provided a common lens through which to view phenomena that at first seemed unrelated. Beginning in the 1960s, physicists began to search in earnest for a unified field theory 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 11 curriculum. This unit is an extension of this work. The study of fields is essential for an understanding of structure in physics and chemistry.

Curriculum Outcomes

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

Magnetic, Electric, and Gravitational Fields
5 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Students could begin a long-term group project in which they select a modern device that employs knowledge of one or more of the principles of magnetism, electricity, or electromagnetism studied in this unit; research the historical development of the science and technology involved; predict future developments in related areas; and prepare a multimedia presentation.

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

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

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

Magnetic, Electric, and Gravitational Fields
5 hours

Tasks for Instruction and/or Assessment

Presentation

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

Paper and Pencil

- An electron is at rest. Can this electron be set into motion by applying
  (a) a magnetic field?
  Yes, only when the magnetic field is moving or changing intensity will it induce the electron to move.
  (b) an electric field?
  Yes, the electric field is a force that either attracts or repels the electron if strong enough and close enough.
  Explain your answers. (328-1)

- A charged particle is moving with a constant velocity through a certain region of space. Is a magnetic field present? Explain. (328-1) Yes, because moving charges create a magnetic field in a circular pattern around its motion.

Resources/Notes

Magnetic, Electric, and Gravitational Fields (continued)
5 hours

Outcomes

Students will be expected to

- describe magnetic, electric, and gravitational fields as regions of space that affect mass and charge (328-1)
- describe magnetic, electric, and gravitational fields by illustrating the source and direction of the lines of force (328-2)
- describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles (328-3)
  - draw the magnetic field around one or more bar magnets in various orientations
  - describe the Earth's magnetic field and how it changes with time

Elaborations—Strategies for Learning and Teaching

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

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

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

Magnetic, Electric, and Gravitational Fields (continued)
5 hours

Tasks for Instruction and/or Assessment

Journal

- What is your understanding of magnetic, electric, and gravitational fields? How are these related? (328-2, 328-3) Electric and gravitational fields are similar in which a force is provided from one object onto another. Gravitational fields rely on mass, electric on the charge. Magnetic fields require two distinct poles and cannot be created by a single pole. Thus, magnetic fields have no real origin or termination point.

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

Paper and Pencil

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

Presentation

- In groups, research and discuss the past changes in the orientation of the Earth's magnetic field over geological periods of time. (328-3)

Resources/Notes

Coulomb's Law
5 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

Although it is possible to conduct a laboratory investigation of Coulomb's Law using pith balls in a chimney apparatus, the results are often frustrating. Leakage of charge during the conduct of trials makes it virtually impossible to demonstrate the relationship effectively. On the one hand, it is an excellent opportunity to appreciate the vagaries of the scientific process, and the need for ongoing interpretation and refinement. On the other, when the results are unconvincing, what are the students to believe?

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

$$Fe = \frac{Kq_1q_2}{r^2}$$

Fe = Electric force

r = distance between charges

K- Coulomb's constant

q_1 / q_2 = charges

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

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

Coulomb's Law
5 hours

Tasks for Instruction and/or Assessment

Performance

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

  Blow up the two balloons so that they are approximately the same size. Measure and record the mass of the balloon. Tie the two balloons together with a piece of string approximately 150 cm long. Drape them over one of the metre sticks or a bar 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.

  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)
- Three point charges, $q_1 = 3.6 \times 10^{-6}$, $q_2 = -2.7 \times 10^{-6}$ C and $q_3 = 4.5 \times 10^{-6}$ C, are arranged in a linear fashion q_1 30 cm away from q_2 and 50 cm away from q_3. What is total force on q_3? (328-4) 2.2 N

Resources/Notes

Electric Circuits
15 hours

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
  - draw a schematic diagram for series, parallel, and simple combination 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

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

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

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

Electric Circuits
15 hours

Tasks for Instruction and/or Assessment

Informal Observation

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

Journal

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

Paper and Pencil

- A multimeter is placed within a circuit. It can measure Watts, Volts and Amperage. Explain what is it really measuring at:
  - (a) watts setting Power $\Rightarrow$ rate electrical energy is passed on to various loads
  - (b) volt setting Energy transferred by the charge flow. It measures energy of chrges before and after it has gone through resistor.
  - (c) amperes setting Amount of charge moving past a point divided by time. Rate of charge flow.

Resources/Notes

Electric Circuits (continued)
15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

- two in parallel
- one in series with two in parallel
- one in parallel with two in series

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

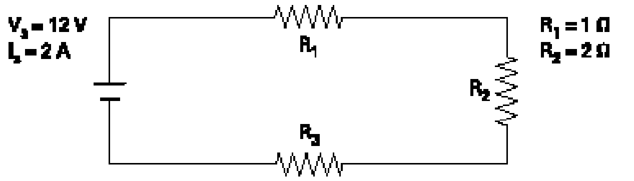
Students should conduct a laboratory investigation comparing mechanical work done to electrical energy consumed. For example, a small electric motor (3 V toy) could be mounted with the shaft parallel to the floor at a some height greater than 1.0 m. A mass is attached with a string to the shaft so that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

Electric Circuits (continued)
15 hours

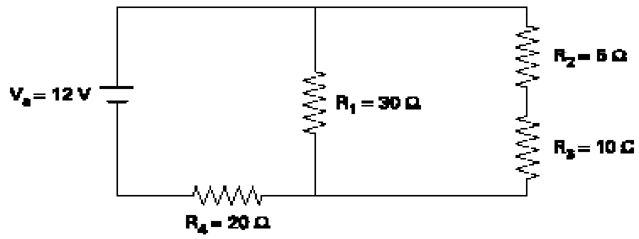
Tasks for Instruction and/or Assessment

Paper and Pencil

- Prepare a written report based on the lab investigation. (ACP-3)
- Solve problems such as the following: Two resistors are connected in series across a 30 V source. Draw a diagram of the circuit.
  - If the current from the source is 1.3 A, what is the current through each resistor? It is 1.3A for each.
  - If the voltage across one resistor is 12.4 V, what is the voltage across the other? 17.6V
  - Find the resistance for each resistor. (ACP-3) 9.54 *Ω* and 13.54 *Ω*
- Three resistors having values of 5 Ω, 4 Ω, and 3 Ω are connected to a 3.0 V source. Find the current through each resistor if they are connected:
  - in parallel 0.25 A in all
  - in series (ACP-3) 0.6 A, 0.75 A and 1 A respectively
- A 6.0 V battery is set up in a circuit. All of the current passes through a 10 Ω resistor, and then splits between two branches one of which has a 5 Ω resistor and the other a 15 Ω resistor. Determine the total resistance and the current and voltage in each resistor. (ACP-3) 13.75 R_T, the 10 *Ω* receives 0.44 A and uses 4.4 V, the 5 *Ω* receives 0.32 A and 1.6 V whereas the 15 receives 0.12 A and 1.6 V.
- The following circuit is connected to a source that can provide a current of 2A when the potential difference (voltage) is 12 V.



  What is the resistance of R_3? Show all your work. (ACP-3) 3 *Ω*
- A series-parallel electric circuit is illustrated below.
  What is the potential difference across the terminals of resistor R_1?



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

Resources/Notes

Electric Circuits (continued)
15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

Finally, students should do diagrams and solve circuit problems.

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

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

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

Electric Circuits (continued)
15 hours

Tasks for Instruction and/or Assessment

Journal

- How has your understanding of voltage, current, and resistance changed since grade 9? (ACP-3)

Paper and Pencil

- List all the differences (qualitative and numerical) between four resistors of 10 Ω each when placed:
  (a) in series R_T = 40 Ω each gets some amperage and voltage drop would be the same amount for each.
  (b) parallel R_T = 2.5 Ω each get same division of amperage and same voltage as what power source provides.
  (ACP-3)

Performance

- Students should be given opportunities to find efficiency of heating water with a variety of electrical items. (213-2, 213-3, 213-8, 212-4, 212-6)

Resources/Notes

Electromagnetism and Electromagnetic Induction
5 hours

Outcomes

Students will be expected to

- describe the magnetic field produced by a current in a long, straight conductor, and in a solenoid (328-6)
  - illustrate the use of hand rules
- analyse qualitatively the forces acting on a moving charge in a uniform magnetic field (328-5)
- analyse qualitatively electromagnetic induction by both a changing magnetic flux and a moving conductor (328-7)
  - use Lenz's law to predict the directions of induced current
  - describe the construction and operation of step-up and step-down transformers, including ratio of turns and power in power out calculations

Elaborations—Strategies for Learning and Teaching

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

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 build on their understanding of the relationship among force, F, magnetic field strength, B, and the length of conductor in a magnetic field to understand the factors for the force on a charge moving in a uniform magnetic field, charge, voltage, and angle. Emphasis should include determining the direction of the force based on whether the charge that is moving is negative or positive. Numerical calculations are not required.

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

Electromagnetism and Electromagnetic Induction
5 hours

Tasks for Instruction and/or Assessment

Performance

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

Journal

- Write an entry in your journal that summarizes your understanding of Lenz's law and the left hand rule for conductors. This could take the form of a series of diagrams and explanatory notes. (328-7)
- Make a journal entry comparing the field line distribution around a long straight conductor, a single coil, and a solenoid. (328-6)

Paper and Pencil

- The output coil of a transformer has three times as many coils as the input coil. Proportionally compare the following:
  - output voltage to input voltage 3 : 1
  - output current to input current 1 : 3
  - output energy to input energy (328-7) 1 : 1
- The north pole of a permanent magnet is thrust into a coil of wire. Using diagrams indicate the direction of the current in the coil as the magnet is inserted and withdrawn. (328-6)

Resources/Notes

Generators and Motors
5 hours

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Outcomes

Students will be expected to

- compare and contrast the ways a motor and generator function, using the principles of electromagnetism (328-9)
- describe and compare direct current and alternating current (ACP-4)
  – illustrate the third hand rule for motors
- describe the historical development of a technology (115-4)
- describe the functioning of domestic and industrial technologies, using scientific principles (116-5)
- analyse natural and technological systems to interpret and explain their structure and dynamics (116-7)
- select and integrate information from various print and electronic sources or from several parts of the same source (213-7)

Elaborations—Strategies for Learning and Teaching

A teacher demonstration of the force on a current-carrying wire in the field of a strong horseshoe magnet is a good way to introduce the notion of force. Students should try to devise a hand rule 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.

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

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

Students should be given the opportunity to research and/or discuss the development of the modern electric motor. As an extension, students could attempt to discover how mechanical energy converts to electrical energy.

For level 1 students only.

Generators and Motors
5 hours

Tasks for Instruction and/or Assessment

Informal Observation

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

Journal

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

Presentation

- In groups, prepare a multimedia presentation on the history of the development of the modern electric motor. (115-4, 116-5, 116-7, 213-7)

Resources/Notes

STSE CONNECTIONS

SCIENCE, TECHNOLOGY, SOCIETY AND THE ENVIRONMENT

Important Note

These STSE modules are intended for teacher reference. Each is designed to target specific outcomes within Physics 12. It should be noted that the activities associated with each module are NOT mandatory. They are suggested activities to be used at the discretion of the teacher.

The Physics of Juggling

Outcomes:

1. Analyze qualitatively and quantitatively the horizontal and vertical motion of a projectile. (325-6)
2. Analyze natural and technological systems to interpret and explain their structure. (116-7)
3. Distinguish between problems that can be solved by the application of physics-related technologies and those that cannot. (118-8)
4. Compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flowcharts, tables and graphs. (214-3)
5. Analyze and describe examples where technological solutions were developed based on scientific understanding. (116-4)
6. Define and delimit problems, estimate quantities, and interpret patterns and trends in data, and infer or calculate the relationship among variables. (212-2, 213-4, 214-5)

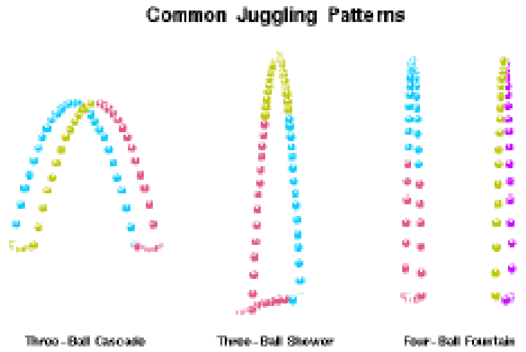
Introduction

An old riddle tells of a 148-pound man who had to cross a canyon over a bridge that could only support 150 pounds (Beek & Lewbel, 1995). Unfortunately the man was carrying three one-pound cannonballs and only had time for one trip across. The solution to the riddle was that the man would juggle the cannonballs while crossing the bridge. In reality, juggling the balls would not have been much help since catching one of the cannonballs would have exerted a force on the bridge that would have exceeded the weight limit. The poor man would have ended up at the bottom of the canyon! Though not very helpful in this particular case, juggling does have relevance beyond riddles or entertainment.

Beek and Lewbel (1995) suggest the application of juggling in the study of human movement, robotics, and mathematics. Studying the mathematics of juggling became popular in the 1980's though juggling itself is an ancient tradition dating back to Egypt and Rome. The term "juggling" comes from the Latin "joculare" meaning "to jest". Before the mid-twentieth century juggling was mainly a part of magic shows (Juggling). Public interest in juggling as a hobby increased after 1948 when the first juggling convention was held in the United States. That interest has persisted over the years as people continue to test physical limits for the number of objects juggled. Currently, the world record for the greatest number of objects juggled is 13 rings, 12 balls or 9 clubs (List of Numbers Juggling Records, 2002). While these numbers may seem impossibly high, they are in fact attainable with the right combination of physical ability and physics knowledge.

Theory

Good jugglers make juggling look so easy that it is difficult to imagine all the physics that comes into play. Gravity has a significant effect on the number of objects juggled. Each ball must be thrown high enough to allow the juggler time to handle the other balls. While throwing higher gives the juggler extra time, it also increases the risk of error. Juggling 'low' on the other hand, requires the juggler to catch and throw quickly, also increasing the risk of error. The need for speed or height will also change dramatically as the number of objects being juggled increases. Beek and Lewbel (1995) assert that learning to juggle three balls can be accomplished in just hours or days. This learning time can increase to weeks or months for four balls, and months or years for five balls.

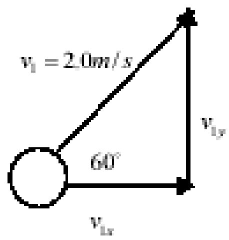


In the cascade, the hands alternate throwing balls to each other, resulting in a figure eight. In the shower pattern the balls are thrown around in a circle. In the fountain pattern the balls are either thrown (and caught) simultaneously with both hands (in sync), or by catching a ball with one hand and throwing one with the other at the same time (out of sync). Despite the identification of these patterns, it is important to note that due to factors like the oscillation of the jugglers' hands, or individual vision and feel, no two throws or catches are exactly the same.

In an attempt to measure juggling consistency, "dwell ratio" has been defined as the "fraction of time that a hand holds on to a ball between two catches (or throws)" (Beek & Lewbel, 1995, p. 3). A large dwell ratio means that the hand cradles the ball for a longer period of time. This means that the juggler has more time to throw accurately. A small dwell ratio means that the balls have a longer time in the air, which allows the juggler time to make corrections to hand repositioning. Novice jugglers typically like larger dwell ratios while professionals tend towards smaller values because they are more interested in shifting patterns.

A knowledge of projectile motion can give a juggler valuable information on the time available to throw and catch balls in a juggling pattern. Let us consider some numbers for throwing one ball in the air at around 2.0 m/s. The equations for projectile motion can tell us how long the juggler has to catch the ball, how high it will rise and about how far apart to keep the hands. In the following calculations assume that the ball is being thrown from the left hand to the right at an angle of 60° to the horizontal (neglecting air resistance on the ball). Using trigonometry we see that,

$$v_{1x} = v_1 \cos 60^\circ$$
$$v_{1y} = v_1 \sin 60^\circ$$



At the peak of its ascent the velocity of the ball in the y-direction will be 0 m/s. The time taken to reach that maximum height can be found from the equation,

$$a = \frac{v_{2y} - v_{1y}}{t}.$$

Solving for t gives,

$$t = \frac{v_{2y} - v_{1y}}{a}$$

where $a = -9.8 m/s^2$

$v_{1y} = v_1 \sin 60^\circ$

$v_{2y} = 0 m/s$.

Therefore,

$$t = \frac{0m/s - v_1 \sin 60^\circ}{-9.8m/s^2}$$

$$t = \frac{0m/s - (2.0m/s)(\sin 60^\circ)}{-9.8m/s^2}$$

$$t = 0.18s$$

Since the ball traces out a parabolic path, doubling this time will allow us to figure out how far the ball travels in the x-direction (i.e. the range). This distance is how far the hands should be apart, and is given by:

$$d_x = v_{1x}t + \frac{1}{2}a_x t^2$$

where acceleration in the horizontal direction is zero (i.e. $a_x = 0m/s^2$). Thus,

$$d_x = v_{1x}t$$
$$d_x = v_1 \cos 60^\circ t$$

$$d_x = (2.0m/s)(\cos 60^\circ)(2x0.18s)$$
$$d_x = 0.36m$$

We can also figure out how high the ball will travel using the following equation:

$$d_y = v_{1y}t + \frac{1}{2}a_y t^2$$

$$d_y = (2.0m/s)(\sin 60^\circ)(0.18s) + \frac{1}{2}(-9.8m/s^2)(0.18s)^2$$
$$d_y = 0.15m$$

These calculations reveal that a ball initially travelling at 2.0 m/s will reach a height of 0.15 m (≈6 in) in 0.18 s, and that horizontally it will travel 0.36 m (≈14 in). This information will be extremely useful to a juggler (especially a novice juggler).

To juggle two balls under these conditions would entail throwing the second ball just as the first is reaching its peak (at around 0.18 s). For three balls, you would start with two balls in one hand and one in the other. The third ball would then be thrown when the second is at its peak and the first ball again when the third reaches its peak. The trick is to throw the third ball and catch the first one with the same hand, in the limited time available.

Conclusion

A basketball or volleyball coach would probably advise their players to keep their eye on the ball. The best advice for a juggler however would be to keep their eye off the ball, since a jugglers' attention must continually shift from one ball to the next. Possessing information on the timing and height of ball flight would make this job a little easier. Becoming a good juggler then requires patience, practice and physics.

Questions

1. A ball is thrown at an initial velocity of 3.0 m/s upward at an angle of 80° to the horizontal. How high will the ball rise? How far apart should the juggler hold his/her hands?
2. A juggler throws a ball (at an angle of 70° to the horizontal) that reaches a height of 0.42 m. If the ball took 0.20 s to reach its maximum height, at what initial velocity was it thrown?
3. How is knowledge of projectile motion principles useful to a juggler?
4. Research: Who holds the current world record for greatest number of balls juggled?

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Activities

Activity 1: Projectile Motion

Adapted from: http://www.iit.edu/~smile/ph9204.html.

Purpose: To explore projectile motion.

Materials: Meter stick, Spring, Tape, Protractor

Procedure and Analysis:

1. Hold a meter stick against the wall. Mark a 1 meter mark with tape and then measure up 2 more meters and mark with tape.
2. Stretch a spring on a meter stick, hold it parallel to the wall and then shoot the spring straight up. Do this several times until you can repeat a shot to go exactly 2 m several times. Write down how far you stretched the spring. Get an assigned angle for your launch from your teacher. (TEACHER: assign 15°, 30°, 45°)
3. Calculate the speed at which the spring is fired, using the equation $v^2 = 2ad$.
4. Determine the vertical and horizontal components of the original velocity by using $v_{vertical} = v\sin(angle)$ and $v_{horizontal} = v\cos(angle)$.
5. Use the vertical velocity to find the flight time, $t = \frac{2v_{vertical}}{a}$.
6. Use the flight time and the horizontal velocity to calculate the range $d = v_{horizontal}\, t$.
7. Measure off this distance and shoot the spring using the same stretch. See how close you come to the measured distance.

Activities

Activity 2: Learn to Juggle

Adapted from: http://yoyoguy.com/info/ball/index2.html.

These instructions will teach you exercises so you can juggle 3 balls. The first few exercises are not complete juggling patterns, but are exercises that will teach you to juggle.

One Ball Exercise: Start with one ball. Throw the ball in an arc from hand to hand about eye level. The pattern will be an arc, not a circle.

Two Ball Exercise: Start with one ball in each hand. First toss the ball in your right hand (1) in the arc to about eye level to your left hand. When this ball (1) reaches the highest point in its arc throw ball (2) in an arc from your left hand to your right. Catch (1) in your left hand. Then catch (2) in your right hand. Stop. Do this same exercise, except start with your left hand instead of your right. Practice until you can do this smoothly. Common mistakes include throwing two balls in a circle, or throwing both balls at the same time.

Juggling 3 Balls: Start with 2 balls in one hand (1&3) (in this case the right hand, but if you are a lefty, use your left hand) and one ball (2) in the other. Start by throwing the ball in the front of your right hand in an arc to your left hand. When ball (1) reaches its highest point, throw the ball in your left hand (2) in an arc to your right hand. Catch (1) in your left hand. This is like the two ball exercise. When the ball thrown to your right hand reaches its height, throw the ball from your right hand (3) in an arc to your left hand. Catch (2) in your right hand. This move can be difficult. It is often helpful to roll the ball (3) in your right hand to the front of your hand with a slight downward motion of the hand before you throw it. When that ball (3) reaches its highest point, throw the ball in your left hand (1) in an arc to your right hand. Catch (3) in your left hand. And so on . . .

Problems and Solutions:

I move foward as I juggle.

This is a common problem. Stand in front of a wall, or a bed to keep you from moving forward.

I can't throw ball number (3), I just catch ball number (2).

Concentrate on throwing ball number (3). Do not even try to catch ball (2).

The balls keep hitting/there isn't time for to make the throws.

Concentrate on making your throws an even height at eye level.

The Half shower: Instead of having the balls cross in the standard 3 ball pattern, throw a ball from the right hand over the rest of the pattern. When it comes down, continue juggling. Do this for a throw or every throw; from either hand, or both hands.

The Physics of Cellular Telephones

Outcomes:

1. Identify questions, analyze, 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)
2. Explain Oersted's Principle. (328-6)
3. Analyze qualitatively and quantitatively electromagnetic induction by both a changing magnetic flux and a moving conductor. (328-7)
4. State Faraday's law of magnetic induction. (328-7)
5. Analyze and evaluate, from a variety of perspectives, using a variety of criteria, the risks and benefits to society and the environment of a particular application of scientific knowledge and technology. (118-2, 118-4)
6. Identify, analyze and describe examples where technologies were developed based on scientific understanding, their design and function as part of a community's life and science and technology related careers. (116-4, 116-6, 117-5, 117-7)

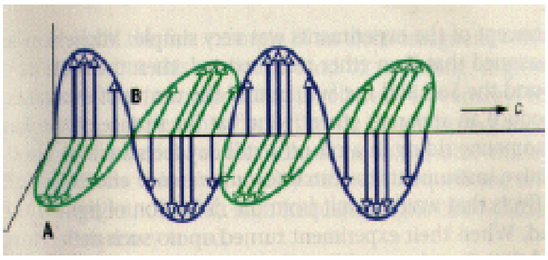
Introduction

What does the name Marconi mean to you? If you live in Atlantic Canada, probably quite a bit. In 2001 Newfoundland and Labrador celebrated the 100th anniversary of the reception of the first transatlantic wireless message at Signal Hill by Guglielmo Marconi. This signal was sent from Poldhu, England on December 12, 1901. In the 1890's Marconi had invented and developed the wireless telegraph to send messages over large distances. At the age of twenty-seven, his success on Signal Hill marked a turning point in world-wide communication. Marconi's work laid the foundation for the development of today's cellular telephones. Marconi though, could not have imagined the enormous impact his work would have on future generations. The number of people using cellular telephones has risen dramatically during the past decade. "Experts estimate that by 2005 there will be over 1.26 billion wireless telephone users worldwide" (Cellular Telephone Use and Cancer). Neither could Marconi have imagined the possible health risks currently associated with wireless communication – risks attributed to electromagnetic fields.

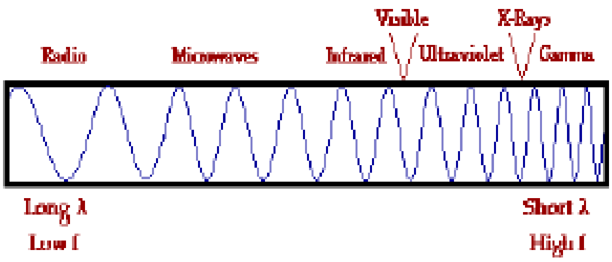
Theory

Electromagnetic Fields

By the time you leave for school in the morning you have already been exposed to a number of electromagnetic fields – from your blow dryer to your toaster to your microwave. What are these electromagnetic fields and where do they come from? A 'field' exists in a region of space surrounding an object. We cannot necessarily see a field, but we can observe the effects of its presence. A dropped object for example, is drawn towards the earth because of the pull of the earth's gravitational field. Oersted found that a magnetic field is produced around a wire carrying an electric current. Faraday found conversely that an electric field is induced by a changing magnetic field. Maxwell extended Faraday's and Oersted's work by hypothesizing that a changing electric field would also produce a magnetic field. Maxwell went on to say that if a changing magnetic field produces an electric field, that electric field is itself changing. This changing electric field would then produce a changing magnetic field, and so on. The net result of the interaction of these changing fields was a 'wave' of electric and magnetic fields travelling through space. These waves are called electromagnetic waves. They are transverse waves where the electric and magnetic fields are perpendicular to each other and to the direction of travel.



At point A the electric and magnetic fields associated with the wave are at maximum strength and at point B the fields are at minimum strength.



Electromagnetic waves are waves of fields, not of matter as are water waves. It is because they are fields that electromagnetic waves can travel in empty space at the speed of light. It is interesting to note that Heinrich Hertz did not experimentally detect electromagnetic waves until 1887 – eight years after Maxwell's death. Electromagnetic waves have since been detected over a wide range of frequencies known as the electromagnetic spectrum.

Radio frequency (RF) radiation is one of the several types of electromagnetic radiation. It is the type of radiation emitted by cellular telephones.

Cellular Telephones and Electromagnetic Radiation

There are many different types of cellular telephones available to consumers. They all convert voice into impulses that are transmitted over radio waves at frequencies ranging from about 800 to 2100 megahertz. Moving charges in the transmitting radio antenna, create electromagnetic waves that radiate away from the antenna (and can be picked up by a receiving antenna). All cellular telephones emit non-ionizing radio frequency radiation. This is different from ionizing radiation produced by X-ray machines, which can present a health risk at certain doses. According to the National Cancer Institute, the level of exposure to radio frequency radiation depends on, the amount of cellular telephone traffic; the quality of transmission; how far the antenna is extended; and the size of the handset.

The main source of radio frequency energy is the cell phone antenna. The closer the antenna is to the head, the higher the exposure to radio frequency radiation. The intensity of the electromagnetic wave actually changes as $\frac{1}{r^2}$ (where r represents distance). The antenna would be closest to the person's head in a hand-held cellular phone since the antenna is actually in the handset.

The intensity of the radio frequency radiation also depends on the power level of the signal sent to and from the nearest base station. Each zone in a particular geographic region has its own base station. When a call is made from a cell phone, a signal is sent to this base station. The base station then sends the call through a switching center where it is transferred to another base station, another cell phone or to the local land line system. The farther a cell phone user is from the base station, the more power is required to maintain the connection. This will increase the amount of radio frequency radiation for the user. It should also be noted that digital phones (which operate at different frequencies and power levels) are believed to emit less radiation than the older analog versions.

Health Risks

"Amazing, fast-paced, ever-evolving technology is progress. But progress often comes with a price. The price might be negative effects on our health" (Cell Phones and Electromagnetic Health Hazards). Recently there has been concern that the use of cell phones (particularly hand-held models) may be linked with loss of memory, Parkinson's disease, headaches and even cancer. This concern has prompted several studies, particularly on the link between cell phone use and cancer. Overall, most of these studies do not support such a link. However, based on the fact that cellular telephones have been available for a relatively short period of time, it would be premature to conclude that there is no link between cellular telephone use and cancer. It is important to continue the research, addressing the effects of long term cell phone use as well as the differences between analog and digital technologies. Slesin (2002) notes that a, "lack of studies about the adverse effects of EMF's may also prevent us from finding beneficial effects" (p. 2). In the meantime preventative measures can be taken at least regarding cell phone use. Consumers can purchase a device called a 'Wave Buster' which claims to absorb up to seventy percent of electromagnetic fields from cell phones (due to its ceramic composition). The Wave Buster has two pieces – one that attaches near the antenna and the other over the speaker. In the absence of such a device, users can limit cell phone use or switch to a phone with a headset where there is more distance between the antenna and the user. It is your responsibility to take EMF exposure into your own hands. "As more evidence uncovers the truth about EMF's, it's prudent to protect you and your family, while enjoying all that technology has to offer" (Cell Phones and Electromagnetic Health Hazards, p. 2).

Conclusion

Electromagnetic fields surround us constantly – whether they be from cell phones or microwaves or television sets. Moreover the number of EMF sources are growing rapidly. Unfortunately "the entire effect of multiple electromagnetic fields on human physiology is not completely understood" (Electromagnetic Fields and your Health). Since the adverse effects of exposure to EMF's appear to arise slowly, the consequences of living in a world filled with EMF's may not be known for many years. Until then we can only continue the exploration begun in part by Marconi.

Questions

1. What is an electromagnetic wave?
2. An electromagnetic field is measured at a distance 'r ' away from the source. How will the electromagnetic field change at a distance '2r ' from the source?
3. What is the difference between ionizing and non-ionizing radiation?
4. Research: What are some other kinds of electromagnetic radiation?
5. Research: How does the digital cellular telephone differ from the analog phone?

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Activities

Activity 1: (taken from Deley, 2002)

Purpose: To measure electromagnetic fields in the home.

Materials: Gaussmeter

Background: Electromagnetic radiation is measured in Gauss or milligauss. Deley states that people living in urban areas average 3 milligauss while those in rural areas average 1 milligauss. Generally, electromagnetic fields drop to naturally occurring levels at around 3 feet from the source (except around power lines).

Procedure:
Students will use the gaussmeter to measure the electromagnetic fields around cell phones and other home appliances. Take measurements in several different rooms and at different distances from the same object. Students could then graph electromagnetic field against distance to observe the relationship between the two.

Activity 2: Radio Wave Transmission
For a simulation and some information on how a radio wave is transmitted, go to:
http://www.pbs.org/wgbh/aso/tryit/radio/.

Make a Solar Cell in your Kitchen

Adapted from: http://www.angelfire.com/ak/egel/solcell.html

A solar cell is a device for converting energy from the sun into electricity. The high-efficiency solar cells you can buy at Radio Shack and other stores are made from highly processed silicon, and require huge factories, high temperatures, vacuum equipment, and lots of money. If we are willing to sacrifice efficiency for the ability to make our own solar cells in the kitchen out of materials from the neighbourhood hardware store, we can demonstrate a working solar cell in about an hour.

Our solar cell is made from cuprous oxide instead of silicon. Cuprous oxide is one of the first materials known to display the photoelectric effect, in which light causes electricity to flow in a material. Thinking about how to explain the photoelectric effect is what led Albert Einstein to the Nobel prize for physics, and to the theory of relativity.

Materials:

1. A sheet of copper flashing from the hardware store. This normally costs about $5.00 per square foot. We will need about half a square foot.

2. Two alligator clip leads.

3. A sensitive micro-ammeter that can read currents between 10 and 50 microamperes.

4. An electric stove. An 1100 Watt one-burner electric hotplate will also work.

5. A large clear plastic bottle off of which you can cut the top. I used a 2 liter spring water bottle. A large mouth glass jar will also work.

6. Table salt. We will want a couple tablespoons of salt.

7. Tap water.

8. Sand paper or a wire brush on an electric drill.

9. Sheet metal shears for cutting the copper sheet.

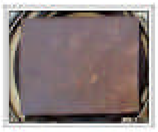
How to build the solar cell

The burner looks like this:

The first step is to cut a piece of the copper sheeting that is about the size of the burner on the stove. Wash your hands so they don't have any grease or oil on them. Then wash the copper sheet with soap or cleanser to get any oil or grease off of it. Use the sandpaper or wire brush to thoroughly clean the copper sheeting, so that any sulphide or other light corrosion is removed. Next, place the cleaned and dried copper sheet on the burner and turn the burner to its highest setting.

As the copper starts to heat up, you will see beautiful oxidation patterns begin to form. Oranges, purples, and reds will cover the copper.

As the copper gets hotter, the colors are replaced with a black coating of cupric oxide. This is not the oxide we want, but it will flake off later, showing the reds, oranges, pinks, and purples of the cuprous oxide layer underneath.

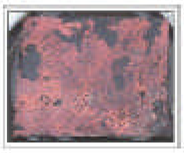


The last bits of color disappear as the burner starts to glow red.

When the burner is glowing red-hot, the sheet of copper will be coated with a black cupric oxide coat. Let it cook for a half an hour, so the black coating will be thick. This is important, since a thick coating will flake off nicely, while a thin coat will stay stuck to the copper.

After the half hour of cooking, turn off the burner. Leave the hot copper on the burner to cool slowly. If you cool it too quickly, the black oxide will stay stuck to the copper.

As the copper cools, it shrinks. The black cupric oxide also shrinks. But they shrink at different rates, which makes the black cupric oxide flake off.



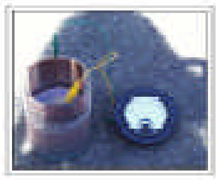
The little black flakes pop off the copper with enough force to make them fly a few inches. This means a little more cleaning effort around the stove, but it is fun to watch.

When the copper has cooled to room temperature (this takes about 20 minutes), most of the black oxide will be gone. A light scrubbing with your hands under running water will remove most of the small bits. Resist the temptation to remove all of the black spots by hard scrubbing or by flexing the soft copper. This might damage the delicate red cuprous oxide layer we need to make the solar cell work.

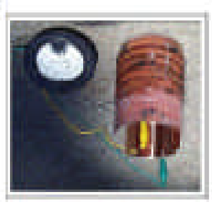
The rest of the assembly is very simple and quick. Cut another sheet of copper about the same size as the first one. Bend both pieces gently, so they will fit into the plastic bottle or jar without touching one another. The cuprous oxide coating that was facing up on the burner is usually the best side to face outwards in the jar, because it has the smoothest, cleanest surface.

Attach the two alligator clip leads, one to the new copper plate, and one to the cuprous oxide coated plate. Connect the lead from the clean copper plate to the positive terminal of the meter. Connect the lead from the cuprous oxide plate to the negative terminal of the meter.

Now mix a couple tablespoons of salt into some hot tap water. Stir the saltwater until all the salt is dissolved. Then carefully pour the saltwater into the jar, being careful not to get the clip leads wet. The saltwater should not completely cover the plates — you should leave about an inch of plate above the water, so you can move the solar cell around without getting the clip leads wet.



The photo above shows the solar cell in my shadow as I took the picture. Notice that the meter is reading about 6 microamps of current. The solar cell is a battery, even in the dark, and will usually show a few microamps of current.



The above photo shows the solar cell in the sunshine. Notice that the meter has jumped up to about 33 microamps of current. Sometimes it will go over 50 microamps, swinging the needle all the way over to the right.

Theory

Cuprous oxide is a type of material called a semiconductor. A semiconductor is in between a conductor, where electricity can flow freely, and an insulator, where electrons are bound tightly to their atoms and do not flow freely.

In a semiconductor, there is a gap, called a bandgap between the electrons that are bound tightly to the atom, and the electrons that are farther from the atom, which can move freely and conduct electricity.

Electrons cannot stay inside the bandgap. An electron cannot gain just a little bit of energy and move away from the atom's nucleus into the bandgap. An electron must gain enough energy to move farther away from the nucleus, outside of the bandgap.

Similarly, an electron outside the bandgap cannot lose a little bit of energy and fall just a little bit closer to the nucleus. It must lose enough energy to fall past the bandgap into the area where electrons are allowed.

When sunlight hits the electrons in the cuprous oxide, some of the electrons gain enough energy from the sunlight to jump past the bandgap and become free to conduct electricity.

The free electrons move into the saltwater, then into the clean copper plate, into the wire, through the meter, and back to the cuprous oxide plate.

As the electrons move through the meter, they perform the work needed to move the needle. When a shadow falls on the solar cell, fewer electrons move through the meter, and the needle dips back down.

FORMULAS/SYMBOLS CHECKLIST

This list is provided for guidance and awareness of the various symbols and formulas encountered within the study of Physics

Teachers may pick and choose which symbols and formulas students are responsible for memorizing. It is not intended that all formulas be utilized.

See Physics 11 for Symbols and Formulas students have been working with in that course.

To represent vector quantities symbolically, we draw an arrow above the variable symbol. When referring to the magnitude or scalar part of the vector, the arrow is omitted. Thus, when quoting a value for $\vec{d}$, a direction must be given.

Unit 1 - Dynamic Extension
Symbols

$\vec{F}_{net}$ = net force

$\vec{F}_n$ = Normal force

$\vec{F}_g$ = gravitational force (weight)

F_f = frictional force

μ = coefficient of friction

$F_\perp$ =component of gravity perpendicular to surface

μ_s = coefficient of static friction

μ_k = coefficient of kinetic friction

m = mass

$\vec{a}$ = acceleration

F_{ll} - component of gravity parallel to surface

T = torque

Formulas

$\vec{F}_{net} = m\vec{a}$

$\vec{F}_{net} = \vec{F}_1 + \vec{F}_2 ... \vec{F}_n = 0$ for static equilibrium

$\vec{F}_{net} = \vec{F}_{net} \cos\theta$

$M_1\vec{V}_1 + M_2\vec{V}_{20} = M_1\vec{V}_{1f} + M_2\vec{V}_{2f}$ for conservation of momentum

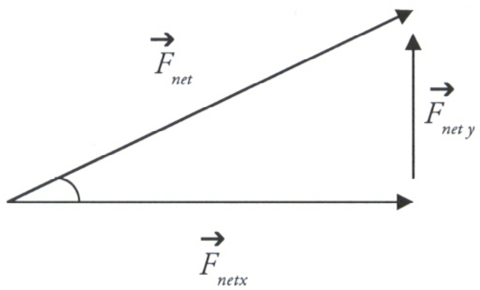
$F_f = \mu F_n$

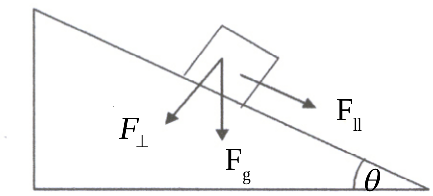
$\vec{P}_{total\ initial} = \vec{P}_{total\ final}$

$\vec{T} = \vec{r} \times \vec{F}$

$F_\perp = F_g \cos\theta$

$F_{ll} = Fg \sin\theta$





Many of the formulas are not new for students. It is their application that should be new in this unit.

Unit 2 - Projectiles, Circular Motion and Universal Gravitation

Symbols

F_g = force of gravity (force of attraction between two objects)

G = universal gravitational constant = 6.67 x 10^{-11} N m^2/kg^2

m = mass

K = spring constant

a_c = centripetal acceleration

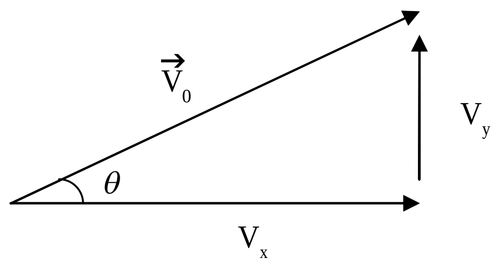
T = period of rotation

$\vec{F}_c$ = centripetal force

V = orbital speed

M = mass of Earth = 5.98 x 10^{24} kg

E_T = total energy



Formulas

$V_x = \vec{V}_o \cos\theta$

$V_y = \vec{V}_o \sin\theta$

$$Fg = \frac{Gm_1m_2}{r^2}$$

m = mass of objects
r = distance between object centers

$$a_c = \frac{v^2}{r}$$

r = radius of circular motion

$$a_c = \frac{4\pi^2 r}{T^2}$$

$$F_c = \frac{mv^2}{r}$$

$$F_c = \frac{m4\pi^2 r}{T^2}$$

$$v = \sqrt{\frac{Gm}{r}}$$

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

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

L = length

$$E_T = \frac{1}{2}mv^2 + \frac{1}{2}kx^2$$

Unit 3 - Fields

Symbols

q = charge in Coulombs

F_e = electric force

k = constant = 9.0 x 10^9 N m^2/c^2

$\vec{E}$ = field strength

V = electric potential (volt)

I = current (amperes)

E = electrical energy

R = resistance (ohms)

P = electrical power

B = magnetic field strength (tesla)

Formulas (Because there are many variations, only the basic formulas are found here.)

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

$$\vec{E} = \frac{\vec{Fe}}{q}$$

$$V = \frac{E}{q}$$

$$I = \frac{q}{t}$$

$$E = VIt$$

$$R = \frac{V}{I}$$

Series circuit

$$V_T = V_1 + V_2 + V_3 \ldots$$

$$I_T = I_1 - I_2 = I_3$$

$$R_T = R_1 + R_2 + R_3 \ldots$$

Parallel circuit

$$V_T = V_1 = V_2 = V_3 \ldots$$

$$I_T = I_1 + I_2 + I_3$$

$$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R3} + \frac{1}{R_4} \ldots$$

$$P = IV = I^2 R = \frac{V^2}{R}$$

$$F = BIL \sin\theta$$

$$\frac{Vp}{Vs} = \frac{Is}{Ip} = \frac{Np}{Ns}$$

for transformers
p = primary
s = secondary
N = number of turns