Atlantic Canada Science Curriculum

New Brunswick
Department of Education
Educational Programs & Services Branch

New Brunswick Nouveau Brunswick

Physics 11

S

CURRICULUM

2003

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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 11 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 making is an intrinsic part of learning in science, helping students better record, organize, and understand information from a variety of sources. The process of creating webs, maps, charts, tables, graphs, drawing, and diagrams to represent data and results helps students learn and also provides them with useful study tools.

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

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

The Three Processes of Scientific Literacy

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

Inquiry

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

Problem Solving

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

Decision Making

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

Meeting the Needs of All Learners

Foundation for the Atlantic Canada Science Curriculum stresses the need to design and implement a science curriculum that provides equitable opportunities for all students according to their abilities, needs, and interests. Teachers must be aware of, and make adaptations to accommodate, the diverse range of learners in their classes. To adapt instructional strategies, assessment practices, and learning resources to the needs of all learners, teachers must create opportunities that will to address students' 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., 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 andinterpret 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 in advance the purpose of an assessment, the method used, and the marking scheme being used. In order that fomative assesssment to 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 equipment 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 ot 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 written form for display 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 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/pictorial form, by project summary (science fair), or by using electronic systems such as video or computer software. Whatever the level of complexity, or format used, it is important to consider the curriculum outcomes as a guide to assessing the presentation. The outcomes indicate the process, concepts, and context for which and about which a presentation is made.

Portfolio

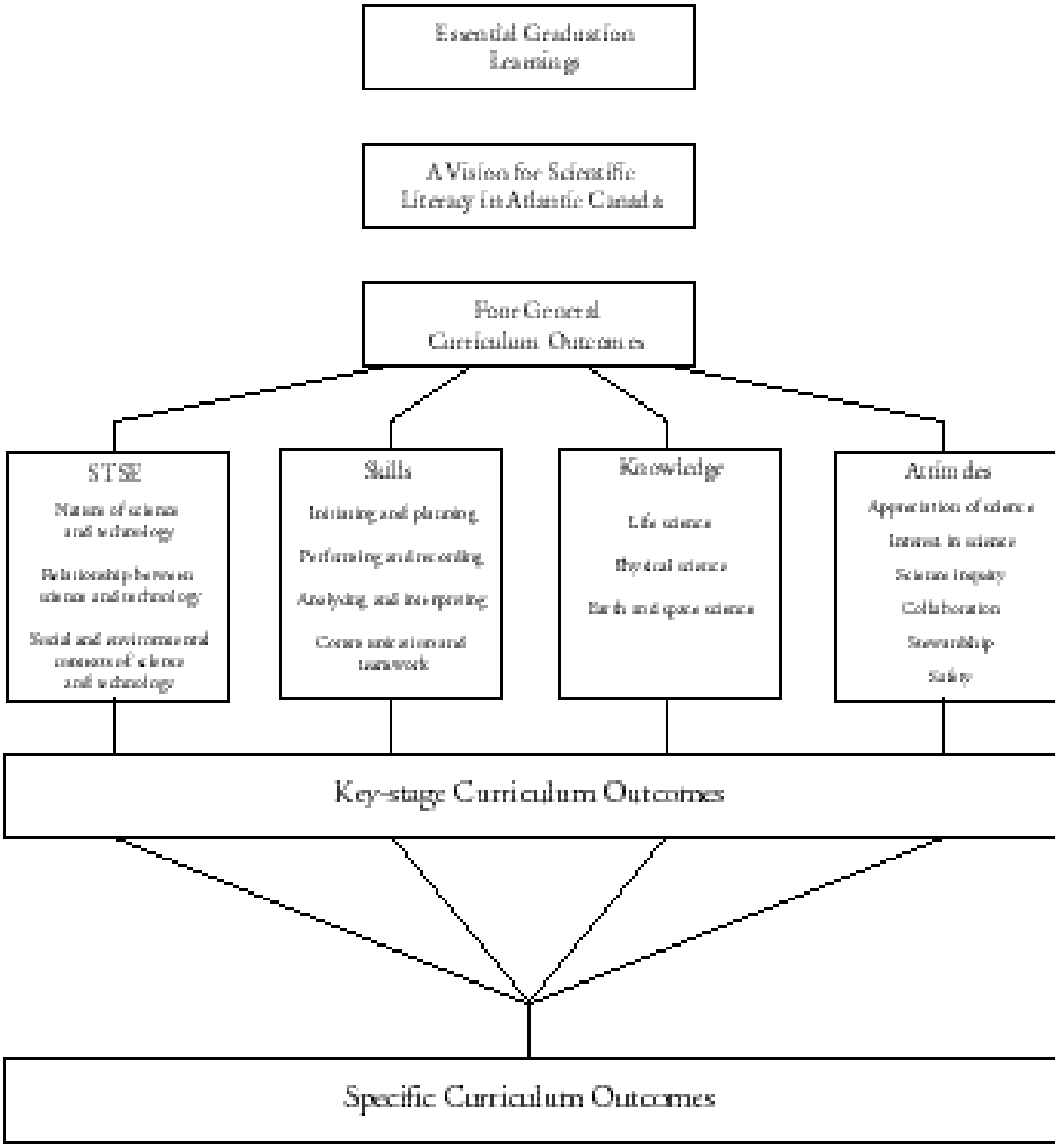
Portfolios offer another option for assessing student progress in meeting curriculum outcomes over a more extended period of time. This form of assessment allows the students to be central to the process. There are decision about the portfolio, and its contents, which can be made by the students. What 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 to 12*.

Specific Curriculum Outcomes

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

Specific curriculum outcomes are organized in units for each grade level.

Attitude Outcomes

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

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

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

Curriculum Guide Organization

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

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

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

Unit Organization

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

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

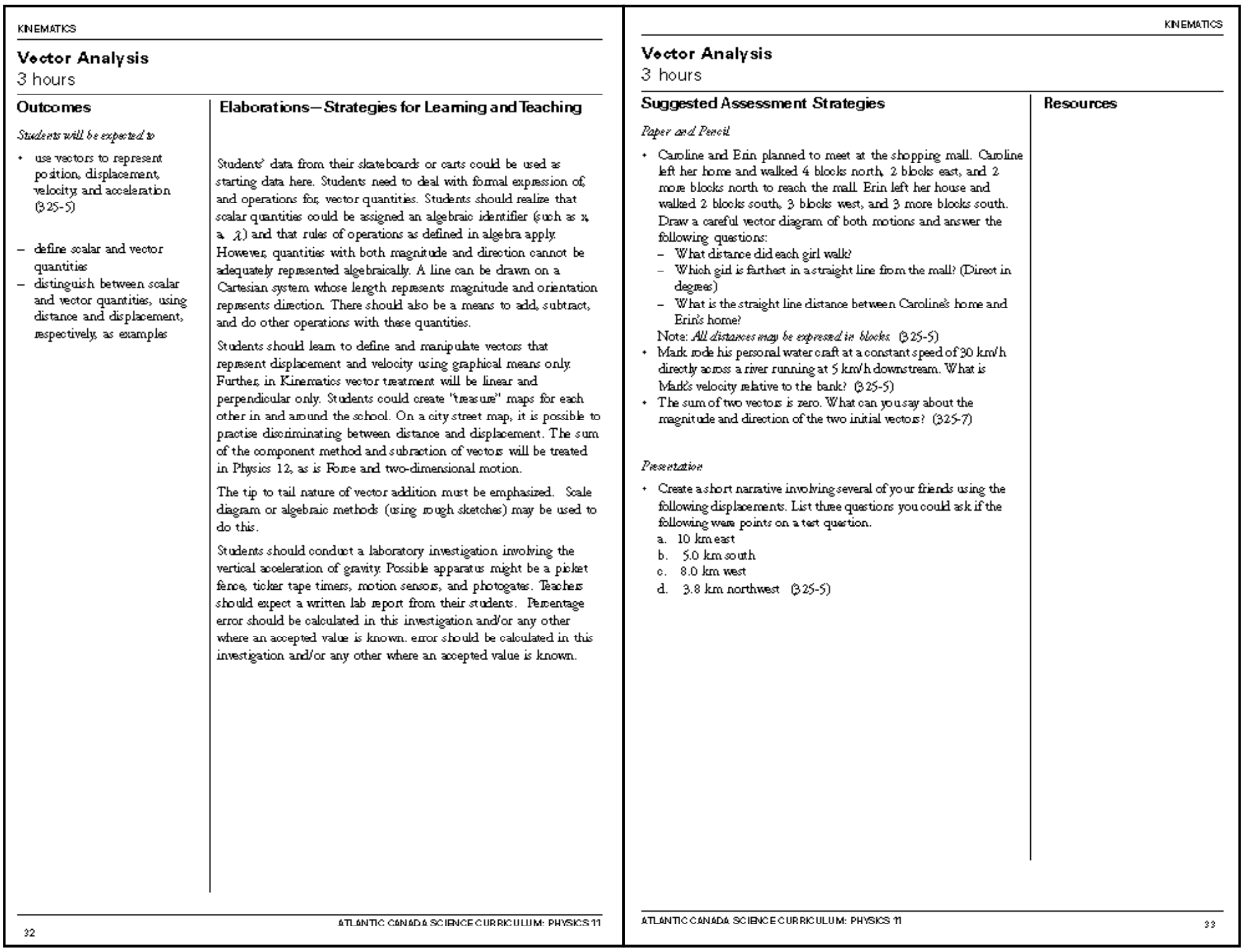
- 100s—Science-Technology-Society-Environment (STSE) outcomes
- 200s—Skills outcomes
- 300s—Knowledge outcomes
- 400s—Attitude outcomes (see pages 21-22)
- ACPs—Atlantic Canada Physics outcomes

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



KINEMATICS

Vector Analysis
3 hours

Outcomes

Students will be expected to

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

– define scalar and vector quantities
– distinguish between scalar and vector quantities, using distance and displacement, respectively, as examples

Elaborations—Strategies for Learning and Teaching

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

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

The tip to tail nature of vector addition must be emphasized. Scale diagram or algebraic methods (using rough sketches) may be used to do this.

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

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KINEMATICS

Vector Analysis
3 hours

Suggested Assessment Strategies

Paper and Pencil

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

  Note: *All distances may be expressed in blocks.* (325-5)
- Mark rode his personal water craft at a constant speed of 30 km/h directly across a river running at 5 km/h downstream. What is Mark's velocity relative to the bank? (325-5)
- The sum of two vectors is zero. What can you say about the magnitude and direction of the two initial vectors? (325-7)

Presentation

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

Resources

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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 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

Kinematics

Suggested Time: 15 Hours

Kinematics

Introduction

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

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

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

Focus and Context

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

Science Curriculum Links

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

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to **Relationships Between Science and Technology** 116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of invention technology 116-6 describe and evaluate the design of technological solutions and the way they function, using scientific principles	Students will be expected to **Initiating and Planning** 212-1 identify questions to investigate that arise from practical problems and issues 212-3 design an experiment identifying and controlling major variables 212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making **Performing and Recording** 213-2 carry out procedures controlling the major variables and adapting or extending procedures where required 213-3 use instruments effectively and accurately for collecting data **Analysing and Interpreting** 214-3 compile and display evidence and information, by hand or computer, in a variety of formates, including diagrams, flow charts, tables, graphs, and scatter plots 214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear realationships among variables 214-7 compare theoretical and empirical values and account for discrepancies	Students will be expected to 325-7 identify the frame of reference for a given motion 325-5 use vectors to represent force, velocity, and acceleration 325-2 analyse graphically and mathematically the relationship among displacement, velocity, and time

Vector Analysis
4 hours

Outcomes

Students will be expected to

- identify the frame of reference for a given motion to distinguish fixed and moving frames (325-7)
- identify and investigate questions that arise from practical problems/issues involving motion (212-1)
- use vectors to represent position, displacement, velocity, and acceleration (325-5)
  - – define scalar and vector quantities
  - – distinguish between scalar and vector quantities, using distance and displacement, respectively, as examples

Elaborations—Strategies for Learning and Teaching

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

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

Emphasize the importance of the concept of position, as measured from an arbitrary origin, and of displacement. The following activity may be done to clarify the issue:

Suppose the class is split into a number of teams, with one 'demonstrator' left over. The front of the class is marked off as a number line, but with no axis, direction or origin specified. Each team is asked to pick one of the marks as an origin, and a direction for positive motion, without telling the others. The 'demonstrator' then moves to a mark of their own choice, and the teams specify the position vector relative to their origin - this is *, the initial position vector. The 'demonstrator' now moves to a new spot on the line, and each team specified *, the final position vector. Now the teams work out the displacement: *, a 'final minus initial' quantity. Perhaps teams could trade their position vector information, so that they can deduce each other's choice of axis system. The important thing to emphasize is that while each team's position vectors will be very different, according to their choice of axis system, the displacement vector will have the same magnitude for each team, with a sign dictated by the particular choice of positive axis direction. As long as you know the axis frame, the displacement vector will always be the same vector in space.

Students should learn to define and manipulate vectors that represent displacement and velocity using graphical means and simple trigonometric ratios only. Further, in Kinematics vector treatment will be linear and perpendicular only. (The sum of the component method and subraction of vectors will be treated in Physics 12, as is force and two-dimensional motion.)

Vector Analysis
4 hours

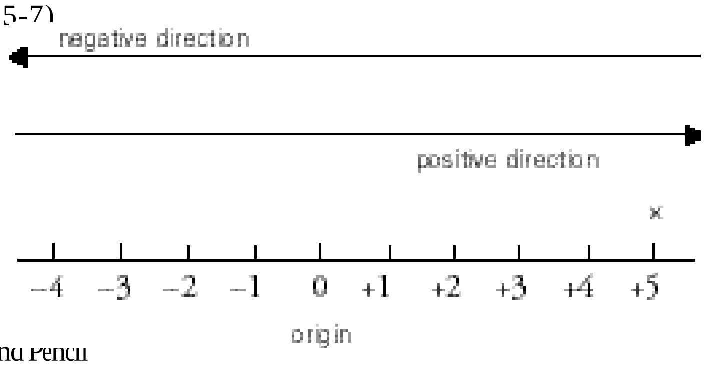
Suggested Assessment Strategies

Journal

- What does the speedometer of a car measure: speed, velocity, or both? Explain. (325-7) Speed: Does not indicate direction on an average speedmeter

Presentation

- Draw a diagram of the picture of the activity you chose for motion. Use coordinate axes where possible. Choose which direction is positive and which is negative. (325-7)
- How are position, distance and displacement the same? different? (212-1)
  Distance: Meaure of total travel, regardless of direction
  Displacement: Net travel measured from starting point. Need direction.
  Position: Displacement from starting point. Need direction.
- Using the diagram below, identify which pairs give a positive displacement:
  a) +5m, -2m b) -3m, +6m c) -4m, -2m
  (325-7)



Paper and Pencil

- Caroline and Erin planned to meet at the shopping mall. Caroline left her home and walked 4 blocks north, 2 blocks east, and 2 more blocks north to reach the mall. Erin left her house and walked 2 blocks south, 3 blocks west, and 3 more blocks south. Draw a careful vector diagram of both motions and answer the following questions:
  – What distance did each girl walk? Caroline - 8 blocks, Erin - 3 blocks
  – Which girl is farthest in a straight line from the mall? (Direct in degrees) Caroline - 6.3 blocks N[18.4^0]E; Erin 5.8 blocks S[30.9^0]W
  – What is the straight line distance between Caroline's home and Erin's home? 12.1 blocks

  Note: All distances may be expressed in blocks. (325-5)
- Mark rode his personal water craft at a constant speed of 30 km/h directly across a river running at 5 km/h downstream. What is Mark's velocity relative to the bank? (325-5) 30.4 km/h at 80.1^0 to the bank.
- The sum of two vectors is zero. What can you say about the magnitude and direction of the two initial vectors? (325-7) Same magnitude and opposing directions.

Resources

Graphical Analysis
5 hours

Outcomes

Students will be expected to

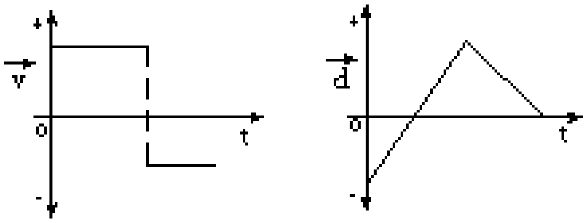
- analyze graphically and mathematically the relationship among displacement, velocity, and time (325-2)
  - explain how one can tell from the position-time graph whether the magnitude of an object's velocity is increasing, decreasing, or constant
  - using the sign convention that motion to the left is negative, determine the direction of motion of uniformly accelerating objects from its position-time graph and its velocity-time graph
  - given velocity-time graphs, tell if the velocity is increasing, decreasing or remaining constant
  - use a velocity-time graph for uniform acceleration to derive an equation for
    - (i) displacement in terms of initial velocity (or final velocity), acceleration, and elapsed time
    - (ii) relating final velocity, initial velocity, acceleration, and displacement

Elaborations—Strategies for Learning and Teaching

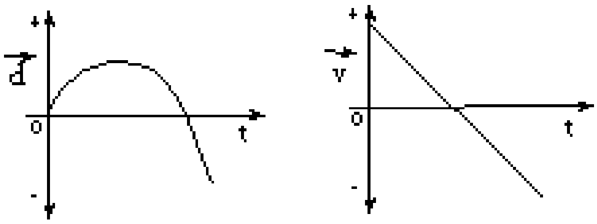
The graphical and mathematical analysis should apply to both uniform and accelerated motion. (Some of this will entail a review of concepts addressed in Science 10.)

The students should be able to interpret and draw graphs such as the following:

(i) uniform motion

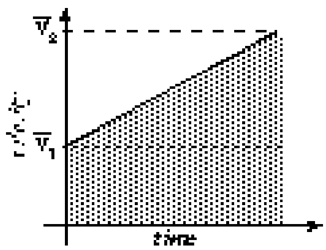


(ii) uniform acceleration



Algebraic formulae are nothing more than definitions and familiar relationships suitably rearranged for problem solving.

The students should be able to produce two derivations based on the graph shown below.



(i) $\vec{a} = \dfrac{\vec{v}_2 - \vec{v}_1}{t}$ (ii) $\vec{d} = \dfrac{1}{2}(\vec{v}_2 + \vec{v}_1)\Delta t$

Students can then use substitutions to derive the following:

$\vec{d} = \vec{v}_2 t - \frac{1}{2}\vec{a}t^2$ $\vec{d} = \vec{v}_1 t + \frac{1}{2}\vec{a}t^2$ $v_2^2 = v_1^2 + 2\vec{a}\vec{d}$

Graphical Analysis
5 hours

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Suggested Assessment Strategies

Presentation

- With data collected from their motion trials at the beginning of this unit, students could make a table of their data and draw d/t and v/t graphs from this information. They should explain what their graphs show. (325-2)

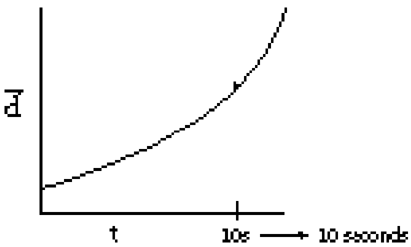
- In groups of two or more, students could draw some representative position-time and velocity-time graphs. They could then have another group describe the motion of the object for each graph. (325-2)

Performance

- Using the CBR™ have students collect distance vs time data from various situations. The task is to guess what the velocity-time graph may look like! (325-2)

Paper and Pencil

- Have students calculate average velocity for the first 10 seconds and instantaneous velocity (at time 10s) for



Note: For many students, this is an outcome in Function and Relations Math 111/112.

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For Level 1, students should be responsible for deriving equations from d/t and v/t graphs

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Resources

Mathematical Analysis
6 hours

Outcomes

Students will be expected to

- analyze graphically and mathematicially the relationship among displacement, velocity and time (325-2)

Elaborations—Strategies for Learning and Teaching

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

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

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

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

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

Mathematical Analysis
6 hours

Suggested Assessment Strategies

Presentation

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

Paper and Pencil (a good review from Grade 10 Science)

- A car is travelling at 12 m/s (about 45 km/h). It approaches a stop sign and decelerates at 4.0 m/s^2.
  - (a) How long does the car take to stop? 3 s
  - (b) How far does the car travel while stopping? 18 m
- A car is travelling at 25 m/s (about 90 km/h). It approaches a stop sign. If it decelerates at 4.0 m/s^2, how far will it travel while stopping? 78.125 m Compare this distance with the distances in the question above. Does twice the speed require more or less than twice the stopping distance? More - almost four times stopping distance
- Ultrasound travels through air at about 340 m/s. Suppose that a camera sends out an ultrasound pulse and the pulse returns 0.060 s later. How far away is the object that is being photographed? 10.2 m
- A laser gun sends out an infrared pulse. The pulse returns from a car 0.400 µs later. After 1.0 s, the laser sends out another pulse. It returns after 0.200 µs. If the speed limit is 80 km/h (22 m/s), decide whether or not the car is speeding. Yes, car is going 30 m/s or 108 km/h.
- Amusement park roller coasters use changing acceleration to thrill their riders. For safety reasons, however, the acceleration is usually kept smaller than 40 m/s^2. A roller coaster called "The Flight of Fear" accelerates its riders smoothly from 0 m/s to 24.6 m/s in 3.9 s. Suppose that on one run, a safety device then caused the cars to brake and come to a stop in 7.80 m.
  - (a) How long would the cars take to stop? 0.63 s
  - (b) What would be the average acceleration of the cars as they stopped? -38.8 m/s^2
  - (c) Would the ride exceed the usual maximum acceleration starting or stopping? No, <40 m/s^2
  - (d) What would be the average acceleration of the ride from start to stop? Zero

Resources

Mathematical Analysis (continued)
6 hours

Outcomes

Students will be expected to

- analyse graphically and mathematically the relationship among displacement, velocity and time (325-2)

Elaborations—Strategies for Learning and Teaching

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

Problems can be created in a variety of formats. Students could create situations involving friends, public figures, or favourite cartoon characters within which the teacher could insert kinematics problems. It is far more engaging to do a problem involving the principal climbing a flagpole than the traditional " a 5.0 kg body . . ." The formulas that students should be comfortable using can be found on page 118.

Mathematical Analysis (continued)
6 hours

Suggested Assessment Strategies

Journal

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

Paper and Pencil

- Alex and Raj always try to outdo each other on their skateboards. They decide to have a "hang time" contest. They begin side by side and push their boards to a speed of 5 m/s. At the same time, they jump straight up as high as they can and land on the moving board. Alex's board goes 7.5 m before he lands, and Raj's board goes 6.0 m before he lands. How long was each boy in the air? How high did each jump? (325-2)

	Time	Height
Alex	1:5 s	2.76 m
Raj	1:2 s	1.76 m

- A rock and a sponge were dropped from a rooftop. The rock hit the ground in 1.4 s. The sponge took 2.0 s to fall. How high was the roof? What was the acceleration of the sponge? Why do you think there is a difference? Explain. (325-2) 9.6 m, 4.9 m/s^2, object (sponge) reached terminal velocity more quickly because it is not as dense as the rock.

Resources

Mathematical Analysis (continued)
6 hours

Outcomes

Students will be expected to

- analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of technology (116-2)
- identify questions to invesigate that arise from practical problems and issues (212-1)
- carry out an experiment to investigate the motion of an object falling vertically near Earth (212-3, 213-2)
- compile and display evidence and information in a variety of formats (214-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate proceses for problem solving, inquiring, and decision making (212-8, 213-3)
- interpret trends in data, and infer or calculate relationships among variables (214-5)
- compare theoretical and empirical values and account for discrepancies (214-7)
- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)

Elaborations—Strategies for Learning and Teaching

The Laboratory outcomes (116-2, 116-6, 212-1, 212-3, 212-8, 213-2, 213-3, 214-3, 214-5) and 325-2 are addressed by completing any Acceleration Due to Gravity Lab.

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

Mathematical Analysis (continued)
6 hours

Suggested Assessment Strategies

Performance

- Students could conduct a lab and write a report on their investigation of the acceleration of gravity. (116-2, 212-3, 212-8, 213-2, 213-3, 214-3, 214-5)

Journal

- In free fall, does the speed of an object affect air friction? Discuss this. (116-2) Yes, faster - more air on that object if body type and structure stay the same.

Presentation

- Students could draw a diagram of the picture of the activity they chose for motion. They should use coordinate axes where possible. Students show which direction is positive and which is negative. (116-2, 325-2)

Resources

Unit 2
Dynamics
Suggested Time: 20 Hours

Dynamics

Introduction

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

Focus and Context

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

Science CurriculumLinks

This unit completes the study of motion begun in Science 10. It provides students with an opportunity to reinforce their skills in using the graphing calculators. It leads students to the more sophisticated concepts of momentum and energy that are necessary for the study of interactions between masses. The concepts developed in the study of dynamics in Physics 11 will be further developed in Physics 12 with the treatment of two dimensional situations (incline planes), uniform, circular motion, and Kepler's Law.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to Nature of Science and Technology 115-3 explain how a major scientific milestone revolutionized thinking in the scientific communities Relationships Between Science and Technology 116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention or technology 116-5 describe the functioning of domestic and industrial technologies, using scientific principles 116-6 describe and evaluate the design of technological solutions and the way they function, using scientific principles 116-7 analyse natural and technological systems to interpret and explain their structure Social and Environmental Contexts of Science and Technology 117-2 analyse society's influence on scientific and technological endeavours	Students will be expected to Initiating and Planning 212-3 design an experiment identifying and controlling major variables 212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making Performing and Recording 213-2 carry out procedures controlling the major variables and adapting or extending procedures where required 213-3 use instruments effectively and accurately for collecting data Analysing and Interpreting 214-3 compile and display evidence and information, by hand or computer, in a variety of formates, including diagrams, flowcharts, tables, graphs, and scatter plots 214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables	Students will be expected to 325-5 use vectors to represent force 325-8 apply Newton's laws of motion to explain inertia, the relationship among force, mass, and acceleration and the interaction of forces between two objects 326-3 use Newton's second law to show how impulse is related to change in momentum

Dynamics Introduction
4 hours

Outcomes

Students will be expected to

- analyse the influence of society on scientific and technological endeavours in dynamics (117-2)
- describe and evaluate the design of technological solutions and the way they function, using scientific principles (116-6)
- analyse natural and technological systems to interpret and explain their structure and dynamics (116-7)
- use vectors to represent forces (325-5)
  - draw free-body diagrams
  - explain what is meant by net force and apply it to several situations

Elaborations—Strategies for Learning and Teaching

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

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

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

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

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

Dynamics Introduction
4 hours

Tasks for Instruction and/or Assessment

Performance

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

Journal

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

Paper and Pencil

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

Presentation

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

KWL Chart

What I know:

____

____

What I want to know:

____

____

What I learned:

____

____

Resources/Notes

Newton's Laws
12 hours

Outcomes

Students will be expected to

- apply Newton's laws of motion to explain inertia; the relationships among force, mass, and acceleration; and the interaction of forces between two objects (325-8)
  - state Newton's first law of motion, and describe applications
  - explain, using Newton's first law of motion, what is meant by an inertial frame of reference
  - physically demonstrate the property of inertia
  - state Newton's second law of motion, and describe applications
  - explain how Newton's second law of motion may be used to define the Newton as a unit of force
  - given two of the net force, the mass, and the acceleration, or information from which they can be determined, calculate the third quantity

Elaborations—Strategies for Learning and Teaching

An important corollary to Newton's First Law of motion which students must appreciate is this: if all forces on an object cancel each other, that is, if $\overline{\mathbf{F}} = 0$, then there are two possibilities for the object's motion: the object is either stopped OR moving with a fixed velocity. There is no dynamic difference between these two conditions.

An inertial frame of reference is one in which Newton's first law of motion is valid. In general, any frame of reference that is not accelerating (i.e., not changing speed or direction) is an inertial frame.

An example would be a bus which is travelling in a straight line at a fixed speed. The frame of reference of the bus is an inertial frame. (Assuming a silent engine, no vibrations, and a perfectly smooth road). If you lay a ball at your feet, it will stay there; if you push it, it will roll up the aisle until it bumps something (Newton's first law). But, suppose just after you lay the ball on the floor, the driver just touches the brake ever so slightly. The ball will then roll forward. You will see it roll forward for no reason at all! After all, objects at rest should remain at rest. The frame of reference of the "accelerating" bus is no longer an inertial frame.

Demonstrations of inertia can include:

(i) pulling a table cloth from a table with objects on it

(ii) flicking a card from underneath a coin balancing on finger

(iii) banging the handle of a hammer against a hard surface to secure the hammer head

Newton's Laws
12 hours

Tasks for Instruction and/or Assessment

Journal

- Teachers could ask students to comment on the following:

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

Paper and Pencil (neglect friction)

- What force is necessary to accelerate a 1200 kg car along a horizontal surface from rest to 130 km/h in 8.0 s? (325-8)

  Approximately 5420 N

- What mass would a sled on ice have if it requires a horizontal force of 100.0 N to change its velocity from 30.0 km/h to 120 km/h in 5.0 s? (325-8) 20 kg

- What is the acceleration of a block having a mass of 0.5 kg which is being pulled in opposite directions by two children. Sean is pulling with a force of 3.0 N to the left, and Diane is pulling to the right with 5.0 N. How far will it move in 3.0 s if these forces combine to be exerted? (325-8) 18 m

- What would the tension be in a cable lifting an elevator and a person having a combined mass of 575 kg moving (a) upward at a rate of 5.0 m/s^2 and (b) downward at a rate of 5.0 m/s^2? (325-8)

  (a) 8510 N (b) 2760 N

- Students could design a problem that uses Newton's Second Law of motion. They should include an answer sheet and exchange their problem with that of another student. (325-8)
- Students could make an original puzzle that includes the following terms and their definitions: acceleration, inertia, applied force, net force, Normal force, static friction, kinetic friction, and coefficient of friction. (325-8)

Resources/Notes

Newton's Laws (continued)
12 hours

Outcomes

Students will be expected to

- apply Newton's laws of motion to explain inertia; the relationships among force, mass, and acceleration; and the interaction of forces between two objects (325-8)
  - state Newton's third law of motion, and describe applications
  - draw diagrams identifying the action-reaction pairs of forces in various interactions of particles or objects
  - explain, qualitatively and quantitatively, what is meant by friction, and describe static and kinetic friction
  - distinguish between mass and weight
  - solve exercises / problems involving Newton's laws of motion

Elaborations—Strategies for Learning and Teaching

Static and kinetic friction will be described both qualitatively and quantitatively. The following formulas should be used, as necessary, when friction is a factor:

$$f_k = \mu_k F_N$$

$$f_s = \mu_s F_N \quad \text{(Max)}$$

Teachers should note that f_s can be less than the Max value. For example, if f_s Max = 5.0N for a book on a table and someone applied a force of 3.0N, the force of static friction under Newton's 3rd law would be 3.0N. When the applied force is greater than f_s Max, Newton's 2nd law can be applied.

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

Newton's Laws problems to be illustrated could include:

(i) pushing or pulling an object on a horizontal surface, with and without friction

(ii) vertical movement of objects (e.g., free fall, elevator problems, lifting an object on a string)

(iii) pushing or pulling two blocks on a horizontal surface

(iv) lifting or lowering two blocks

(v) Atwood's machine

(vi) hanging blocks off tables

(vii) hanging traffic light

Newton's Laws (continued)
12 hours

Tasks for Instruction and/or Assessment

Performance

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

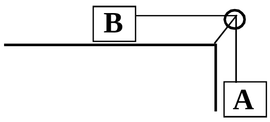
Presentation

- Students could draw a cartoon that explains one of the concepts used in dynamics to this point. They should be sure that it is simple, specific, and short so the reader can learn from it. (325-8, 116-2, 115-3)

Students in Level 1 (or those expecting to take Physics 12) should do a greater variety of problems with friction (static and kinetic)

For example:

- What force is required to accelerate a lawn mower of mass 12 kg to 4.5 km/hr from rest in 3.0 s if $\mu_k = 0.8$?
  Answer: 99 N



If B = 10 kg and μ_s between B and table is 0.2, what is maximum mass for A before B begins to slide?
Answer: 2 kg and less

- If A above has a mass of 10 kg, what would be accelearation of B (if any)? Answer: 7.84 m/s^2

Resources/Notes

Newton’s Laws (continued)
12 hours

Outcomes

Students will be expected to

- investigate the relationship between acceleration and net force (212-3)
- evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making (212-8)
- investigate the relationship between acceleration and mass, for a constant net force (213-2)
- use instruments effectively and accurately for collecting data
- compile and display evidence and information in a variety of formats (214-3)
- interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables (214-5)
- provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion (214-11)

Elaborations—Strategies for Learning and Teaching

These outcomes (212-3, 212-8, 213-2, 213-3, 214-3, 214-5, 214-11) and 325-8 are addressed by completing Newton’s second law in a lab setting.

Whatever the method used for Newton’s second law experiment, good results are obtained if care is taken in setting up the trials. If the gravitational force on a hung weight is used as a driving force, it is accelerating the combined mass that includes the cart and the hung mass. To do trials in which mass is kept constant, the combined mass must not change, and mass must be moved from the cart to the hanger to change the driving force. This is an excellent opportunity for students to learn to control variables and minimize errors. During the course of an investigation, student lab groups could be asked to make periodic progress reports and share ideas.

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

Newton's Laws (continued)
12 hours

Tasks for Instruction and/or Assessment

Informal Observation

- A checklist of skills students should develop is appropriate for the teacher to apply here. Possible skills might include using instrument correctly, doing enough trials for a good average value, and recording the results in an appropriate table. (212-3)

Presentation

- Students could conduct a laboratory investigation of the relationships among force, mass and acceleration. (325-8, 213-2, 213-3)

Paper and Pencil

- Students could write a thorough report on their lab. They should analyse and interpret the data in raw form and graphically. From the raw data, it is possible to see whether the relationship is linear or exponential, direct or inverse. Graphs of $\vec{a}$ a $\vec{F}$ for trials where mass is kept constant, $\vec{a}$ a 1/m for trials where applied force is kept constant, and $\vec{a} \alpha \frac{F(unbalanced)}{m}$ for all trials all lead to the equation a = F/m. Interpreting the numerical value and the dimensions (unit) of the slope on each graph, students realize that F = ma only if Newtons of force are dimensionally the same as kg.m/s^2. (325-8, 212-3, 212-8, 213-2, 213-3, 214-3, 214-5)

Resources/Notes

Momentum Introduction
4 hours

Outcomes

Students will be expected to

- use Newton's second law to show how impulse is related to change in momentum (326-3)

Elaborations—Strategies for Learning and Teaching

Students should be introduced to the concepts of impulse and momentum as a development of Newton's second law. Students might see $\bar{F}\Delta t = mv_2 - mv_1$ as a more logical expression since it isolates the "cause" product at the right. Newton's "quantity of motion," or momentum, might be more meaningful in this context. Students should relate these concepts qualitatively to a variety of situations.

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

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

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

Conservation of momentum in collisions and explosions is done in Physics 12.

Momentum Introduction
4 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Research one example of a technology of your choice, and prepare an article for publication in a science magazine or your school's science newsletter that explains the application of the principles of impulse and momentum. (116-5)
- A parachutist lands, flexes her knees, and rolls in order to stop. Calculate the inpact force on a 70.0 kg parachutist falling at 10 m/s if time to stop was 0.8 s. Compare the force of impact if parachutist lands in a rigid position, standing in attention. The time of stopping is 0.05 s.
  - 875 N (flexing)
  - 14000 N (stiff-legged)
- A 100 g golf ball leaves the tee at 100 m/s. If the club were in contact with the ball for 0.04 s, determine the force exerted on it by the club. (326-3) 250 N
  (The students should be provided with similiar numerical exercises which require a solution for the other terms in the expression.)
- Using the concept of impulse, explain why it is easier to drive a nail with a steel hammer, that with a rubber mallet. (326-3)
  Due to the fact that a steel hammer will have a shorter interaction time, thus more force provided to drive in nail. Rubber mallet will extend interaction time, thus less force available.

Resources/Notes

Unit 3
Work and Energy
Suggested Time: 20 Hours

Work and Energy

Introduction

When the interaction of two or more objects is analysed, this is called a system. Understanding changes that take place in a system is often aided by considering energy exchanges. Students should identify forms of energy and energy exchanges in familiar contexts before discussing less familiar applications.

Focus and Context

Students could begin by describing the changes they feel on various playground equipment or amusement park rides and develop an explanation for these changes using the vocabulary and concepts of energy. Eventually, their understanding of these events will involve the conservation laws, which will allow them to describe, explain, and predict the outcomes of many one-dimensional interactions.

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

Science Curriculum Links

In grade 8 science, students have explored the movement of objects in terms of balanced and unbalanced forces. They have also described quantitatively the relationships among force, area, and pressure.

In Physics 12, students should develop a more precise understanding of momentum and energy and learn to evaluate situations using these concepts. Work dealing with momentum has been moved to Physics 12.

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 114-9 explain the importance of communicating the results of a scientific or technological endeavour using appropriate language and conventions 115-5 analyse why and how a particular technology was developed and improved over time Relationships Between Science and Technology 116-4 analyse and describe examples where technologies were developed based on scientific understanding 116-6 describe and evaluate the design of technological solutions and the way they function using principles of energy and momentum Social and Environmental Contexts of Science and Technology 118-8 distinguish between questions that can be answered by science and those that cannot and between problems that can be solved by technology and those that cannot	Initiating and Planning 212-3 design an experiment identifying and controlling major variables 212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making Performing and Recording 213-2 carry out procedures controlling the major variables and adapting or extending procedures where required 213-3 use instruments accurately for collecting data Analysing and Interpreting 214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots 214-5 interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables 214-7 compare theoretical and empirical values and account for discrepancies 214-11 provide a statement that addresses the problem or answers the question investigated in light of the link between data and the conclusion	325-9 analyse quantitatively the relationships among force, distance, and work 325-10 analyse quantitatively the relationships among work, time, and power 326-1 analyse quantitatively the relationships among mass, height, speed, and heat energy using the law of conservation of energy 326-5 describe quantitatively mechanical energy as the sum of kinetic and potential energies 326-6 analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept 326-7 analyse common energy transformation situations using the work-energy theorem 326-8 determine the percentage efficiency of energy transformations

Work, Power, and Efficiency
5 hours

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* ***

Outcomes

Students will be expected to

- analyse quantitatively the relationships among force, distance, and work (325-9)
- analyse quantitatively the relationships among work, time, and power (325-10)

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*
- design and carry out an experiment to determine the efficiency of simple machines (212-3, 213-2, 213-3, 214-7) *
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***

Elaborations—Strategies for Learning and Teaching

Students should be asked to design and carry out an investigation in which they measure the force, distance, and time, and calculate the work and power. Situations to examine should include lifting a dynamics cart 1.0 m, pushing the dynamics cart 1.0 m horizontally, and pushing it up a ramp to a height of 1.0 m.

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

*** As an extension, students could calculate the efficiency of
** various simple machines such as ramps, block and tackles and *
* other items (car jack) **
***

Work, Power, and Efficiency
5 hours

Tasks for Instruction and/or Assessment

Informal Observation

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

Journal

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

Paper and Pencil

- As a written record of the dynamics cart exploration, submit work sheets that include neat sketches, data, and calculations for each of the three situations from your lab activity. (325-10)

- A locomotive exerts a constant forward force of 5.4×10^4 N while pulling a train at a constant speed of 25 m/s for 1.0 h. How much work does the locomotive do? 4.9×10^9 J What average power did the locomotive generate while pulling the train? (525-10) 1.4×10^6 w

Presentation

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

Resources/Notes

Transformation, Total Energy, and Conservation
15 hours

Outcomes

Students will be expected to

- analyse quantitatively the relationships among mass, speed, kinetic energy, and heat using the law of conservation of energy (326-1)
  - define gravitational potential, elastic potential, and kinetic energies
  - relate energy transformations to work done
  - solve problems using the law of conservation of energy, including changes in gravitational potential energy, elastic potential energy, and kinetic energy
  - explain the role of friction and the loss of mechanical energy from a system
- describe quantitatively mechanical energy as the sum of kinetic and potential energies (326-5)
- compare empirical and theoretical values of total energy and account for discrepancies (214-7)

Elaborations—Strategies for Learning and Teaching

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

During work on these outcomes, students should

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

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

For kinematics, $v_f^2 = v_i^2 + 2a\Delta d$

Rearranging: $v_f^2 - v_i^2 = 2a\Delta d$

But F=ma $a = \frac{F}{m}$

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

$$F\Delta d = \Delta KE = \frac{mv_f^2}{2} - \frac{mv_i^2}{2}$$

Dimensionally, work is N-m. Energy is $kg.m^2/s^2$

$$N\text{-}m = kg.m/s^2 * m = kg.m^2/s^2$$

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

Transformation, Total Energy, and Conservation
15 hours

Tasks for Instruction and/or Assessment

Performance

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

Journal

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

Pencil and Paper

- A car of mass 1000 kg accelerates from 0.0 m/s to 4.0 m/s. How much work is done by the engine? 8000 J
- If the car in problem above travelled 10.0 m, what was the average force exerted on the car as a result of the actions of the engine? 800 N
- A 50.0 g arrow is pulled back a distance of 80 cm in a bow. When the string is released, it exerts an average force of 60 N on the arrow. With what speed does the arrow leave the bow? (326-1) 43.8 m/s

Resources/Notes

Transformation, Total Energy, and Conservation (continued)
15 hours

Outcomes

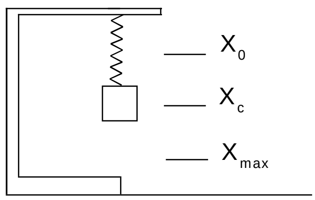
Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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



that holds the spring stretched to something less than half the elastic limit of the spring.

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

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

Transformation, Total Energy, and Conservation (continued)
15 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct your lab (Hooke's law and energy changes) and write a report. (326-1, 326-5, 214-7)

Paper and Pencil

- An average force of 8.0 N is applied to a 1.2 kg dynamics cart that is initially at rest. If the force is maintained for a distance of 0.80 m, what velocity will the cart attain? 3.3 m/s If the force is maintained over a distance of 1.6 m, what speed is reached? 4.6 m/s What is the ratio of the two velocities? ratio is $\sqrt{2}$ Explain in terms of work and energy why this is so. If $F.d = \frac{1}{2} MV_2^2$ when $V_1 = 0$ and F is kept constant, double of d only brings new velocity by $\sqrt{2}$ Compared to the first trial, what could you change to give the cart twice the speed? (326-6) 4 times the distance
- Kristen is playing on a swing. At her highest swing, the seat is 3.2 m above the rest position. What speed does she have as she passes through the lowest position? (326-6) 7.9 m/s
- A pole vaulter wants to clear the bar at a height of 7.0 m above the mat. What vertical speed must he/she have to just clear the bar? 11.7 m/s What role does the pole play in the pole vault? (326-6) Being able to extend force over a longer period of time thus also distance, creating a condition where a vertical speed of 42 km/h is not necessary!
- A boy uses his feet to stop his go-cart from a speed of 10 m/s. The combined mass of boy and his cart is 100.0 kg. Over what distance does he need to drag his feet, if they exerted 700 N of force to stop cart? 7.14 m
- When analysing a problem, how do you decide whether to use kinematics, dynamics, or energy concepts to solve for unknowns? (326-6)

Resources/Notes

Transformation, Total Energy, and Conservation (continued)
15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

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

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

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

Energies of a Falling Mass

h (m)	t (s)	v (m/s)	KE (j)	PE (j)
1.0				
0.8				
0.5				
0.3				
0				

Transformation, Total Energy, and Conservation (continued)
15 hours

Tasks for Instruction and/or Assessment

Presentation

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

Resources/Notes

Transformation, Total Energy, and Conservation (continued)
15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

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

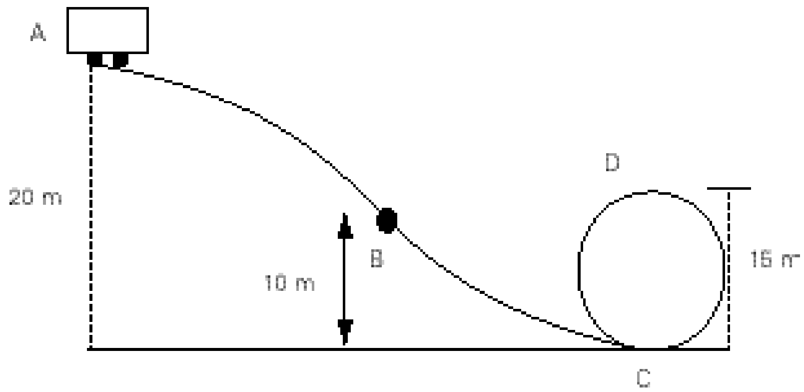
Students should also solve algebraic problems involving energy transformations.

Transformation, Total Energy, and Conservation (continued)
15 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- After referring to the diagram below, answer the following questions: (friction is negligible)
  - How much gravitational potential energy does the roller coaster car have at position A if the loaded mass is 1100 kg? 2.2×10^5 J
  - What is the maximum kinetic energy the car could have at B? 1.1×10^5 J
  - What speed would it have at B? 14 m/s
  - What speed would the car have at position D? (326-7) 9.9 m/s



- Write up your inclined plane activity in a lab report format. (326-7)

- A "superball" is dropped from a height of 1.5 m onto a hard floor and bounces back up to virtually the same height. Describe completely the energy changes undergone by the ball from the time it is released until the time it reaches maximum rebound height. In particular, account for the changes that occur while the ball is in contact with the floor. (326-7) At 1.5 m PE(J) is at max. As ball falls, it gains KE(J) and loses PE(J) at same rate. Maximum KE(J) at floor level. All Work(J) is done to compress ball and when it decompresses, all work energy (J) will transfer to make ball rise, thus KE(J) will convert to PE(J) as ball rises. Because friction is not taken into consideration, all energy transferred to ball and stayed within the situation.

Presentation

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

Resources/Notes

Transformation, Total Energy, and Conservation (continued)

15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

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

Transformation, Total Energy, and Conservation (continued)
15 hours

Tasks for Instruction and/or Assessment

Journal

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

Paper and Pencil

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

Presentation

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

Performance

- Slide a book across the floor and record time (s), and distance (m) from start to stop. Find book's mass (kg). With data find
  - starting velocity
  - decceleration
  - force of friction
  - energy loss to friction

  (326-8)

Resources/Notes

Transformation, Total Energy, and Conservation (continued)
15 hours

Outcomes

Students will be expected to

- design an experiment, select and use appropriate tools, carry out procedures, compile and organize data, and interpret patterns in the data to answer a question posed regarding the conservation of energy (212-3, 212-8, 213-2, 214-3, 214-5, 214-11, 326-4)
- distinguish between problems that can be solved by the application of physics-related technologies and those that cannot (118-8)

Elaborations—Strategies for Learning and Teaching

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

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

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

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

Transformation, Total Energy, and Conservation (continued)
15 hours

Tasks for Instruction and/or Assessment

Informal Observation

- Using a scale, the teacher can observe students as they conduct the investigation selected for this outcome. (212-3, 213-4, 214-16)

Performance

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

Paper and Pencil

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

Presentation

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

Resources/Notes

Unit 4
Waves
Suggested Time: 25 Hours

Important:

For this unit, extension work for level 1 students will be elaborated in the fourth column

Waves

Introduction

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

Focus and Context

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

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

Science Curriculum Links

In grade 8, students studied optics in relation to their scientific properties, their use in technological devices, and their relationship to society. Physics 12 continues wave theory with the relationship between potential and kinetic energies of a mass in simple harmonic motion and Science 122 with the properties of electromagnetic radiation.

Curriculum Outcomes

STSE	Skills	Knowledge
Students will be expected to	Students will be expected to	Students will be expected to
Nature of Science and Technology 115-5 analyse why and how a particular technology was developed and improved over time Relationships Between Science and Technology 116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology 116-7 analyse natural and technological systems to interpret and explain their structure and dynamics Social and Environmental Contexts of Science and Technology 117-2 analyse society's influence on scientific and technological endeavours 118-2 analyse from a variety of perspectives the risks and benefits to society and the environment of applying scientific knowledge or introducing a particular technology	Initiating and Planning 212-4 design an experiment identifying and controlling major variables 212-7 formulate operational definitions of major variables Performing and Recording 213-1 implement appropriate sampling procedures 213-7 select and integrate information from various print and electronic sources or from several parts of the same source Analysing and Interpreting 214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods 214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise	327-1 describe the characteristics of longitudinal and transverse waves 327-2 apply the wave equation to explain and predict the behaviour of waves 327-7 apply the laws of reflection and the laws of refraction to predict wave behaviour 327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect 327-5 compare and describe the properties of electromagnetic radiation and sound 327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

Fundamental Properties
10 hours

Outcomes

Students will be expected to

- describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves (327-1)

- formulate operational definition of major variables (212-7)
  – describe how energy input affects the appearance/ behaviour of a wave
  – discuss how energy can be transmitted by wave action

Elaborations—Strategies for Learning and Teaching

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

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

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

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

Fundamental Properties
10 hours

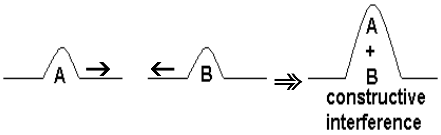
Tasks for Instruction and/or Assessment

Informal Observation

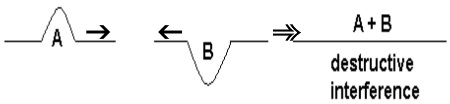
- Observe students demonstrating and making measurements of the characteristics of waves and experimentally verify the universal wave equation. (327-1, 212-7)

Performance

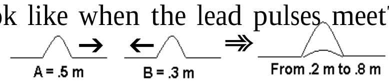
- Demonstrate using a Slinky™ and diagrams of two waves in a phase and two waves completely out of phase. (327-1, 212-7)
- Sketch examples of constructive and destructive interference. (327-1, 212-7)



Out of Phase



Paper and Pencil

- Distinguish between the period and frequency of a wave. (327-1, 212-7) Period is the amount of time it takes a wave to complete one cycle; Frequency is the number of waves (cycles) that can occur in a given time, usually a second.
- Which property of a wave is a measure of the energy in the wave? Use the work-energy theorem to explain your answer. (327-1, 212-7) Amplitude - Think of the transversal wave motion of a skipping rope. To produce a greater amplitude force (F) over greater (d) is needed thus more work (FN) required and more energy tranferred to rope.
- An oscillator vibrates the end of a spring at a frequency of 10.0 Hz. The distance between adjacent crests in the wave pattern formed is 1.50 m. What is the speed of the wave? (327-1) 15 m/s
- Two waves are created from opposite ends of a 10.0 m long spring. The wave from end A has an amplitude of 50.0 cm to the left of the relaxed position and a frequency of 5.00 Hz. The wave from end B has an amplitude of 30.0 cm on the opposite side of the spring and a frequency of 10.0 Hz.
  - What will the spring look like when the lead pulses meet? Draw a sketch. May look 

  - Can you predict at what point on the spring the two pulses meet? (327-1) No, because we need more information, wavelength
- How is a longitudinal wave different from a transverse wave? Give a common example of each. (327-1) The main difference between longditudinal waves and transverse waves is in the direction of the resulting wave.

Resources/Notes

Fundamental Properties (continued)
10 hours

Outcomes

Students will be expected to

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

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

Elaborations—Strategies for Learning and Teaching

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

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

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

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

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

Fundamental Properties (continued)
10 hours

Tasks for Instruction and/or Assessment

Performance

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

Paper and Pencil

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

Presentation

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

Resources/Notes

Fundamental Properties (continued)
10 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

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

- apply the laws of reflection and the laws of refraction to predict wave behaviour (327-7)
  - explain how engineers must take resonance into account when building large structures
  - draw a diagram and explain the refraction of water waves passing from deep to shallow or shallow to deep water
- state a prediction and a hypothesis about wave behaviour based on available evidence and background information (212-4)

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

Fundamental Properties (continued)
10 hours

Tasks for Instruction and/or Assessment

Paper and Pencil

- Prepare a written report about the wave-related technology you researched. (115-5)
- Create a "Help Wanted" notice advertising for a person to work in a wave-related employment field. Your notice will be part of a classroom bulletin board display. (115-5)
- Record observations, both sketches and data, and draw conclusions from a wave activity that you have completed. (327-2, 213-1, 214-8)

Presentation

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

Resources/Notes

Sound Waves and Electromagnetic Radiation
15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

Students should investigate the refraction of light and look for a relation between incident angle and refracted angle. An investigation using a variety of liquids in semicircular plastic containers could be conducted by pairs of students to develop Snell's Law and the formula : $n_1 \sin\theta_1 = n_2 \sin\theta_2$

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

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

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

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

Teachers may wish to do an investigation of Snell's Law or Young's experiment. No need to do both.

Sound Waves and Electromagnetic Radiation
15 hours

Tasks for Instruction and/or Assessment

Performance

- Conduct Young's experiment. (Found in Elaborations page 84) Make a chart of your results. (327-8, 327-7)

Paper and Pencil

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

Presentation

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

Resources/Notes

Sound Waves and Electromagnetic Radiation (continued) 15 hours

*** * ** ** * ***

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

*** ** * Level 1 students should attempt to replicate Young's double-slit experiment and be able to derive the formula. * ** ***

Sound Waves and Electromagnetic Radiation (continued)
15 hours

Tasks for Instruction and/or Assessment

Performance

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

Journal

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

Presentation

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

Resources/Notes

Sound Waves and Electromagnetic Radiation (continued)
15 hours

Outcomes

Students will be expected to

- compare and describe the properties of electromagnetic radiation and sound (327-5)
- describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted (327-6)
  - describe how sound is produced, giving an example of each in nature and technology
  - describe how sound is transmitted
  - list the factors on which the speed of sound depends
  - produce beats (physically) using two sources of slightly different frequency
  - explain the phenomenon of beats
  - explain how standing waves are produced in closed and open pipes
  - make use of the phenomenon of resonance in pipes to experimentally determine the speed of sound in air
  - explain the phenomenon of the sonic boom, describe the problems it causes, and explain how such problems can be minimized

Elaborations—Strategies for Learning and Teaching

The discussion of electromagnetic waves will be covered in more detail in Science 122. One possible context for this section might be the study of communications technology, which has Canadian connections from the invention of the telephone to the design of communication satellites.

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

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

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

Sound Waves and Electromagnetic Radiation (continued)
15 hours

Tasks for Instruction and/or Assessment

Performance

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

Journal

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

Paper and Pencil

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

Presentation

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

Resources/Notes

Sound Waves and Electromagnetic Radiation (continued)
15 hours

Outcomes

Students will be expected to

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

Elaborations—Strategies for Learning and Teaching

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

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

Sound Waves and Electromagnetic Radiation (continued)
15 hours

Tasks for Instruction and/or Assessment

Journal

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

Presentation

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

Resources/Notes

STSE CONNECTIONS

SCIENCE, TECHNOLOGY, SOCIETY AND THE ENVIRONMENT

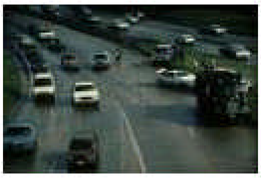
Important Note

These STSE modules are intended for teacher reference. Each is designed to target specific outcomes within Physics 111/112. 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 Tailgating

Outcomes:
1. Analyze and describe vertical motion as it applies to kinematics. (116-2)
2. Describe and evaluate the design of technological solutions and the way they function, using scientific principles. (116-6)
3. Analyze and describe examples where scientific understanding was enhanced or revised as a result of the invention of technology. (116-2)
4. Analyze mathematically the relationship among displacement, velocity and time. (325-2)

Introduction



Have you ever been in a rush to get somewhere and wished that the car ahead of you would just hurry up? Have you ever driven a little too close in an attempt to hurry the driver along? If so, you are guilty of tailgating. Tailgating is a dangerous and usually futile practice: "It only takes one crash in a tailgating line to produce a chain reaction" (Frank, n.d.). The laws of physics and of common sense dictate that you cannot go any faster than the slowest car ahead. Also driving too close forces stronger reactions to everything done by the car in front, making the drive much harder on your nerves and your car. An understanding of the physics of tailgating may be crucial in ensuring road safety and in helping tailgaters slow down and enjoy the ride. It might even result in less 'road rage'.

Theory

Tailgating can lead to multiple car crashes if even one car in a line suddenly slows down. The critical question is "how close is too close?" When learning to drive you are usually told to keep a safe distance of at least two seconds behind the car in front of you. As you observe the car ahead of you pass a fixed point, your own car should pass that same point at least two seconds later. This safe distance can also be expressed as one car length per 22 km/h of speed travelled. These rules of thumb are usually given since it is assumed that most people learning to drive do not understand basic physics. But without an understanding of some simple physics, we may all be at increased risk from tailgating. The physics of tailgating is related to motion and the kinematics equations, and includes principles like stopping distance and reaction time.

Reaction Time

If you are driving along the highway at 95 km/h and the car ahead of you suddenly applies the brakes, you must react quickly. Variables like response time become very important. When you first observe that the car ahead of you is stopping, it takes time for the brain to process this information. Reaction time includes the time taken for this processing plus the time for your foot to move to the brake. Reaction time can be determined by utilizing acceleration due to gravity principles (see activity). Typical reaction times are between 0.2 and 0.7 seconds. Nicklin (1997) tested reaction time with 64 students using computer trials of simulated brake and gas pedals, to find average reaction times of 0.3 to 0.6 seconds.

The reaction times stated above are typically obtained under ideal circumstances where the person being tested is paying attention to the task at hand. In a real situation the driver could possibly be distracted (eg. having a conversation with a friend, or singing along to the radio). Testing

reaction time under these conditions might give a more realistic representation of reaction time. An even more realistic estimate would include adding on an estimation of the time it would take to move your foot from the gas pedal to the brake pedal (Alternative Homework Assignment: Tailgating). Since the foot is farther away from the brain than the hand, the reaction time calculation will be increased slightly.

Stopping Distance

A person's reaction time is important in calculating a stopping distance for the vehicle they are driving. Initially you are travelling along at some constant velocity before your foot hits the brake. The distance travelled during the reaction time is given by, where vi is the initial velocity. When i d vt = the brakes are applied the vehicle begins to decelerate.

During this period of deceleration the distance travelled is given by,

$$2ad = v_f^2 - v_i^2$$

$$d = \frac{v_f^2 - v_i^2}{2a}$$

where $v_f = 0$, so

$$d = \frac{-v_i^2}{2a}$$

where a is negative since the car is decelerating. Thus the total stopping distance for the car is given by,

$$d = v_i t + \frac{-v_i^2}{2a}$$

The following data, originally published in Popular Science and AutoWeek magazines (Nicklin, 1997, p. 78), can be used to solve 'tailgating problems'.

Vehicle	Deceleration (m/s^2) (from 97 km/h)
BMW M3	9.8
Toyota Celica GT	9.2
Lincoln Continental	9
Nissan Maxima	8.3
Chevrolet Blazer	7.5
Dodge Colt GL	7.1

Identical Braking Capacity

Assume that two Lincoln Continentals are travelling along a highway at 97 km/h. The front car slams on its brakes. Knowing the reaction time of the driver we can determine the minimum distance that the second Lincoln should have been behind the first to avoid a rear end collision.

The following calculation shows that the front car will stop in a distance of 41 m.

$$d = \frac{-v_i^2}{2a}$$

$$d = \frac{-(27\ m/s)^2}{2(-9.0\ m/s^2)}$$

$$d = 41m$$

The second car (using a reaction time of 0.45 s) will stop over a distance of,

$$d = v_i t + \frac{-v_i^2}{2a}$$

$$d = (27\,\tfrac{m}{s})(0.45s) + \frac{-(27\,\tfrac{m}{s})^2}{2(-9.0\,\tfrac{m}{s^2})}$$

$$d = 12m + 41m$$

$$d = 53m$$

Note that 12 m of this distance is travelled before applying the brakes, and the other 41 m is required to stop. Thus a safe distance behind the first car would be at least 12 m. Given that the average car length is about 5.0 m, this safe distance translates into about 2.4 car lengths behind. A constant speed of 27 m/s over this 12 m translates into a 'safe time' that is equal to the reaction time.

$$t = \frac{d}{v}$$

$$t = \frac{12m}{27\,\tfrac{m}{s}}$$

$$t = 0.44s$$

The only factor affecting the required separation distance is the reaction time (when both cars are travelling at the same speed and have the same deceleration).

At this point it might appear that the two second rule is overly cautious. However the situation described is an idealized one where both cars have the same braking ability and the tailgater has a reasonably good reaction time. The situation could be much worse if the tailgater had a poor reaction time, if the road conditions were wet or icy, if the lead car were travelling slower than the tailing car, or if the braking capacity of the cars were different.

Different Braking Capacity

The situation with different braking capacities can also be illustrated using data from the table given (Nicklin, 1997). Nicklin describes a situation where two cars are travelling at 121 km/h with a separation distance of 5 car lengths (?24.38 m). Car A decelerates at 9.8 $^m/_s{}^2$ (a BMW), while car B decelerates at 7.5 $m/_s{}^2$ (a Chevrolet Blazer). If the driver of car B has a reaction time of 0.45 s, the following calculations show that car B will in fact hit car A even at 5 car lengths away.

Stopping distance of car A:

$$2ad = v_f^2 - v_i^2 \quad where\ v_f = 0$$

$$d = \frac{-v_i^2}{2a}$$

$$d = \frac{-(33.6\,\tfrac{m}{s})^2}{2(-9.8\,\tfrac{m}{s^2})}$$

$$d = 57.6m$$

Stopping distance of car B:

$$d = v_i t + \frac{-v_i^2}{2a}$$

where the $v_i t$ portion corresponds to the distance travelled during the reaction time.

$$d = (33.61\,\tfrac{m}{s})(0.45s) + \frac{-(33.61\,\tfrac{m}{s})^2}{2(-7.5\,\tfrac{m}{s^2})}$$

$$d = 15.1m + 75.3m$$

$$d = 90.4m$$

Thus when car A has stopped, it would be 24.38 m (5 car lengths) + 57.6 m = 81.98 m from where car B started. If Car A has come to a complete stop, it will still be hit by Car B since Car B requires 90.4 m to stop (it can be shown that Car B will actually collide with Car A 3.4 s after Car A starts to brake). Car B would have been decelerating for 81.98 - 15.1 m = 66.88 m before reaching car A. The final velocity of car B at 66.88 m is,

$$v_f^2 = 2ad + v_i^2$$

$$v_f^2 = 2(-7.5\ m/s^2)(66.88m) + (33.61\ m/s)^2$$

$$v_f^2 = -1003.2\ m^2/s^2 + 1129.63\ m^2/s^2$$

$$v_f = 11.2\ m/s$$

Under these conditions when car A has better brakes and can stop faster, car B will collide with car A even with a good reaction time and a separation distance of five car lengths.

The situation is even more complicated when there is a line of tailgating cars. If the car ahead of you is also tailgating, you have no way of knowing how much they have reduced their own safety margin. As a driver you can roughly tell your own reaction time, velocity, and braking ability. Unfortunately you know nothing about the other driver's reaction time or braking conditions. This lack of knowledge further increases the risk of tailgating.

Getting Ahead?

Traffic lights can be particularly frustrating especially when trying to reach a destination in a hurry. Many drivers think that tailgating and driving as fast as possible between lights will get them there faster than somebody who obeys the speed limit. However this is not necessarily the case. In the case of heavy traffic, tailgating can actually slow you down. How many times have you observed a car whiz by you by weaving in and out of traffic, only to find that four or five lights later they are still only slightly ahead of you? Traffic lights are timed to ensure easy flow of traffic. One way of doing this allows a person following the speed limit to get every green light (once they get one). Tailgaters however are forced to slow down or stop every time a car ahead slows or takes a turn. Getting back up to speed leaves a larger gap in front of the car than if they had been travelling along at a constant speed at a safe distance. This gap is quickly filled in heavy traffic, so the tailgater doesn't get much further ahead. Also, having to get up to speed at every red light causes the slowdown of trailing lines of traffic that would ordinarily have made the light, thus contributing to traffic congestion.

Conclusion

In our fast paced world it is often difficult to slow down when there is so much to do in so little time. Tailgating may give the perception of getting ahead, but a basic understanding of motion shows that this is not the case. So, how close is close enough? In the case of tailgating the answer to this question is 'too close for comfort'.

Questions

1. In a realistic model of tailgating what factors should be considered that would increase the safe stopping distance?

2. What is the stopping distance of a Toyota Celica ($a = -9.2\ m/s^2$) from 97 km/h where the driver has a reaction time of 0.55 s?

3. A Chevrolet Blazer travelling at 97 km/h can stop in 48 m. Given that the actual stopping distance for a certain driver is 54 m, what was the driver's reaction time?

4. An automobile is travelling at 25 m/s on a country road when the driver suddenly notices a cow in the road 30 m ahead. The driver attempts to brake the automobile but the distance is too short. With what velocity would the car hit the cow if the car decelerated at $7.84\ m/s^2$ and the driver's reaction time was 0.75 s?

5. Research: Look in car magazines to determine stopping distances and deceleration rates for your own or family car.

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Activities

Reaction Time

Purpose: To determine a person's reaction time.

Materials: • Meter stick

Procedure:

1. Have a partner hold a meter stick while you position your thumb and forefinger just at the 0 mark. Have your partner release the ruler while you try to catch it as quickly as possible. You can then record the distances of several trials and take an average distance.
2. The meter stick will fall at a rate of 9.8 m/s^2 toward the ground from an initial velocity of 0 m/s. Given this data, reaction time can be calculated from the kinematics formula,

$$d = v_i t + \frac{1}{2} a t^2$$

where $v_i = m$ 0 so,

$$d = \frac{1}{2} a t^2$$

$$at^2 = 2d$$

$$t^2 = \frac{2d}{a}$$

$$t = \sqrt{\frac{2d}{a}}$$

This activity can be repeated under more realistic conditions by having your partner distract you as you try to catch the ruler.

The Physics of Karate

Outcomes:

1. Analyze natural and technological systems to interpret and explain their structure and dynamics (116-7).
2. Describe the functioning of a natural technology based on principles of momentum (116-5).
3. Apply Newton's Laws of motion to explain the interaction of forces between two objects (325-8).
4. Use Newton's second Law to show how impulse is related to change in momentum (326-3).
5. Interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables (214-5).
6. Compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots (214-3).
7. Use appropriate language and conventions when describing events related to momentum and energy (114-9).

Introduction

What kind of person would intentionally bring their hand or foot crashing down onto a slab of wood or concrete? A daredevil? A Hollywood stuntperson? As it turns out, that kind of person is simply someone who understands the physics of karate - someone like you!

Karate means "open or empty hand", and began as a form of weaponless combat in 17th century Japan. In recent years it has become popular in our culture, as a form of fitness, self-defense and self-expression. Karate participants - called Karateka - often break concrete or wooden boards as a demonstration of the strength developed through training. Surprisingly there are no tricks involved in accomplishing such a feat. What is involved is a physics-based knowledge of how to do it properly. "Few things offer more visceral proof of the power of physics than a karate chop. Punch a brick with your bare hand, untutored in the martial arts, and you may break a finger. Punch it with the proper force, momentum and positioning and you'll break the brick instead" (Rist, 2000).

Theory

Force, Speed and Area

Karateka agree that the secret to karate lies in the force, speed and focus of the strike. The more quickly a board is hit, the harder the strike. Maximum hand velocity is actually achieved when the arm reaches 75-80% of extension. Since the hand cannot move forward a distance greater than the length of the arm, it must have a velocity of 0 at full arm's extension. To get the hardest hit, contact must be made with the object before this slowdown begins. Thus a good karate chop has no follow-through (as would a good tennis or golf swing). The hand is typically in contact with the object for fewer than five milliseconds.

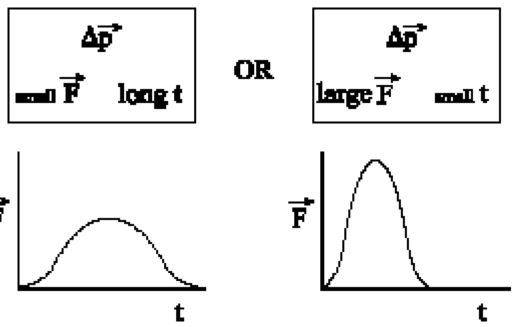
How fast can a karate punch actually move? Experiments done with a strobe light on karateka throwing punches found that beginners can throw a punch at about 6.1 m/s (20 feet/sec), while black belts could chop at 14 m/s (46 feet/sec). At the latter speed a black belt can deliver about 2800 N to the object being hit. (Splitting a typical concrete slab requires only about 1900 N). A concrete slab could probably support a force of 2800 N if it were not concentrated into such a small area. Minimizing the striking surface of the hand, and therefore the area of the target being hit, maximizes the amount of force and energy transferred per unit area. To understand why speed and focus are so important, the principles of momentum and impulse must also be considered.

Momentum and Impulse

Momentum ($\vec{p}$) is defined as an object's mass x velocity. Change in momentum, ($\Delta\vec{p}$) is defined as impulse (symbol $\vec{\mathcal{J}}$), and is given by force x $\mathcal{J}$ time. According to Newton's third law momentum is a conserved quantity. The third law states that for every action force on an object in a given time, there is an equal and opposite reaction force by that object for the same amount of time. Thus, any momentum lost by the first object is exactly gained by the second object. Momentum is transferred from one object to the other. Using,

$$\vec{\mathcal{J}} = \Delta\vec{p} = \vec{F}t$$

we can see that if $\Delta\vec{p}$ remains fixed, then force and time are inversely proportional. This means that if force increases, than time decreases and vice versa. It follows that a fixed amount of momentum can then be transferred with a small force for a long time or with a large force for a short time.



The quicker the karateka can make the chop, the larger the force transferred to the target. According to Newton's second law ($\vec{F} = m\vec{a}$) the part of the object struck with this force will begin to accelerate or oscillate. Breakage occurs if the small area hit accelerates enough relative to the stationary ends of the object. The object will experience strain and begin to crack from the bottom up.

What about the strain experienced by the hand or foot? Fortunately bone can withstand about forty times more force than concrete. Hands and feet can withstand even more than that due to the skin, muscles and ligaments which absorb much of the impact. Despite possessing these "natural shock absorbers", breaking wood, concrete or bricks should not be attempted without proper training. Such training would include toughening up the hand and knowing exactly how and where to hit the object with maximum speed. Over time the knife edge of the hand, called the "shuto", develops a callous which acts to absorb the collision force. As well, experts know to only hit things that can actually be broken. Sihak Henry Cho, a grand master at the Karate Institute in Manhattan sums it up nicely: "Being good at karate is a lot like being good at telling a joke. It's not what you break; it's how you break it" (Rist, 2000).

Questions

1. Why is it important to hit a concrete slab quickly when attempting to break it?

2. Karate black belts often advise beginners before their first attempt at breaking, not to try to break the board, but to aim for the floor underneath the board. How would this advice help?

3. Research: Karate practitioners usually yell "Kiai" when striking an object. Research the meaning of this term?

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Activities

Activity 1: How Much Weight does it take to break a board?

Materials:

- masses (2 kg)
- board
- supports (bricks)
- meter stick

Procedure:

Design a procedure to see how much weight must be placed on the board in order to get the board to break. As the weight is added to the board, measure how far the board bends.

Analysis:

1. Graph applied force (y-axis) versus bending distance (x-axis).
2. Find the slope of your graph. Describe how the applied force is related to the bending distance.
3. Recall that work can be done to a system to change the energy of the system. The work done by a force F can be determined by finding the area under the curve of a force versus distance graph. From your data determine the work that was done to break the board.

Activities

Activity 2: Pretzel

Purpose: To use pretzel sticks to better understand what causes materials to break.

Materials:

- pretzel sticks of varying thickness
- pieces of uncooked spaghetti
- rolls of 50 pennies each, plus 50 loose pennies
- thick string or wire about 6 cm long
- paper cup
- empty plastic film container
- scissors or craft knife
- tweezers

Procedure:

1. Build a pretzel strength-testing machine. Start by cutting a large hole in the bottom of the paper cup. Set the cup on the table, bottom side up. Rest a pretzel stick across the center of the cup.
2. Next create a weight bucket to hang on the pretzel. Take the empty plastic film container and make two holes about 1 cm from the top rim and directly across from each other. Thread the string or wire through the holes and tie the end at each hole. The bucket should hang on the pretzel without touching the table.
3. Begin testing. With the bucket hanging on the pretzel stick begin adding pennies. See how many pennies the pretzel can hold without breaking. Find the average number of pennies one type of pretzel stick can hold.
4. Gaining momentum: Test to see if it makes a difference if you drop the pennies in the bucket or you place them in gently using the tweezers.
5. Breaking point: Test to see if the weakest point of the pretzel is really at the center.
6. Length and width test: Try pretzels of various lengths and widths to see what size and length hold the most and least pennies.
7. Compare with other materials: Do you think a pretzel or an uncooked piece of spaghetti is stronger when bent? Try testing uncooked spaghetti to see how it holds up in comparison to the pretzel sticks.

Questions:

1. Look at the ends of a broken pretzel with a magnifying glass. Does its structure tell you anything about its bending strength?
2. Can you figure out a way to spread weight out across the entire length of the pretzel? Can it hold more weight when the weight is distributed over a larger area?

(Activity designed by Jane Copes, Science Museum of Minnesota and adapted from Newton's Apple Teacher's Guide: Karate)

Activities

Activity 3: (taken from Pushing Air located at http://www.schools.ash.org.au/paa/downloads/actbook.pdf)

Purpose: To relate a successful karate chop to air pressure.

Materials:

- sheet of newspaper
- ruler

Procedure:

1. place a ruler or flat stick on a bench top with about a quarter of its length overhanging.
2. Give the overhanging part of the ruler a quick karate chop from above.
3. Repeat the above steps with a piece of newspaper covering the nonoverhanging part of the ruler.

Questions:

1. Why do you think the ruler snaps during the second part of the experiment?

Explanation:

Air is all around us pushing on everything. It pushes on our skin and on the bench top. The ruler has a small surface area, so the air pushing down on it is not enough to hold the ruler in place when you hit it. The newspaper has a large surface area. The force of the air acts over the whole area. The result is that air holds down the paper which holds the ruler in place. Unable to lift quickly enough when the overhanging part of the ruler is struck, the ruler has no option but to snap.

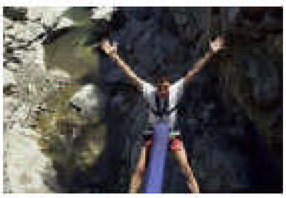
The Physics of Bungee Jumping

Outcomes:

1. Describe and evaluate the design of technological solutions and the way they function, using energy principles. (116-6)
2. Analyze and describe examples where technological solutions were developed based on scientific understanding. (116-4)
3. Distinguish between problems that can be solved by the application of physics-related technologies and those that cannot. (118-8)
4. Analyze and describe examples where energy-related technologies were developed and improved over time. (115-5, 116-4)
5. Analyze the risks and benefits to society and the environment when applying scientific knowledge or introducing a particular technology (118-2)
6. Construct and test a prototype of a device and troubleshoot problems as they arise. (212-14)
7. Analyze quantitatively the relationships among mass, height, gravity, spring constant, gravitational potential energy and elastic potential energy. (326-1)
8. Solve problems using the law of conservation of energy, including changes in elastic potential energy.

Introduction

Would you plunge off a bridge attached only by a soft springy cord that could stretch three to four times its free length? If you understood the physics behind such a daring feat you just might! Bungee jumping involves attaching oneself to a long cord and jumping from extreme heights. It is related to a centuries old practice from the Pentecost Island in the Pacific Archipelago of Vanuatu. On this island, the men jump to show their courage and to offer thanks to the gods for a good harvest of yams. In 1979, members of the Oxford University Dangerous Sport Club jumped off a bridge near Bristol, England, apparently inspired by a film about "vine jumpers". In the early 1990's, the sport gained popularity in the United States and Canada. Today it is still dubbed the "ultimate adrenaline rush" (Menz, 1993).



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Equipment

The old adage of "less is more" certainly applies to bungee jumping. The only equipment required is a springy cord and a harness. However it is very important that the equipment used be strong and secure. The harnesses are similar to those used in mountain climbing, including the caribiner which is the main link between the cord and the harness. The cord itself is soft and springy and is secured tightly to the jumper's body. Jumpers today are typically aided by double hookups. If an ankle jump is chosen, the body harness is used as a backup. If the body harness is chosen, a chest/shoulder harness becomes the backup.

Though there have been some accidents related to bungee jumping (three deaths in France in 1989), they can be traced to human error in attachment, total height of jump available, or a mismatch between the cord and jumper. Minor injuries like skin burn or being hit by the cord happen when jumpers do not follow instructions. Skin burn for example is caused by gripping the cord. Understanding and adhering to some basic physics principles would prevent such problems.

Theory

Energy Distribution

The main physics concepts involved in bungee jumping are the gravitational potential energy of the jumper and the elastic potential energy of the stretched cord. Initially the jumper is attached to the cord which is attached to a supporting structure on the same level as the jumper's center of mass. Standing on the platform, the jumper possesses gravitational potential energy given by,

$$E_p = mgh$$

where is the height from the top to the bottom extremity of the jump. At the beginning of the jump (before the cord reaches maximum length) the jumper experiences free fall. In free fall the only force acting on the jumper (neglecting air friction) is the force of gravity which causes the person to accelerate downward at 9.8 m/s2. Free fall is a funny sensation in that the jumper experiences no outside forces and thus their internal organs are not pushing on each other. The free fall typically lasts between one and two seconds. During this time the bungee cord is not yet stretching and some of the original gravitational potential energy is transferred into kinetic energy (= /). The distribution of energy at a certain height "d" is then given by,

$$E_{total} = mgd + \tfrac{1}{2}mv^2$$

When the cord reaches its full length it begins to stretch and applies an upward force that begins to slow the jumper. At this point some of the jumper's energy is stored in the bungee cord (=/) and the total energy is given by,

$$E_{total} = mgd + \tfrac{1}{2}mv^2 + \tfrac{1}{2}kx^2$$

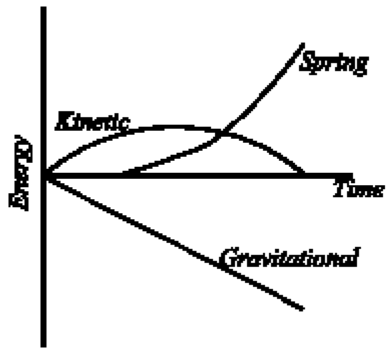
When the jumper reaches the bottom extremity of the jump the velocity of the jumper, and therefore the kinetic energy, is zero. At that point the gravitational potential energy possessed at the top has been totally converted into the elastic potential of the cord. Since energy is conserved in the jump, the gravitational potential energy of the jumper must equal the elastic potential energy of the cord.

$$E_{top} = E_{bottom}$$

$$mgh = \tfrac{1}{2}kx^2$$

The elastic potential energy refers to the energy stored in the cord by virtue of stretching it. The jumper will realize that there is stored energy in the cord when it rebounds to its equilibrium shape. The restoring force of the cord is used to decelerate and eventually stop the jumper.

The figure below (Nowikow & Heimbecker, 2001) shows how the different types of energy change during the jump. Note that as the gravitational potential energy decreases during the fall, the kinetic energy increases. At the bottom extremity of the fall as the cord tightens, the loss in gravitational potential energy is matched by a corresponding increase in the elastic potential energy of the bungee cord. At any point in the fall, the sum of the kinetic and elastic potential energies is equal to the gravitational potential energy lost during the fall.



Hooke's Law and Elastic Potential Energy

The work done to stop the jumper is related to the stiffness of the bungee cord. The cord acts like a spring that obeys Hooke's Law. Hooke's Law is given by,

$$F = kx$$

where F is the restoring force, k is the spring constant and x is the stretch of the cord. The elastic potential energy possessed by the cord at the bottom of the fall is given by,

$$E_p = \tfrac{1}{2} kx^2$$

Thus we can write that,

Potential energy at the top relative to the bottom of the fall.	=	Elastic potential energy of cord at the bottom extremity of the fall.

or mathematically,

$$mgh = \tfrac{1}{2} kx^2$$

$$mg(L + x) = \tfrac{1}{2} kx^2$$

where , h = (L + x), L is the length of the bungee cord and x is the stretch of the bungee cord.

This relationship allows the correct matching of cord with person or of jump height with person. If for example a given jump height (L + x) is to be matched with a given person of mass m, we can determine what stiffness (k) of cord should be used for that jump.

$$mg(L = x) = \tfrac{1}{2} kx^2$$

$$kx^2 = 2mg(L + x)$$

$$k = \frac{2mg(L + x)}{x^2}$$

If however a given cord of length L and stiffness k is to be matched with a person of mass m, then the amount of stretch can be determined as follows,

$$mg(L + X) = \tfrac{1}{2} kx^2$$

$$mgL + mgx = \frac{kx^2}{2}$$

$$2mgL + 2mgx = kx^2$$

$$kx^2 = 2mgx - 2mgL = 0$$

$$x = \frac{2mg \pm \sqrt{(2mg)^2 + 4k(2mgL)}}{2k}$$

$$x = \frac{2mg \pm \sqrt{4m^2g^2 + 8kmgL}}{2k}$$

$$x = \frac{2mg \pm \sqrt{4mg(mg + 2kL)}}{2k}$$

$$x = \frac{mg \pm \sqrt{mg(mg + 2kL)}}{k}$$

In most cases the latter method is the way the match would be made so that the total fall (L + x) will fit the jumping facility.

Hooke's Law can also be applied to determine the maximum force experienced by a jumper. If for example a 68 kg person is to jump using a 9.0 m cord which will stretch 18 m, we get the following.

$$k = \frac{2mg(L + x)}{x^2}$$

$$= \frac{2(68kg)(9.8\,m/s^2)(9.0m + 27m)}{(27m)^2}$$

$$= 111\,N/m$$

Therefore,

$$F = kx$$

$$= (111\,N/m)(18m)$$

$$= 1998N$$

Thus the force is about three times the person's weight. A cord with more stretch would give a "softer" ride. If for example the stretch of the 9.0 m cord were 27 m,

$$k = \frac{2mg(L + x)}{x^2}$$

$$= \frac{2(68kg)(9.8\,m/s^2)(9.0m + 27m)}{(27m)^2}$$

$$= 66\,N/m^2$$

and

$$F = kx$$

$$= (66\,N/m^2)(27m)$$

$$= 1782N$$

This exerts a lesser force on the jumper for a more comfortable jump. In reality of course, one must consider that given facilities will have a limited number of cords of differing length and stiffness. Also, bungee cords have been found to demonstrate variable stiffness over their range of use (i.e. k does not remain constant).

Results of calculations for three different jumps					
Jumper Weight (N)	Cord	Stretch (m)	F_{max} (N)	g's	Jump Height (m)
1112	Stiff	17.9	3187	2.87	28.7
800	Medium	16.7	2311	2.99	27.5
490	Soft	13.8	1478	3.02	24.6

Menz (1993) recommends that a proper match of cord and jumper should produce maximum accelerations of the order of 3 g's (where g=9.8 m/s2).

Conclusion

Bungee jumping then deals with the conversion of gravitational potential energy into the elastic potential energy of a stretched cord. It is an extreme sport that requires courage, daring and a knowledge of physics – at least by the people organizing the jump.

Questions

1. A person of mass 65 kg is to bungee jump from a platform that is 18.5 m above the ground. If the bungee cord used has a stiffness of 204 N/m and a length of 9.5 m, is it safe for the person to jump?
2. A 75 kg person is to bungee jump with a cord of length 8.0 m that will stretch 10.0 m. What force will be exerted on the person?
3. Describe the energy conversions that take place as a person bungee jumps.
4. Research: What were bungee cords originally designed for?

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Activities

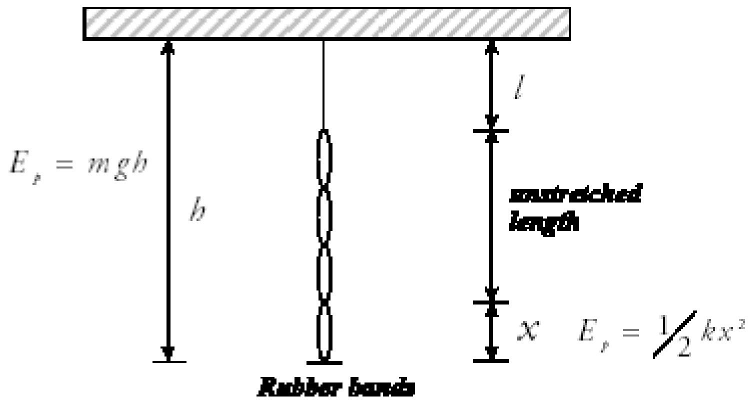
Activity 1: Bungee Egg

Purpose: To drop an egg attached to a bungee cord and have it come as close to the ground as possible without breaking.

Materials:
- ten rubberbands
- meterstick
- mass balance
- sandwich baggie (to minimize mess)
- masses
- egg (or eggs)

Procedure:

1. The procedure for this activity will be student designed. Their goal is to use energy calculations to determine the height of drop that will allow the egg to land safely. Students should be aware that the design of bungee jumps involves calculating the point at which the gravitational potential energy lost during the fall will equal the elastic potential energy gained by the elastic cord (or rubber bands). The following diagram may be useful in helping them visualize what they have to do. (Hint: Don't forget to take into account the height of the "egg in bag" attachment).



Where h is the total drop height, l is a fixed string (optional), and x is the amount of stretch.

Raw eggs are dropped in a harness made from a sandwich baggie. Evaluate students on how close they come to the floor without breaking the egg.

Activity 1: Bungee Egg (continued)

Notes to Teacher:

1. The bungee cord can be constructed from rubber bands or a bungee cord if one is available. The piece of string of length l, may or may not be used. The rubber bands (or cord) could be attached directly to an adjustable platform (eg. ring stand). If the string is used we will ignore its stretch in the calculations.

2. Students will first determine the spring constant k for their bungee cord by hanging masses from the cord and measuring the amount of stretch. The slope of a graph of force versus stretch will then give the value of k. This is Hooke's Law.

3. Energy conservation principles can then be used to figure out the stretch of the cord at the bottom extremity of its fall:

$$mgh = \tfrac{1}{2}kx^2$$

$$mg(L + x) = \tfrac{1}{2}kx^2$$

   where L is the length of the unstretched bungee cord and x is the amount of stretch.

4. Use the amount of stretch to determine what height the egg can be safely dropped from (by either adjusting the platform or adding a string to adjust the length).

5. Students should present calculations supporting their proposed drop height before any actual testing takes place.

Activities

Activity 2: Bungee Egg Drop 2

Refer to the following website (or see below) for another type of bungee egg drop experiment using a graphical analysis: http://www.physics.ucok.edu/~chughes/~plrc/Labs/BungeeEgg2.

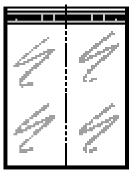
Introduction:

You may have seen the bungee egg apparatus in a previous experiment: Bungee Egg Drop 1. The apparatus is constructed from a minimum 2 meter length of unstretchable string or cord, a minimum of 6 standard size rubber bands, one grade AA large egg, one small safety pin, and one "half size" ziplock bag. Briefly, the egg is placed in the plastic bag which is then attached to a string of rubber bands tied together. This is, in turn, attached to the unstretchable length of cord. Detailed instructions for constructing this object are presented below.

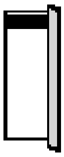
The egg is dropped by attaching the unstretchable cord to a support arm a chosen height above the floor. During the first part of the jump, only gravity acts on the egg causing it to fall faster and faster. When the egg has fallen a distance greater than the unstretched cord's length, the cord pulls upward causing the egg to come to a stop somewhere above the ground (hopefully). This maximum height through which the egg is dropped can be adjusted by changing the length of the cord.

Constructing the Bungee Apparatus

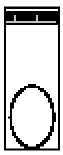
The egg holder is constructed by taking a normal ziplock bag and cutting it lengthwise down the middle with a pair of sharp scissors:



One of the resulting half size bags will be used as the egg holder (the other one should be kept as a spare). To keep the egg from rolling out, it is necessary to tape the open side of the bag with transparent tape. This should be done carefully to make sure that the top still opens and closes with the ziplock.



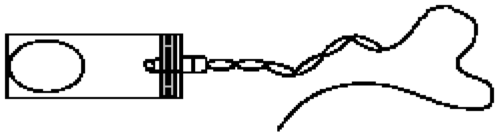
Finally, a hole should be punched in the top of the bag with a hole punch. After placing the egg in the bag, a safety pin is attached to the bag through the hole.



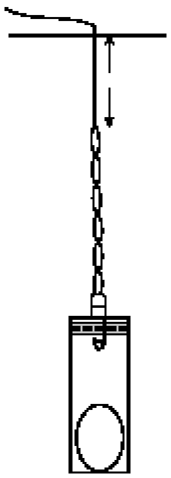
Activities

Activity 2: Bungee Egg Drop 2 (continued)

Next the "bungee" part of the apparatus must be constructed. At least six standard rubber bands should be tied end-to-end to produce an elastic chain. One end of the rubber band chain is attached to the top of the safety pin. The other is tied to the piece of unstretchable cord.



The exact number of rubber bands, and the length of the string needed, must be chosen so that the bungee apparatus can cover the range of distances when the egg is dropped: from 100 cm to500 cm



The different maximum distances that the egg falls through are achieved by changing the length of the unstretchable part of the cord, that is, the length between the topmost rubber band and the point where the cord is tied to the support arm. As this distance gets bigger, the egg will fall through a larger distance.
It may take a little experimentation to find a workable combination of cord length and number of rubber bands that will effectively cover the range of values needed. One group of students may choose to have more rubber bands and shorter string lengths while another may opt for less rubber bands and a longer string length. The only restriction is that each group must have a minimum of six rubber bands and a minimum of 2 meters of string.

Springs

A rubber band doesn't look much like a spring, but it really has behavior very similar to that of a spring.

Taking and Analyzing the Data

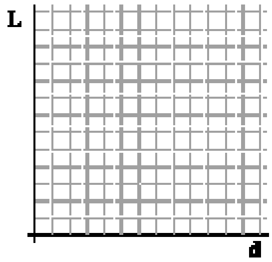
Ultimately you will have to use your measurements to make predictions. With this in mind, you might wonder about the best way to keep track of the data from the measurements.
You probably will want to start with a data table:

d(cm)	L(cm)

Activities

Activity 2: Bungee Egg Drop 2 (continued)

1. You should take enough data points so that the length L can be easily predicted to produce a given distance d in the range necessary for the contest. If the data points are too far apart, it becomes difficult to interpolate between the data.
2. The data table represents an insight into the real physics behind this apparatus. As such, it only gives a few pieces of information that point the way to explaining the relationship between L and d. The best way to use the data to explore this relationship is with a graph (as on the right). A graph of the data will show a collection of points on the graph. If enough points are found, a "curve" can be sketched through the data. While the line through the data is called a "curve," the line can actually be curved or straight. Its shape depends on the underlying physical law that relates the quantities being plotted. The curve is the first clue about the nature of that physical law. It tells a theoretical physicist that "this is the information which your theory must match."

   For our purposes, the curve simply means an infinite number of data points, each representing how far an egg will drop for a given choice of string length. The curve should be a smooth line drawn through the data. Some data points might lie on either side of the final curve because of errors in measurement. This gives an indication of the uncertainty in your measurements and should be taken into account when selecting a string length for the contest.

The Contest

The graph of L vs d provides a visual description of the physics of your bungee apparatus. If you made careful measurements and took care to draw a neat curve through your data, you should be able to predict the length of string needed to cause the egg to drop exactly the distance d.
Your bungee apparatus should be able to accurately predict the length of string necessary to make the egg fall, between 100 cm and 500 cm

When you arrive for the contest, you will be shown the area where the egg will be dropped. You will then have 5 minutes to measure the height of the drop with a meter stick, determine the proper length of the string for your apparatus, and drop your egg. The winner will be the group of students with the egg that gets closest to the ground without cracking. Closeness to the ground will be judged by your instructor (whose opinion is final). Eggs must be raw and may not be cushioned in any way. The bag is merely to hold the egg. The eggs will be "tested for rawness" at the end of the competition (so don't get too attached to your egg).

The Physics of Guitars

Outcomes:

1. To describe and evaluate the design of technological solutions and the way they function, using scientific principles. (116-6)
2. To analyze natural and technological systems to interpret and explain their structure. (116-7)
3. To analyze and describe examples where technological solutions were developed based on scientific understanding. (116-4)
4. To analyze society's influence on scientific and technological endeavours. (117-2)
5. To analyze why and how a particular technology was developed and improved over time. (115-5)
6. To analyze and describe examples where scientific understanding was enhanced as a result of the invention of a technological device. (116-2)
7. To describe what is meant by a vibration, and give examples from technology.
8. To explain how standing waves are produced on a stretched string.
9. Given the fundamental frequency and fundamental wavelength of a vibrating string, produce diagrams of various overtones labelled to show wavelength and frequency of each.
10. Describe how sound as a form of energy is produced and transmitted.

Introduction

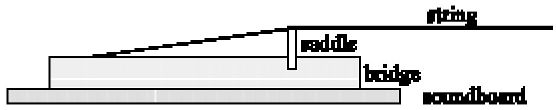
Chris Griffiths of St. John's, Newfoundland has had a lifelong interest in music, beginning guitar lessons at the age of twelve. He began building guitars at the age of seventeen. Since then he has turned his interest into the successful guitar making business known as Griffith's Guitar Works - a 20 000 square foot, multimillion dollar high tech acoustic guitar factory. Though Griffiths may not have chosen physics as a career, a knowledge of physics was certainly important in producing great sounding guitars like his latest creation - the Garrison. The Garrison guitar line includes a full range of acoustic guitars, beginning with the G-10 and following through to the top of the line G-50. Through innovative construction techniques, these guitars offer "superb playability and clarity of tone" that is setting a new standard for acoustic guitars (Garrison Guitars).

Construction

There are many different types of acoustic guitars, producing varying qualities of sound. However they all share some basic construction features. The three main parts of any guitar are the hollow body, the neck and the head.

Body

The guitar body includes the soundboard, a wooden piece mounted on the front of the guitar. The soundboard should be made so that it can vibrate up and down relatively easily. It is usually made of spruce or another light springy wood. Griffith's Garrison guitars are constructed from all solid wood including East Indian rosewood, sapele, englemann spruce, sitka spruce, Canadian birch and western red cedar. There is a large hole in the soundboard called the sound hole. Also attached to the soundboard is the bridge. The bridge anchors one end of the six strings. On the bridge is a saddle which the strings rest against.



When the strings are plucked they vibrate. The vibrations travel through the saddle and bridge to the soundboard. The hollow body of the guitar then amplifies the vibrations of the soundboard. These vibrations then disturb the air producing a sound wave reaching our ears. Without the amplification of sound produced by the hollow body, these vibrations would be barely audible. Bracing refers to the internal reinforcement of a guitar that must add strength where necessary but still allow the top to vibrate as freely as possible. Garrison guitars boast a single-unit brace that allows the resonant sound to travel uninterrupted through the guitar no matter where the vibration is created.

Neck

The neck of the guitar joins the body to the head. On the face of the neck (called the fingerboard) are metal pieces called frets that are cut at specific intervals. When a string is pressed onto a fret, the length of the string is changed. Changing the length changes the sound that is produced. The frequency of sound produced is inversely proportional to length ($f \propto \frac{1}{L}$). As length decreases frequency increases. The six strings on guitars also have different weights which affect the sound produced. The first string is as fine as a thread while the sixth is wound much heavier and thicker. More massive strings vibrate more slowly. The frequency of sound produced is inversely proportional to the square root of the density of the string ($f \propto \frac{1}{\sqrt{\rho}}$). As the density decreases the frequency increases. The frequency is also inversely proportional to the diameter of the string ($f \propto \frac{1}{d}$). This means that as the diameter decreases, the frequency increases.

The strings themselves do not make much noise when plucked since they do not cause a large disturbance to the air around them. It is the vibrations of the bridge and body that produce such pleasing sounds.

Head

Joining the neck to the head is a piece called the nut. The nut has grooves to hold the strings. From the nut the strings are connected to the tuning pegs on the head. Turning these pegs allows the tension in the strings to be increased or decreased. These pegs are used to tune the guitar. The tighter the string the higher the pitch and frequency of sound produced. In fact, frequency varies directly as the square root of the tension ($f \propto \sqrt{T}$).

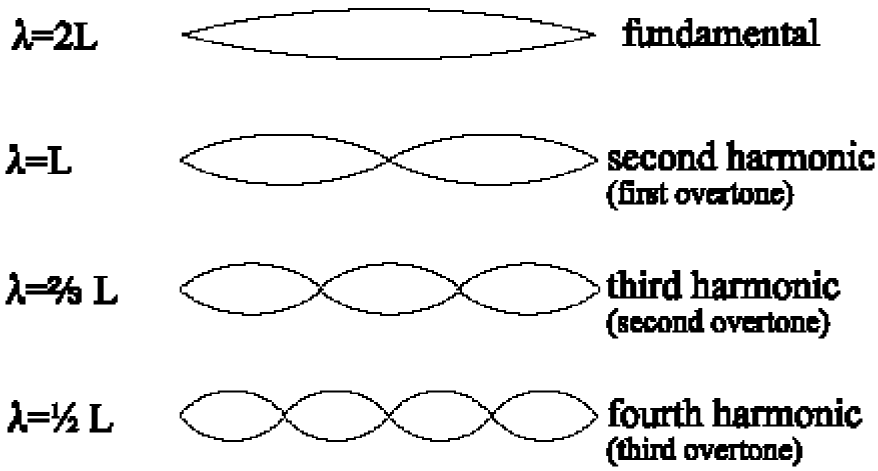
Electric Guitars

The major difference between electric guitars and acoustic guitars is in the body. Electric guitars have a solid body with no sound hole. A string plucked on an electric guitar makes almost no sound if not connected to an amplifier. This is because without a hollow body there is nothing to amplify the sound. Electric guitars therefore rely on amplifiers and speakers to produce sound. Vibrations are sensed electronically and then sent to the amplifier and speaker.

Theory

Standing Waves

Guitar strings are fixed on both ends by the saddle and the nut. The body of the guitar will resonate when standing waves are set up on the strings. A string will resonate when its length is equivalent to $\frac{1}{2}\lambda, \lambda, \frac{3}{2}\lambda, 2\lambda$, etc. This is the same pattern of resonant lengths that exist in an open air column. The standing waves in the strings are illustrated in the following diagrams.



Note that since the string is fixed at both ends, any vibration of the string will have nodes at each end. This limits the possible vibrations that can be achieved on a given length of string. We can see that for each of the diagrams, the wavelengths are $2L, L, \frac{2}{3}L \text{ and } \frac{1}{2}L$. In general this is written as $\lambda = \frac{2L}{n}$ where n is the harmonic number. Thus for each standing wave pattern, the frequencies are as follows (where v is the speed of sound):

Fundamental: $f = \frac{v}{\lambda} = \frac{v}{2L} = f_1$

Second Harmonic: $f = \frac{v}{\lambda} = \frac{v}{L} = 2f_1$

Third Harmonic: $f = \frac{v}{\lambda} = \frac{v}{2L} = \frac{3v}{2L} = 3f_1$

Fourth Harmonic: $f = \frac{v}{\lambda} = \frac{v}{L/2} = \frac{2v}{L} = 4f_1$

Since all waves in the same string travel with the same speed, then waves with these different wavelengths must have different frequencies. The frequencies f_1, $2f_1$, $3f_1$, $4f_1$, etc. are referred to as the harmonic series. It is the rich variety of harmonics that make a guitar or any stringed instrument interesting to hear.

Conclusion

Guitar construction is really a combination of art and science. Physics principles dictate the kind of sound produced in terms of frequency and wavelength. However it is the craftsman's artistry in constructing the shape of the body and soundboard that give each guitar its distinctive sound. For Griffiths there has been a "brilliant blend of technology, art and craftsmanship" which has set a new standard for acoustic guitars worldwide.

Questions

1. A guitar string of length 0.60 m has a frequency of 395 Hz. If the string is shortened to 0.30 m, what is it's new frequency?
2. A standing wave is set up on a guitar string of length 0.60 m. If the string vibrates in the third harmonic, what is the wavelength of the sound produced?
3. What is the main function of the body of the guitar in producing the music we hear?
4. A guitar string has an original tension of 146 N. How would the tension have to change to have the string vibrate with a frequency of 292 Hz?
5. Research: How has Griffith's guitars upped the standard for worldwide acoustic guitar construction?

References

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Activity

Activity:

Purpose: To experimentally determine whether the soundboard really amplifies sound.

Materials:
- large bowl
- plastic wrap
- tape
- rubber band

Procedure:

1. Tightly seal a large bowl with plastic wrap (you may need to use tape to wrap the plastic tightly to the sides).

2. Tape a rubber band to the center of the taut plastic wrap and twang the rubber band.

3 Compare the sound heard to the twang of an identical rubber band not taped to the plastic wrap. You should notice a big difference. The plastic wrap greatly increases the amount of surface area that is vibrating, so the sound is much louder. (This activity is taken from the web site "How stuff works" http://www.howstuffworks.com/guitar1.htm)

4. Demonstrate how to produce standing waves for students. A very effective way to do this is to attach one end of a string to an electric drill, and the other securely to some immovable object. When the drill is turned on at varying speeds, students can clearly see standing waves at the fundamental frequency and various overtones.

5. Refer to the activity at the following web site for an activity on making standing wave patterns on a guitar: http://scienceworkshop.freeyelllo.com/sound_guitar.htm

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.

For vector quantities, we draw arrows above the variable symbols. If magnitude (scalar) part of vector is referred only, arrow is omitted. Thus, when $\vec{d}$ is used, a direction must follow.

Unit 1 - Kinematics
Symbols

d = distance

$\vec{d}$ = displacement

$\vec{v}$ = velocity

v = velocity without direction

t = time

$\triangle d = d_2 - d_1$

$\triangle t = t_2 - t_1$

$\triangle \vec{d} = \vec{d}_2 - \vec{d}_1$

$\vec{a}$ = acceleration

a = acceleration without direction

Formulas

$$v = \frac{d}{t} \qquad \vec{v} = \frac{\vec{d}}{\triangle t}$$

$$v_{avg} = \frac{v_2 + v_1}{2} \qquad v_{avg} = \frac{\vec{v}_2 + \vec{v}_1}{2}$$

$$a = \frac{v_2 - v_1}{t} \qquad \vec{a} = \frac{\vec{v}_2 - \vec{v}_1}{\triangle t}$$

$$d = v_1 t + \tfrac{1}{2} a t^2 \qquad \vec{d} = \vec{v}_1 \triangle t + \tfrac{1}{2} \vec{a} \triangle t^2$$

$$d = v_2 t + \tfrac{1}{2} a t^2 \qquad \vec{d} = \vec{v}_2 \triangle t + \tfrac{1}{2} \vec{a} \triangle t^2$$

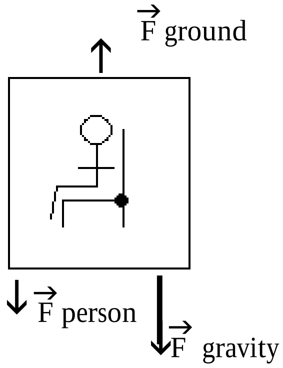
$$v_2^2 = v_1^2 + 2ad \qquad \vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a} \triangle \vec{d}$$

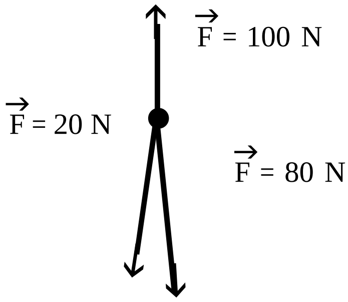
$$d = \left(\frac{v_2 + v_1}{2}\right) t \qquad \vec{d} = \left(\frac{\vec{v}_2 + \vec{v}_1}{2}\right) \triangle t$$

Unit 2 - Dynamics

FBD - free-body diagam = a diagram in which all the forces acting on an object are shown as acting on a point representing the object

Forces on chair





Symbols

$\vec{F}$ = Force

m = mass

$\vec{g}$ = acceleration due to gravity

$\vec{F}_{net}$ = Resultant Force when all negative and positive forces are considered

F_f = Frictional force

F_k = Kinetic friction force

F_s = Static friction force

F_n = Normal force

μ_k = coefficient of friction kinetic

μ_s = coefficient of friction static

$\vec{p}$ = momentum

$\triangle\vec{p} = \vec{p}_2 - \vec{p}_1$

$\vec{j}$ = impulse

Formulas

$\vec{F}_{net} = m\vec{a}$	$F_k = \mu_k Fn$	$\vec{p} = m\vec{v}$
$\vec{F} = m\vec{g}$	$F_s = \mu_s Fn$	$\vec{\triangle p} = \vec{F}\triangle t$
$F_f = \mu F_n$	$\vec{j} = \vec{F}\triangle t$	$\vec{F}\triangle t = m\vec{v}_2 - m\vec{v}_1$

Unit 3 - Work and Energy

Symbols

W = work

h = height

$\triangle h = h_2 - h_1$

P = Power

KE = Kinetic energy

PE = Potential energy

E_K - Kinetic energy

$\triangle E_K = E_{K2} - E_{K1}$

E_g = gravitational potential energy

$\triangle E_g = E_g 2 - E_g 1$

Formulas

$W = \vec{F}\triangle\vec{d}$

$W = \triangle E_k$

$W = m_{\vec{g}}\triangle d$

$W = \triangle E_g$

$Eg = M_{\vec{g}}\triangle d$ and $PE = M_{\vec{g}}\triangle d$

$W = m_g \Delta d$

$$P = \frac{w}{t}$$

$$Ek = \frac{1}{2}mv^2$$

$$Efficiency = \left(\frac{useful\ output\ energy}{input\ energy}\right)100\%$$

Unit 4 - Waves

Due to the overwhelming number of symbols and formulas associated with the study of waves, only a selection of symbols and formulas is provided. Teachers are encouraged to use others.

Symbols

f = frequency

T = period

λ = wavelength

c = speed of light (3.0×10^8 m/s) in a vacuum

v = speed of light in a medium

n = absolute refractive index

n_1 = index of refraction for medium 1

I = Wave Intensity

A = area perpendicular to wave

L = resonant length

β = decibels

Formulas

$$T = \frac{1}{f}$$

$$V = \lambda f$$

$$C = \lambda f$$

$$n = \frac{c}{v}$$

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

Doppler effect for light (electromagnetic)

$$f_2 = f_1\left(1 + \frac{vr}{c}\right)$$ if objects approaching each other

$$f_2 = f_1\left(1 - \frac{vr}{c}\right)$$ if objects moving away from each other

f_1 = emitted frequency
f_2 = observed frequency
vr = relative speed between source and observance
c = speed of light

Doppler effect for sound

$$f_2 = f_1\left(\frac{vs}{vs - vo}\right)$$ Towards stationary observer

$$f_2 = f_1\left(\frac{vs}{vs + vo}\right)$$ Away from stationary observer

f_1 = emitted frequency
f_2 = observed frequency
Vs = Velocity of sound
Vo = Velocity of object

$$I = \frac{P}{A}$$

$$B = 10\log\left(\frac{I_2}{I_1}\right)$$

$$L = \frac{n\lambda}{2}$$