Catholic District School Board Writing Partnership

Science

Course Profile

Physics

Grade 12
University Preparation
SPH4U

• *for teachers by teachers*

This sample course of study was prepared for teachers to use in meeting local classroom needs, as appropriate. This is not a mandated approach to the teaching of the course. It may be used in its entirety, in part, or adapted.

Spring 2002

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Catholic District School Board Writing Teams – Physics

Catholic Curriculum Cooperative of Central Ontario (CCCC) Writing Partnership - Science

Lead Board
Hamilton-Wentworth Catholic District School Board
Remo Presutti, Manager

Course Profile Writing Team
Gerry Fuchs, Hamilton-Wentworth CDSB (Lead Writer)
Kristina Salciccioli, Hamilton-Wentworth CDSB
Michael Varrasso, Hamilton-Wentworth CDSB

Course Profile Internal Review Team
Dr. Anthony Cuschieri, Hamilton-Wentworth CDSB
Joseph Garbat, Hamilton-Wentworth CDSB

University Destination Reviewer
Dr. Stefan Zukotynski, University of Toronto

Institute for Catholic Education (ICE)
Angelo Bolotta

Course Overview
Physics, SPH4U, Grade 12, University Preparation

Policy Document: *The Ontario Curriculum, Grades 11 and 12, Science, 2000.*
Prerequisite: Grade 11, Physics, University Preparation

Course Description
This course enables students to deepen their understanding of the concepts and theories of physics. Students further explore the laws of dynamics and energy transformations, and investigate electrical, gravitational, and magnetic fields; electromagnetic radiation; and the interface between energy and matter. They will further develop inquiry skills, learning, for example, how the interpretation of experimental data can provide indirect evidence to support the development of a scientific model. Students will also consider the impact on society and the environment of technological applications of physics.

How This Course Supports The Ontario Catholic School Graduate Expectations
Through the study of physics, students have the opportunity to "discover the laws which govern the universe, as well as their interrelationship." They (scientists and therefore students) can "stand in wonderment and humility before the created and feel drawn to the love of the Author of all things" (address of Pope John Paul II to the Jubilee of Scientists May 25, 2000). The study of any science helps students to learn to be reflective, critical, and creative thinkers, as well as discerning believers, who can apply their knowledge to the world around them. They can then make appropriate decisions in light of Gospel values and Church teachings. Through the study of the techniques of science, particularly experimentation, students learn to be collaborative contributors to an interdependent team, respecting the rights, responsibilities, and contributions of others. Overall, students become aware of the spiritual, as well as the physical dimension of the world and of the need to respect the environment and to use resources wisely in order to fulfil their roles as stewards of God's creation. "By increasing his knowledge of the universe ... man has a veiled perception ... of the presence of God...." (address of Pope John Paul II to the Jubilee of Scientists May 25, 2000).
As well, students are encouraged to make the connection with elements of their faith culture with regards to the sacramental nature of the physical environment and the mandate for responsible stewardship of the earth. As the U.S. Bishops point out, "Catholic tradition insists that we show our respect for the Creator by our stewardship of creation. Care for the earth …is a requirement of our faith…This environmental challenge has a fundamental moral and ethical dimension which cannot be ignored" (Origins, June, 1998).

Course Notes
Students of physics not only go on to study the theoretical aspects of the discipline but also enroll in engineering and other technical programs at the postsecondary level. Throughout the course students are given many opportunities to analyse, describe, and explain various technological applications of the physics principles being studied.
The teacher will provide ample opportunities for students to engage in safe, effective laboratory activities in all units of the course. The health and safety of teachers and students must be of paramount importance when conducting laboratory activities. All must comply with the provisions of Workplace Hazardous Materials Information System (WHMIS) legislation and must practise established safe laboratory procedures.

Experimental work provides students with an opportunity to develop their inquiry skills in each unit of the course. The skills essential for scientific investigation are found on pages 101 and 102 of *The Ontario Curriculum Grades 11 and 12 Science 2000*. These skills apply to all areas of the course and must be developed in all the course units. Assessment of the students' mastery of these skills must be included in the evaluation of their achievement of the expectations for the course. In this profile these skill expectations have been coded as Scientific Investigation Skills (SIS.01 to SIS.12).

Students are expected to use computer technology that has been developed for use in physics. Computer interfaces for laboratory equipment, multimedia applications, databases, and computer-based simulations should be used wherever appropriate to do so. Care must be taken, however, to ensure that students are provided with an adequate opportunity to learn how to use the computer technology and to understand the physics concepts being studied.

Consistent with the expectation of an academic environment enriched with theological, moral and scriptural insights, students are provided with opportunities to explore connections between the scientific knowledge and elements of their faith culture.

The underlying theme of the course is that physics develops theories of the way the universe works and that experiments may verify or refute these theories. The strands of the course are recommended as the units of study. It is recommended that the first unit should be Forces and Motion: Dynamics, followed by Energy and Momentum. This way students begin by investigating the theoretical underpinnings of the fundamentals of physics in a real-world context, before they move on to the more abstract concepts of modern physics in the topics of Electric, Gravitational, and Magnetic Fields; The Wave Nature of Light; and Matter-Energy Interface. It is also important in the modern physics section that the unit dealing with the concept of fields should be taught before The Wave Nature of Light and Matter-Energy Interface in order that students may understand and use the concept in these units. In all units students are encouraged to examine technological applications of theoretical concepts in order that they may relate theory to possible applications in the world around them.

Frequently students have their own concepts about how the world works and this has implications for their learning of physics concepts. If teachers can anticipate these preconceptions or alternate concepts they can address them explicitly in their teaching. A useful source to help teachers identify possible preconceptions is a website called, "Students' Alternate Conceptions," found at http://phys.udallas.edu/C3P/altconcp.html.

Units: Titles and Time

Unit 1	Forces and Motion: Dynamics	22 hours
* Unit 2	Energy and Momentum	22 hours
Unit 3	Electric, Gravitational, and Magnetic Fields	22 hours
Unit 4	The Wave Nature of Light	22 hours
Unit 5	Matter-Energy Interface	22 hours

* This unit is developed in this Course Profile

Unit Overviews

Unit 1: Forces and Motion: Dynamics

Time: 22 hours

Unit Description

During this unit, students expand the framework of knowledge acquired in Grade 11. The resolution of vectors into perpendicular components is used to predict the motion of projectiles and objects on inclined planes. Uniform circular motion is introduced through an understanding of inertial and noninertial frames of reference. Experiments are designed to study uniform circular motion and objects that travel in two dimensions. Using data analysis, students compare the results of investigations with theoretical predictions. Students predict the motion of satellites using Newton's law of universal gravitation. Simulations of complex dynamics problems are used to aid the student in identifying patterns and verifying the results of investigations. The final activity for this unit allows for a detailed analysis of motion using the principles of dynamics. This includes describing how a specific motion can be modified and a description of projectile or circular motion in a technology such as an amusement park ride.

Note: The numbering of the Scientific Investigation Skills (SIS) is taken from the order of the expectations given on page 101 and 102 of *The Ontario Curriculum Grades 11 and 12 Science 2000.* Since each Cluster includes several Learning Expectations, various Achievement Chart categories may be assessed, however, one or more areas tend to have a greater emphasis. These categories have been indicated in bold in order that it is clear to the teacher which category should be weighted more heavily.

Unit Synopsis Chart

Cluster	Learning Expectations	Assessment Categories	Focus/Task
1	FMV.01, FMV.02, FM1.01, FM1.02, FM2.01, FM2.02 SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2bcd, 5a	**Knowledge** **Inquiry** Communication	Dynamics Concepts and Inclined Planes: Experiments, problem solving, and simulations examining motion on inclined planes.
2	FMV.01, FMV.02, FM1.03, FM2.01, FM2.03 SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2bcd, 5a	**Knowledge** **Inquiry** Communication	Projectile Motion: Investigation, problem solving, and simulation of projectile motion.
3	FMV.01, FMV.02, FMV.03, FM1.01, FM1.04, FM1.05 SIS.04, .05, .06, .07, .08, .09, .11 CGE 2bcd, 5a	Knowledge	Inertial and Noninertial Frames: Define and compare frames of reference. Circular motion terminology and problem solving.
4	FMV.01, FMV.02, FM1.06, FM2.04 SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2bcd, 5a	Knowledge **Inquiry** Communication	Newton's Law of Universal Gravitation and Orbit: Investigate uniform circular motion for an object in orbit.
5	FMV.01, FMV.02, FMV.03, FM1.02, FM1.03, FM1.04, FM3.01, FM3.02 SIS.04, .05, .06, .07, .08, .09, .11, .12 CGE 2bcd, 5a	Knowledge Communication **Making Connections**	Application of Dynamics: Analysis of a specific motion and a relevant technology.

Unit 2: Energy and Momentum

Time: 22 hours

Unit Description

Students learn the concepts of work, energy, and momentum, and the laws of energy and momentum for objects moving in two dimensions. They investigate these laws experimentally for both elastic and inelastic collisions, and then solve problems involving these laws using vectors, graphs, and free body diagrams. Students study Hooke's law and analyse it in quantitative terms. They also analyse planetary and satellite motion in terms of energy and energy transformations. As a conclusion, students investigate the economic and social costs and benefits of various types of protective equipment and safety devices used in the world around them.

Unit Synopsis Chart

Cluster	Learning Expectations	Assessment Categories	Focus/Tasks
1	EMV.01, EM1.01, EM1.03, EM1.05, EM1.08, EM2.02 SIS.04, .06, .07, .08, .09, .10, .11 CGE 2d, 3c, 4f, 5ae	**Knowledge** Inquiry Making Connections	Energy Concepts: Brainstorming Concept mapping Present simulations Problem solving Analysis of problems
2	EMV.01, EM1.01, EM1.03, EM1.05 SIS.05, .06, .07, .08, .09, .11, .12 CGE 2c, 3c, 4f, 5ae	**Knowledge** Inquiry Communication Making Connections	Energy Transformations: Analysis of issue Class discussion Problem solving Teacher-directed lesson View video clips Analysis of video clip
3	EMV.01, EMV.02, EM1.01, EM1.02, EM1.03, EM1.04, EM1.05, EM2.01, EM2.02 SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2c, 3c, 4f, 5ae	**Knowledge** **Inquiry** Communication	Conservation of Momentum and Energy: Teacher-directed lesson Mathematical problem solving Computer simulations Student-designed experiments
4	EMV.01, EM1.03, EM1.06, EM1.07, SIS.04, .06, .07 CGE 2c, 4f	**Knowledge** Inquiry Communication Making Connections	Energy and Satellite Motion: Teacher-directed lesson Student problem solving Computer simulation of satellite motion
5	EMV.03, EM1.03, EM1.05, EM3.01, EM3.02 SIS. 03, .04, .10, 12 CGE 2de, 3bcef, 4f, 5ade, 7hj	**Knowledge** **Inquiry** **Communication** **Making Connections**	Energy and Protective Equipment and Devices in Automobile Safety: Criteria development Brainstorming Investigation of issues Independent study Tracking sheet Presentations

Unit 3: Electric, Gravitational, and Magnetic Fields

Time: 22 hours

Unit Description

The concept of a field is presented to students as a scientific model to deal with forces that act at a distance. A historical development of experiments allows students to evaluate different theories and the effect of technological advances on scientific thinking. The properties of gravitational, electric and magnetic fields are introduced. Students quantitatively analyse the fields around a mass, charged particles, and a conductor. Through experimentation and simulations, students describe the motion of a charged mass in a combination of fields. The theory of energy conservation is applied to objects that travel in gravitational and electrical fields. An experiment is conducted to analyse the factors that affect the electrical field around a conductor. Forces derived from uniform magnetic fields on current-carrying conductors and charged particles are determined. Finally, students evaluate the social and economic impact of new field-based technologies using the principles of the Catholic faith tradition and the social teaching of the Church.

Unit Synopsis Chart

Cluster	Learning Expectations	Assessment Categories	Focus/Task
1	EGV.01, EGV.03, EG1.01, EG3.01, EG3.02, SIS.04, .05, .06, .07, .08, .09, .10, .11 CGE 2bcd, 3cf, 5a	**Knowledge** Communication **Making Connections**	Concepts and History of Field Theory: Concepts and terminology. Experiments, technological developments, and implications.
2	EGV.01, EGV.02, EG1.01, EG1.02, EG1.03, EG1.06, EG1.07, EG2.02, SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2bcd, 3c, 5a	**Knowledge** **Inquiry** Communication	Electric Forces and Fields: Concepts and problem solving. Investigation of the factors that change the electrical field around a conductor.
3	EGV.01, EGV.02, EG1.01, EG1.04, EG1.08, EG2.01, SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2bcd, 3c 5a	**Knowledge** **Inquiry** Communication	Magnetic Forces and Fields: Concepts and problem solving. Investigations and simulations of the motion of charged particles in electric and magnetic fields.
4	EGV.01, EGV.03, EG1.01, EG1.05, EG3.03, SIS.04, .05, .06, .07, .08, .09, .10, .11 CGE 2abcd, 3bcf, 5a	Knowledge **Communication** **Making Connections**	Energy in Fields: Problem solving, applying the conservation of energy. Case study of a field-related technology.

Unit 4: The Wave Nature of Light

Time: 22 hours

Unit Description

The wave nature of light provides students with an understanding of many of the phenomena that have become the basis for applications of electromagnetic radiation (e.g. lasers, compact disks). Using field theory from the preceding unit as a basis, students develop an understanding of light as an electromagnetic wave. The electromagnetic spectrum is examined. Students investigate the wave behaviour of light through the properties of reflection, refraction, dispersion, diffraction, interference, and polarization. Experiments include investigations of diffraction (Young's experiment), the separation of light into colours (thin films), and polarization. Various applications of the wave nature of light are examined with an emphasis on new technologies that resulted from advancement of scientific theories. Students investigate careers associated with the advances in applications of electromagnetic radiation. Students discuss ways that progress in laser technology can be used both for the enhancement and for the destruction of human life, e.g., in the medical field or in weaponry and wars. Students are also encouraged to explore the symbolic use of light within their faith tradition and in scripture.

Unit Synopsis Chart

Cluster	Learning Expectations	Assessment Categories	Focus
1	WAV.01, WA1.01, WA1.02, WA1.03, WA1.05, WA2.03, WA2.04 SIS.06 CGE 3c, 7j, 4f	**Knowledge**	Field Theory: Brief review of field theory as it relates to electromagnetic waves Investigate the behaviour of light as a wave and examine the electromagnetic spectrum
2	WAV.02, WA1.01, WA1.05, WA2.01, WA2.03, WA2.04, WA3.03 SIS.02, .03, .05, .06, 0.7, .09, .10, .11 CGE 2c, 3c, 4f, 5ae, 7j	Knowledge **Inquiry**	Reflection and Refraction: Investigate reflection and refraction through experiments and problem solving emphasizing the similarities with sound
3	WAV.01, WAV.02, WAV.03, WA1.01, WA1.02, WA1.05, WA2.01, WA2.03, WA2.04, WA3.03 SIS.02, .03, .05, .06, .07, .09, .10 CGE2c, 3c, 4e, 5aef, 7j	Knowledge **Making Connections** **Inquiry**	Dispersion and Colour: Investigate dispersion and colour (e.g., interference in thin films) through experiments and problem solving Descriptions and analysis of applications of the separation of light into colour (e.g., thin films)
4	WAV.01, WAV.02, WA1.01, WA1.02, WA1.03, WA1.04, WA1.05, WA2.01, WA2.02, WA2.03, WA2.04 SIS.02, .03, .05, .06, .07, .09, .10 CGE 2c, 3c, 4f, 5ae, 5f, 7j	Knowledge **Making Connections** **Inquiry**	Diffraction, Interference and Polarization: Investigating these concepts through experimentation and problem solving (e.g., Young's experiment, single and double slit interference, diffraction of light) including the similarities to sound
5	WAV.03, WA3.01, WA3.02 SIS.04, .12 CGE 2c, 3e, 4f, 7ij	**Making Connections**	Applications: Investigating, describing, and assessing societal impact of new technologies related to advances in electromagnetic radiation (e.g., Polaroid filters, compact disks)

Unit 5: Matter-Energy Interface

Time: 22 hours

Unit Description

In this unit students investigate two theories that gave rise to modern physics: quantum theory and the theory of relativity. Students use critical thinking, problem solving and thought experiments to examine these theories. These theories are related to matter and energy to describe various phenomena including the particle nature of light and the wave nature of matter. Students apply modern and classical physics in an investigation of the atom and principal forms of nuclear decay through an analysis of emission spectra, trajectories of elementary particles, simulations, and information collection. Canadian contributions to physics are examined in this unit. Students apply the historical development of modern physics to describing new scientific advances that have benefited society. A fundamental dogma of the Catholic faith is the belief in the resurrection of the body, of matter that has undergone a qualitative change. Students are encouraged to read and discuss 1 Cor.15.36-58 where St Paul tries to address the matter of the resurrection of the body.

Unit Synopsis Chart

Cluster	Learning Expectations	Assessment Categories	Focus/Task
1	MEV.01, MEV.03, ME1.01, ME1.03 SIS.04, .05, .06, .07, .08 CGE 2e, 3c, 4f, 5e	**Knowledge**	Quantum Theory, Photoelectric Effect: Particle model of light Wave nature of matter Investigated through calculations, critical thinking and problem solving
2	MEV.01, MEV.02, MEV.03, ME1.01, ME1.02, ME1.04, ME1.07, ME2.01, ME2.03, ME2.04 ME3.01 SIS.02, .03, .04, .05, .06, .07, .08, .09, .10, .11, .12 CGE 2e, 3c, 4f, 5ae	**Knowledge** **Inquiry** Making Connections	Model of the Atom: Historical development of the Bohr model of hydrogen Compare the principal forms of nuclear decay Standard model of elementary particles Analysis of emission spectra, trajectories of elementary particles, simulations and data collection related to the atom and elementary particles
3	MEV.01, MEV.02, MEV.03, ME1.01, ME1.05, ME1.06, ME2.01, ME2.02 SIS.04, .06, .07, .08 CGE 2e, 3c, 4f, 5ae	**Knowledge** **Inquiry**	Einstein's Theory of Relativity: Law of conservation of mass-energy, mass equivalent Inertial frames of reference, time dilation, length contraction Investigated through thought experiments, and problem solving

Cluster	Learning Expectations	Assessment Categories	Focus/Task
4	MEV.01, MEV.03, ME3.02, ME3.03 SIS.04, .12 CGE 3c, 4f, 7j	**Making Connections**	Applications of Quantum Theory and Special Relativity: Describe the practical applications of these theories (e.g., electron microscopes, lasers) that have benefited society Describe and evaluate the contributions of Canadian physicists

Teaching/Learning Strategies

Since this is a university preparation course, teaching and learning strategies emphasize the theoretical aspects of the course content, but they also include concrete applications. Physics is an activity as much as it is an organized body of knowledge. It cannot be learned in any meaningful way by reading and discussion alone. The experimental nature of physics is emphasized. Theories are developed and then tested through critical experiments to see if the theory is supported or refuted.

An essential expectation of this course requires students to examine, criticize, and refine theoretical models of matter and its behaviour based upon experiment. It is important that students understand that models are human constructs that may be tested according to their predictions and then accepted as a way of understanding matter, or rejected if their predictions cannot be verified by experiment.

Faith implies that one interprets the realities and phenomena of this world as manifestations of the mystery of God, who created and sustains the universe. Writing a reflection paper is a strategy that can help students raise their thoughts to this transcendental reality. The reflection paper can also help students achieve some of the Catholic Graduate Expectations. In writing a Reflection Paper, students should consider a “Learning/Valuing/Acting Model”. “Learning” involves the students reflecting on what they have learned from the course, from reading newspapers, from watching television news shows, or from their own experience about an issue. “Valuing” requires students to reflect on which Catholic values are important in dealing with the issue. “Acting” requires students to decide on a course of action, so that they can take what they value, and to put it into practice using what they have learned.

This model promotes the importance of the need to act appropriately in light of what we know and what we value. In this way, students are constantly challenging themselves about the social teachings of the Church and the importance of every individuals’ actions in working towards the common good. This model should be considered when dealing with issues of environmental stewardship, community, social justice, and the wise use of resources. Whenever this model is suggested as the basis for a reflection, it will be referenced as the “Learning/Valuing/Acting Model.” Another aspect of this reflection paper can focus on the relationship between scientific knowledge and knowledge based on faith. Students recognize that empirical knowledge does not exhaust the boundaries of knowledge and truth. There are “truths” that are unknown to science and cannot be discovered through empirical or scientific means, but can be recognized “when reason is suspended.” (Soren Kierkegaard)

Throughout the course, students are given numerous and varied opportunities to acquire knowledge and to develop skills. Some instructional strategies are more suited to the development of particular types of understanding. Therefore instructional strategies may be placed into categories similar to the categories of learning of the Achievement Charts. Some strategies may be used to develop several types of understanding.

Expectations that require the development of **Knowledge/Understanding** may be developed through:

- Audio-visual presentations – films or videos viewed to illustrate concepts or examples that may be difficult to observe directly;
- Collaborative/Cooperative Learning – various small group learning techniques as constructed by the teacher (e.g., think/pair/share, jigsaw);
- Computer-based Learning – students use simulations and relevant computer programs to explore science problems;
- Concept Maps – students may use various ways of illustrating their understanding of the interrelationships among concepts;
- Equation List – a list of equations used in a particular unit, along with their definition or other explanations of each symbol and its corresponding unit;
- Independent Study – students explore and research a topic of interest;
- Notebook – a student collection of daily work, teacher handouts, and homework attempted and completed;
- Teacher-Directed Lessons and Demonstrations – introductions to key concepts of the course used in all units;
- Vocabulary List – a list of specific physics terminology used in a particular unit, along with their definitions or other explanations of their meanings.

Expectations that involve the development of **Inquiry Skills** may be developed through:

- Case Study - investigation of real and simulated problems provided by the teacher;
- Independent Study - students explore and research a topic of interest;
- Lab-Based Inquiry - students perform investigations in the laboratory under the supervision of the teacher;

Expectations that encourage the development of **Communication** may be developed through:

- Conferencing - teacher to student discussion;
- Concept Maps - a type of graphic organizer that is a diagram that represents how science ideas are related;
- Debate - an organized argument between two points of view about an issue;
- Graffiti Sheets - the free expression of ideas relating to a topic by students on large sheets of paper placed around a room;
- Interviewing - students engage in a conversation or dialogue with a person in order to gain information or insights from the person being interviewed or to give information to a person conducting the interview;
- Lab Book - a notebook or a binder that students use to record their observations of all in-class experiments;
- Report/Presentation - an oral and/or written presentation of a researched topic to the class, perhaps as a poster or a videotaped format.

Expectations that provide opportunities for students to expand their knowledge and to **Make Connections** may be developed through:

- Guest Speaker - an expert is invited from outside the school to present ideas, alternative perspectives, opinions, descriptions of real-life experiences, and answer questions generated by students;
- Journal - personal student reflective writing concerning issues raised in the course (particularly useful in considering issues such as stewardship, justice regarding the fair distribution of natural resources, and the need to invest fairly in developing countries from a Catholic perspective; the “Learning/Valuing/Acting Model” should be used);

- Outreach - students are invited to contact local charitable organizations (St. Vincent de Paul Society, Salvation Army, Scarborough Missions, etc.) and to see if there is a need for used eyeglasses or other technological devices such as computers that may be collected and then donated to those who are less fortunate;
- Reflection Paper - a thoughtful written report by a student attempting to relate the ideas of the course to their Catholic values and beliefs.

Assessment & Evaluation of Student Achievement

Assessment is the process of gathering information from a variety of sources that accurately reflects how well a student is achieving the curriculum expectations. In science these expectations include the Understanding of Basic Concepts which may be assessed for Knowledge and Understanding; the Development of Skills of Inquiry and Communication which may be assessed for Inquiry and Communication; and Relating Science to Technology, Society, and the Environment which may be assessed for Making Connections.
Assessment strategies will include the following:

Paper-and-Pencil Tasks

- quizzes
- tests
- lab reports

Performance Tasks

- student demonstration of science skills
- student interviews
- student-performed experiments

Personal Communication

- short written reports
- journals
- lab reports
- log books
- self-assessment
- student-teacher conferences

Observation

- formal/informal by teacher

Assessment tools include:

- checklists
- marking schemes
- rubrics
- anecdotal comments with suggestions for improvement

Evaluation refers to the process of judging the quality of student work on the basis of established criteria, and then assigning a value to represent that quality. The value assigned will be in the form of a percentage grade. According to *Program Planning and Assessment 2000*, 70% of the student's course grade will be based on the assessments and evaluations conducted throughout the course and 30% will be based upon an examination, performance, essay and/or other method of evaluation suitable to the course content and administered towards the end of the course. The assessment and evaluation in this university preparation science course reflects the course emphasis on theoretical aspects of the content as well as the concrete applications. It is recommended that a final examination should be used as the final evaluation. The Final Examination should be evaluated for all four categories identified in the

Achievement Chart. This examination should contain questions relating to both the theoretical aspects of the course as well as the concrete applications. In order that students may be adequately prepared for the examination, they should have many opportunities to answer questions of the types to be used on the examination over the course of the term.

Accommodations

The teacher must consider the needs of exceptional students in planning the delivery of the science curriculum. Accommodations to the program activities and/or to the learning environment may be necessary. For students with physical or learning impairments, classroom and laboratory activities should be altered to permit as much participation as possible. Where possible, peers should be encouraged to assist students in order to permit participation in some group or individual activities. For assessment it may be necessary to use oral testing, a scribe to record answers given orally, or other demonstrations of learning in order to determine the level of achievement of certain students.

Enrichment possibilities should be considered. Students may be encouraged to read historical articles relating to the development of scientific theories or devices. They may also be encouraged to participate in a science fair, science olympics, or other special event sponsored by colleges or universities that allow them to extend their work beyond the day-to-day and ordinary.

For English as a Second Language (ESL) students or English Literacy Development (ELD) students, the teacher should provide opportunities for students to demonstrate their learning by alternative means (such as spoken English, direct demonstration and pictorial representation) while written English is developing.

Resources

Units in this Course Profile make reference to the use of specific texts, magazines, films, videos, and websites. The teacher needs to consult their board policies regarding use of any copyrighted materials. Before reproducing materials for student use from printed publications, the teacher needs to ensure that their board has a Cancopy licence and that this licence covers the resources they wish to use. Before screening videos/films with their students, the teacher needs to ensure that their board/school has obtained the appropriate public performance videocassette licence from an authorized distributor, e.g., Audio Cine Films Inc. The teacher is reminded that much of the material on the Internet is protected by copyright. The copyright is usually owned by the person or organization that created the work. Reproduction of any work or substantial part of any work on the Internet is not allowed without permission of the owner.

Print

Various approved textbooks that exist for the previous Grade 12 and OAC Physics courses should be consulted in order to determine proper procedures for science skill development as well as background knowledge for students. The teacher should consult *The Ontario Curriculum, Grades 11 and 12, Science 2000* to be sure appropriate activities are pursued.

Science classrooms should also have a Bible available for reference. The teacher should consult the religion department in the school or the school chaplain for the version used by the school. Many schools use the *New American Catholic Bible*, published by Fireside Catholic Bible Publishers, Wichita, Kansas 67201, 1992.

Magazines such as *Physics Today* published monthly by the American Institute of Physics, *The Physics Teacher* published by the American Association of Physics Teachers and *The Crucible* published by the Science Teachers Association of Ontario are sources of current information about physics and the teaching of physics.

Some textbook resources include the following:

Dick, Greg, A. Geddis, E. James, T. McCaul, B. McGuire, R. Poole, B. Holzer. *McGraw-Hill Physics 11.* Toronto: McGraw-Hill Ryerson, 2001. ISBN 0-07-088691-1

Giancoli, D.C. *Physics: Principles with Applications,* 2nd edition. Toronto: Prentice-Hall, 1985. ISBN 0-13-672627-5

Hirsch, Alan J. *Physics for a Modern World.* Toronto: John Wiley and Sons, 1986. ISBN 0-471-79747-2

Hirsch, Alan, D. Martindale, S. Bibla, and C. Stewart. *Nelson Physics 11.* Toronto: Nelson Thomson Learning, 2002. ISBN 0-17-612102-1

Hobson, Art. *Physics: Concepts and Connections,* Second Edition Toronto: Prentice-Hall, 1999. ISBN 0-13-095381-4 (pbk)

Kane, J.W. and M.M. Sternheim. *Physics*, 3rd edition. Toronto: John Wiley and Sons, 1988. ISBN 0-471-85221-X

Martin, B. and C. Sprank. *Physic-AL: An Activity Approach to Physics.* Edmonton: J.M.Lebel Enterprises Ltd, 1989. ISBN 0-920008-30-5

Martindale, D.G. et al. *Fundamentals of Physics: An Introductory Course.* Toronto: D.C.Heath, 1987. ISBN 0-669-95113-7

Martindale, D.G., R.W. Heath, and P.C. Eastman. *Fundamentals of Physics: A Senior Course.* Toronto: D.C.Heath, 1986. ISBN 0-669-95047-5

McFarland, E. L. *Special Relativity: An Introduction.* Guelph: Department of Physics, University of Guelph, 1987. ISBN 0-88955-098-0

Nowikow, Igor and Brian Heimbecker. *Physics: Concepts and Connections.* Toronto: Irwin Publishing, 2001. ISBN 0-7725-2872-1

Spencer, P.T., K.G. McNeill, and J.H. MacLachlan. *Matter and Energy: The Foundation of Modern Physics,* 3rd edition. Toronto: Irwin Publishing, 1987. ISBN 0-7725-1558-1

Wolfe, T.J.E., E. Brown, D. Parker, and F. Mustoe. *Physics Today 1.* Scarborough: Prentice-Hall Canada Inc., 1989. ISBN 0-13-669391-1

Wolfe, T.J.E., E. Brown, and D. Parker. *Addison-Wesley Physics 11.* Toronto: Pearson Education Canada Inc., 2002. ISBN 0-201-70792-6

Various other print resources that teachers may wish to have available are identified in the unit developed in detail. Refer to the introduction to the unit for specific examples.

Videotapes

Beyond the Mechanical Universe series of 26 videos available through Magic Lantern Communications Ltd. (www.magiclantern.ca)

Collisions available through Classroom Video (www.classroomvideo.com)

Energy and Society available through Hawkhill Video (www.hawkhill.com)

Mechanical Universe: Introduction to Physics series of 26 videos available through Magic Lantern Communications Ltd. (www.magiclantern.ca)

Physics Demonstrations in Electricity and Magnetism available through Physics Curriculum and Instruction (www.physicscurriculum.com)

Physics Demonstrations in Light available through Physics Curriculum and Instruction (www.physicscurriculum.com)

Physics Demonstrations in Mechanics available through Physics Curriculum and Instruction (www.physicscurriculum.com)

Physics Demonstrations in Sound and Waves available through Physics Curriculum and Instruction (www.physicscurriculum.com)

Physics Essentials series of 6 videos available through Magic Lantern Communications Ltd. (www.magiclantern.ca)

Physics of Motion available through Classroom Video (www.classroomvideo.com)

Physics-The Basic Science available through Hawkhill Video (www.hawkhill.com)

Physics: What Matters, What Moves series of 6 videos available through Magic Lantern Communications Ltd. (www.magiclantern.ca)

Computer Software

Crocodile Physics - simulations of various physics phenomena available through Spectrum Educational Supplies (www.spectrumed.com)

Data Studio and related probes available through Merlan Scientific (www.merlan.ca)

Interactive Physics 2000 - a modeling and simulation program available from Tangent Scientific (www.tangentscientific.com)

Professor Sanctuary's General Physics - a CD of movies, animations and audio of physics ideas available from Tangent Scientific (www.tangentscientific.com)

Internet sites

The URLs for the websites were verified by the writers prior to publication. Given the frequency with which these designations change, teachers should always verify the websites prior to assigning them for student use.

American Association of Physics Teachers – www.aapt.org

American Physical Society – http://physicscentral.com

Batesville High School (physics) – www.batesville.k12.in.us/physics

BBC Scotland Education Physics Review – www.bbc.co.uk/scotland/revision/physics/energy/

Ben Wiens Energy Science – www.benwiens.com

Catholic Information Network – www.cin.org/

Contemporary College Physics Simulation library – http://webphysics.ph.msstate.edu/jc/library/

Contemporary Physics Education Project – www.cpepweb.org

How Stuff Works – www.howstuffworks.com/sports-physiology.htm

Multimedia Physics Studios – http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html#work

Physical Sciences Resource Center – www.psrc-online.org

Physics Misconception Center Homepage
– http://www.physics.montana.edu/physed/misconceptions/Quarknet – http://quarknet.fnal.gov

Science Joy Wagon – www.sciencejoywagon.com/physicszone/

Science Teachers' Association of Ontario – www.stao.org

String Theory Web Site – www.superstringtheory.com

Students' Alternate Conceptions – http://phys.udallas.edu/C3P/altconcp.html

The Institute of Physics – http://physicsweb.org/resources

The Physics Teacher's Index – http://www.messiah.edu/hpages/facstaff/barrett/phy_ind.htm

Models and Manipulatives

Air tables, air tracks, electrical and magnetic devices, power supplies, voltmeters, ammeters, oscilloscopes, soldering irons, wire strippers, computers, and relevant interfaces along with assorted laboratory equipment.

OSS Considerations

The document *The Ontario Curriculum, Grades 11 and 12: Science 2000* emphasizes the need for scientific literacy for all, defined as "possession of the scientific knowledge, skills, and habits of mind required to thrive in the science-based world..." (p. 3). Although this course is intended to prepare students for the specialist study of physics-related fields, not all students taking the course will do so. The teacher should ensure that all students become scientifically literate.

The document also emphasizes the role of technology in the curriculum. Students should have the opportunity to use air tables, electrical meters, electronic probes, and computers as part of this physics course.

Cooperative education is also identified in the science document as an aspect of science that should be addressed. Students should be encouraged to gain experiences outside of school to help them see the application of the knowledge and skills of the physics course.

The teacher of this course should also refer to *The Ontario Curriculum, Grades 9 to 12, Program Planning and Assessment 2000* in order to be aware of the role of the Achievement Chart in the assessment and evaluation of students. The document also stresses the need for the teacher to "think critically about their methods of instruction and the overall effectiveness of their program." (p. 16)

Coded Expectations, Physics, Grade 12, University Preparation, SPH4U

Scientific Investigation Skills

SIS.01 - demonstrate an understanding of safety practices by selecting, operating, and storing equipment appropriately, and by acting in accordance with the Workplace Hazardous Materials Information System (WHMIS) legislation in selecting and applying appropriate techniques for handling, storing, and disposing of laboratory materials (e.g., wear appropriate protective clothing when handling radioactive substances);

SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., select appropriate instruments, such as stopwatches, photogates, and/or data loggers, when preparing an investigation concerning the law of conservation of energy);

SIS.03 - demonstrate the skills required to design and carry out experiments related to the topics under study, controlling major variables and adapting or extending procedures where required (e.g., design an experiment to determine the relationship between the force applied to a spring and the extension produced);

SIS.04 - locate, select, analyse, and integrate information on topics under study, working independently and as part of a team, and using appropriate library and electronic research tools, including Internet sites;

SIS.05 - compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., analyse the forces acting on an object, using free-body diagrams);

SIS.06 - use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;

SIS.07 - analyse and synthesize information for the purpose of identifying problems for inquiry, and solve the problems using a variety of problem-solving skills;

SIS.08 - select and use appropriate SI units, and apply unit analysis techniques when solving problems;

SIS.09 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation (e.g., algebraic equations, vector diagrams, ray diagrams, graphs, graphing programs, spreadsheets) to communicate scientific ideas, plans, and experimental results;

SIS.10 - communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research papers, and account for discrepancies between theoretical and experimental values with reference to experimental uncertainty;

SIS.11 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;

SIS.12 - identify and describe science- and technology-based careers related to the subject area under study (e.g., mechanical engineer, civil engineer, medical doctor, astronomer, air-traffic controller, nuclear physicist).

Forces and Motion: Dynamics

Overall Expectations

FMV.01 · analyse the motion of objects in horizontal, vertical, and inclined planes, and predict and explain the motion with reference to the forces acting on the objects;

FMV.02 · investigate motion in a plane, through experiments or simulations, and analyse and solve problems involving the forces acting on an object in linear, projectile, and circular motion, with the aid of vectors, graphs, and free-body diagrams;

FMV.03 · analyse ways in which an understanding of the dynamics of motion relates to the development and use of technological devices, including terrestrial and space vehicles, and the enhancement of recreational activities and sports equipment.

Specific Expectations

Understanding Basic Concepts

FM1.01 – define and describe the concepts and units related to dynamics (e.g., inertial and non-inertial frames of reference);

FM1.02 – analyse and predict, in quantitative terms, and explain the linear motion of objects in horizontal, vertical, and inclined planes;

FM1.03 – analyse and predict, in quantitative terms, and explain the motion of a projectile with respect to the horizontal and vertical components of its motion;

FM1.04 – analyse and predict, in quantitative terms, and explain uniform circular motion in the horizontal and vertical planes with reference to the forces involved;

FM1.05 – distinguish between inertial and accelerating (non-inertial) frames of reference, and predict velocity and acceleration in a variety of situations;

FM1.06 – describe Newton's law of universal gravitation, apply it quantitatively, and use it to explain planetary and satellite motion.

Developing Skills of Inquiry and Communication

FM2.01 – analyse experimental data, using vectors, graphs, trigonometry, and the resolution of vectors into perpendicular components, to determine the net force acting on an object and its resulting motion;

FM2.02 – carry out experiments or simulations involving objects moving in two dimensions, and analyse and display the data in an appropriate form (e.g., investigate the motion of objects on a horizontal or inclined plane; or the motion of projectiles);

FM2.03 – predict the motion of an object, and then design and conduct an experiment to test the prediction (e.g., verify predictions for such quantities as the time of flight, range, and maximum height of a projectile);

FM2.04 – investigate, through experimentation, the relationships among centripetal acceleration, radius of orbit, and the period and frequency of an object in uniform circular motion; analyse the relationships in quantitative terms; and display the relationships using a graph.

Relating Science to Technology, Society, and the Environment

FM3.01 – describe, or construct prototypes of, technologies based on the concepts and principles related to projectile and circular motion (e.g., construct a model of an amusement park ride and explain the scientific principles that underlie its design; explain, using scientific concepts and principles, how a centrifuge separates the components of blood);

FM3.02 – analyse the principles of dynamics and describe, with reference to these principles, how the motion of human beings, objects, and vehicles can be modified (e.g., analyse the physics of throwing a baseball; analyse the frictional forces acting on objects and explain how the control of these forces has been used to modify the design of objects such as skis and car tires).

Energy and Momentum

Overall Expectations

EMV.01 · demonstrate an understanding of the concepts of work, energy, momentum, and the laws of conservation of energy and of momentum for objects moving in two dimensions, and explain them in qualitative and quantitative terms;

EMV.02 · investigate the laws of conservation of momentum and of energy (including elastic and inelastic collisions) through experiments or simulations, and analyse and solve problems involving these laws with the aid of vectors, graphs, and free-body diagrams;

EMV.03 · analyse and describe the application of the concepts of energy and momentum to the design and development of a wide range of collision and impact-absorbing devices used in everyday life.

Specific Expectations

Understanding Basic Concepts

EM1.01 – define and describe the concepts and units related to momentum and energy (e.g., momentum, impulse, work-energy theorem, gravitational potential energy, elastic potential energy, thermal energy and its transfer [heat], elastic collision, inelastic collision, open and closed energy systems, simple harmonic motion);

EM1.02 – analyse, with the aid of vector diagrams, the linear momentum of a collection of objects, and apply quantitatively the law of conservation of linear momentum;

EM1.03 – analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat), and the laws of conservation of momentum and of energy;

EM1.04 – distinguish between elastic and inelastic collisions;

EM1.05 – analyse and explain common situations involving work and energy, using the work-energy theorem;

EM1.06 – analyse the factors affecting the motion of isolated celestial objects, and calculate the gravitational potential energy for each system, as required;

EM1.07 – analyse isolated planetary and satellite motion and describe it in terms of the forms of energy and energy transformations that occur (e.g., calculate the energy required to propel a spaceship from the Earth's surface out of the Earth's gravitational field, and describe the energy transformations that take place; calculate the kinetic and gravitational potential energy of a satellite that is in a stable circular orbit around a planet);

EM1.08 – state Hooke's law and analyse it in quantitative terms.

Developing Skills of Inquiry and Communication

EM2.01 – investigate the laws of conservation of momentum and of energy in one and two dimensions by carrying out experiments or simulations and the necessary analytical procedures (e.g., use vector diagrams to determine whether the collisions of pucks on an air table are elastic or inelastic);

EM2.02 – design and conduct an experiment to verify the conservation of energy in a system involving kinetic energy, thermal energy and its transfer (heat), and gravitational and elastic potential energy (e.g., design and conduct an experiment to verify Hooke's law; develop criteria to specify the design, and analyse the effectiveness, through experimentation, of an "egg-drop" container).

Relating Science to Technology, Society, and the Environment

EM3.01 – analyse and describe, using the concepts and laws of energy and of momentum, practical applications of energy transformations and momentum conservation (e.g., analyse and describe the operation of a shock absorber, and outline the energy transformations that take place; analyse and explain, using scientific concepts and principles, the design of protective equipment developed for recreational and sports activities; research and explain the workings of a clock);

EM3.02 – identify and analyse social issues that relate to the development of vehicles (e.g., analyse, using their own or given criteria, the economic and social costs and benefits of the development of safety devices in automobiles).

Electric, Gravitational, and Magnetic Fields

Overall Expectations

EGV.01 · demonstrate an understanding of the concepts, principles, and laws related to electric, gravitational, and magnetic forces and fields, and explain them in qualitative and quantitative terms;

EGV.02 · conduct investigations and analyse and solve problems related to electric, gravitational, and magnetic fields;

EGV.03 · explain the roles of evidence and theories in the development of scientific knowledge related to electric, gravitational, and magnetic fields, and evaluate and describe the social and economic impact of technological developments related to the concept of fields.

Specific Expectations

Understanding Basic Concepts

EG1.01 – define and describe the concepts and units related to electric, gravitational, and magnetic fields (e.g., electric and gravitational potential energy, electric field, gravitational field strength, magnetic field, electromagnetic induction);

EG1.02 – state Coulomb's law and Newton's law of universal gravitation, and analyse and compare them in qualitative terms;

EG1.03 – apply Coulomb's law and Newton's law of universal gravitation quantitatively in specific contexts;

EG1.04 – compare the properties of electric, gravitational, and magnetic fields by describing and illustrating the source and direction of the field in each case;

EG1.05 – apply quantitatively the concept of electric potential energy in a variety of contexts, and compare the characteristics of electric potential energy with those of gravitational potential energy;

EG1.06 – analyse in quantitative terms, and illustrate using field and vector diagrams, the electric field and the electric forces produced by a single point charge, two point charges, and two oppositely charged parallel plates (e.g., analyse, using vector diagrams, the electric force required to balance the gravitational force on an oil drop or on latex spheres between parallel plates);

EG1.07 – describe and explain, in qualitative terms, the electric field that exists inside and on the surface of a charged conductor (e.g., inside and around a coaxial cable);

EG1.08 – predict the forces acting on a moving charge and on a current-carrying conductor in a uniform magnetic field.

Developing Skills of Inquiry and Communication

EG2.01 – determine the net force on, and resulting motion of, objects and charged particles by collecting, analysing, and interpreting quantitative data from experiments or computer simulations involving electric, gravitational, and magnetic fields (e.g., calculate the charge on an electron, using experimentally collected data; conduct an experiment to verify Coulomb's law and analyse discrepancies between theoretical and empirical values);

EG2.02 – analyse and explain the properties of electric fields and demonstrate how an understanding of these properties can be applied to control or alter the electric field around a conductor (e.g., demonstrate how shielding on electronic equipment or on connecting conductors [coaxial cables] affects electric and magnetic fields).

Relating Science to Technology, Society, and the Environment

EG3.01 – explain how the concept of a field developed into a general scientific model, and describe how it affected scientific thinking (e.g., explain how field theory helped scientists understand, on a macro scale, the motion of celestial bodies and, on a micro scale, the motion of particles in electromagnetic fields);

EG3.02 – describe instances where developments in technology resulted in the advancement or revision of scientific theories, and analyse the principles involved in these discoveries and theories (e.g., analyse the operation of particle accelerators, and describe how data obtained through their use led to enhanced scientific models of elementary particles);

EG3.03 – evaluate, using their own criteria, the social and economic impact of new technologies based on a scientific understanding of electric, gravitational, and magnetic fields.

The Wave Nature of Light

Overall Expectations

WAV.01 · demonstrate an understanding of the wave model of electromagnetic radiation, and describe how it explains diffraction patterns, interference, and polarization;

WAV.02 · perform experiments relating the wave model of light and technical applications of electromagnetic radiation (e.g., lasers and fibre optics) to the phenomena of refraction, diffraction, interference, and polarization;

WAV.03 · analyse phenomena involving light and colour, explain them in terms of the wave model of light, and explain how this model provides a basis for developing technological devices.

Specific Expectations

Understanding Basic Concepts

WA1.01 – define and explain the concepts and units related to the wave nature of light (e.g., diffraction, dispersion, wave interference, polarization, electromagnetic radiation, electromagnetic spectrum);

WA1.02 – describe, citing examples, how electromagnetic radiation, as a form of energy, is produced and transmitted, and how it interacts with matter;

WA1.03 – describe the phenomenon of wave interference as it applies to light in qualitative and quantitative terms, using diagrams and sketches;

WA1.04 – describe and explain the phenomenon of wave diffraction as it applies to light in quantitative terms, using diagrams;

WA1.05 – describe and explain the experimental evidence supporting a wave model of light (e.g., describe the scientific principles related to Young's double-slit experiment and explain how his results led to a general acceptance of the wave model of light).

Developing Skills of Inquiry and Communication

WA2.01 – identify the theoretical basis of an investigation, and develop a prediction that is consistent with that theoretical basis (e.g., predict diffraction and interference patterns produced in ripple tanks; predict the diffraction pattern produced when a human hair is passed in front of a laser beam; predict effects related to the polarization of light as it passes through two polarizing filters);

WA2.02 – identify the interference pattern produced by the diffraction of light through narrow slits (single and double slits) and diffraction gratings, and analyse it in qualitative and quantitative terms;

WA2.03 – collect and interpret experimental data in support of a scientific theory (e.g., conduct an experiment to observe the interference pattern produced by a light source shining through a double slit and explain how the data supports the wave theory of light);

WA2.04 – analyse and interpret experimental evidence indicating that light has some characteristics and properties that are similar to those of mechanical waves and sound.

Relating Science to Technology, Society, and the Environment

WA3.01 – describe instances where the development of new technologies resulted in the advancement or revision of scientific theories (e.g., outline the scientific understandings that were made possible through the use of such devices as the electron microscope and interferometers);

WA3.02 – describe and explain the design and operation of technologies related to electromagnetic radiation (e.g., describe the scientific principles that underlie Polaroid filters for enhancing photographic images; describe how information is stored and retrieved using compact discs and laser beams);

WA3.03 – analyse, using the concepts of refraction, diffraction, and wave interference, the separation of light into colours in various phenomena (e.g., the colours produced by thin films), which forms the basis for the design of technological devices (e.g., the grating spectroscope).

Matter-Energy Interface

Overall Expectations

MEV.01 · demonstrate an understanding of the basic concepts of Einstein's special theory of relativity and of the development of models of matter, based on classical and early quantum mechanics, that involve an interface between matter and energy;

MEV.02 · interpret data to support scientific models of matter, and conduct thought experiments as a way of exploring abstract scientific ideas;

MEV.03 · describe how the introduction of new conceptual models and theories can influence and change scientific thought and lead to the development of new technologies.

Specific Expectations

Understanding Basic Concepts

ME1.01 – define and describe the concepts and units related to the present-day understanding of the nature of the atom and elementary particles (e.g., radioactivity, quantum theory, photoelectric effect, matter waves, mass-energy equivalence);

ME1.02 – describe the principal forms of nuclear decay and compare the properties of alpha particles, beta particles, and gamma rays in terms of mass, charge, speed, penetrating power, and ionizing ability;

ME1.03 – describe the photoelectric effect in terms of the quantum energy concept, and outline the experimental evidence that supports a particle model of light;

ME1.04 – describe and explain in qualitative terms the Bohr model of the (hydrogen) atom as a synthesis of classical and early quantum mechanics;

ME1.05 – state Einstein's two postulates for the special theory of relativity and describe related thought experiments (e.g., describe Einstein's thought experiments relating to the constancy of the speed of light in all inertial frames of reference, time dilation, and length contraction);

ME1.06 – apply quantitatively the laws of conservation of mass and energy, using Einstein's mass-energy equivalence;

ME1.07 – describe the Standard Model of elementary particles in terms of the characteristic properties of quarks, leptons, and bosons, and identify the quarks that form familiar particles such as the proton and neutron.

Developing Skills of Inquiry and Communication

ME2.01 – collect and interpret experimental data in support of a scientific theory (e.g., conduct an experiment, or view prepared slides, to analyse how the emission spectrum of hydrogen supports Bohr's predicted transition states in his model of the atom);

ME2.02 – conduct thought experiments as a way of developing an abstract understanding of the physical world (e.g., outline the sequence of thoughts used to predict effects arising from time dilation, length contraction, and increase of mass when an object travels at several different velocities, including those that approach the speed of light);

ME2.03 – analyse images of the trajectories of elementary particles to determine the mass-versus-charge ratio;

ME2.04 – compile, organize, and display data related to the nature of the atom and elementary particles, using appropriate formats and treatments (e.g., using experimental data or simulations, determine and display the half-lives for radioactive decay of isotopes used in carbon dating or in medical treatments).

Relating Science to Technology, Society, and the Environment

ME3.01 – outline the historical development of scientific views and models of matter and energy, from Bohr's model of the hydrogen atom to present-day theories of atomic structure (e.g., construct a concept map of scientific ideas that have been developed since Bohr's model, and outline how these ideas are synthesized in the Standard Model);

ME3.02 – describe how the development of the quantum theory has led to scientific and technological advances that have benefited society (e.g., describe the scientific principles related to, and the function of, lasers, the electron microscope, or solid state electronic components);

ME3.03 – describe examples of Canadian contributions to modern physics (e.g., contributions to science and society made by Bert Brockhouse, Werner Israel, Ian Keith Affleck, Harriet Brooks, Richard Taylor, or William George Unruh).

Ontario Catholic School Graduate Expectations

The graduate is expected to be:

A Discerning Believer Formed in the Catholic Faith Community who

CGE1a -illustrates a basic understanding of the **saving story** of our Christian faith;
CGE1b -participates in the **sacramental life** of the church and demonstrates an understanding of the centrality of the Eucharist to our Catholic story;
CGE1c -actively reflects on **God's Word** as communicated through the Hebrew and Christian scriptures;
CGE1d -develops attitudes and values founded on Catholic **social teaching** and acts to promote social responsibility, human solidarity and the common good;
CGE1e -speaks the **language of life**... "recognizing that life is an unearned gift and that a person entrusted with life does not own it but that one is called to protect and cherish it." (Witnesses to Faith)
CGE1f -seeks intimacy with God and celebrates **communion** with God, others and creation through prayer and worship;
CGE1g -understands that one's purpose or **call in life** comes from God and strives to discern and live out this call throughout life's journey;
CGE1h -respects the **faith traditions**, world religions and the life-journeys **of all people of good will**;
CGE1i -integrates faith with life;
CGE1j -recognizes that "sin, human weakness, conflict and forgiveness are part of the human journey" and that the cross, the ultimate sign of forgiveness is at the heart of **redemption**. (Witnesses to Faith)

An Effective Communicator who
CGE2a -listens actively and critically to understand and learn in light of gospel values;
CGE2b -reads, understands and uses written materials effectively;
CGE2c -presents information and ideas clearly and honestly and with sensitivity to others;
CGE2d -writes and speaks fluently one or both of Canada's official languages;
CGE2e -uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology and information systems to enhance the quality of life.

A Reflective and Creative Thinker who
CGE3a -recognizes there is more grace in our world than sin and that hope is essential in facing all challenges;
CGE3b -creates, adapts, evaluates new ideas in light of the common good;
CGE3c -thinks reflectively and creatively to evaluate situations and solve problems;
CGE3d -makes decisions in light of gospel values with an informed moral conscience;
CGE3e -adopts a holistic approach to life by integrating learning from various subject areas and experience;
CGE3f -examines, evaluates and applies knowledge of interdependent systems (physical, political, ethical, socio-economic and ecological) for the development of a just and compassionate society.

A Self-Directed, Responsible, Life Long Learner who

CGE4a -demonstrates a confident and positive sense of self and respect for the dignity and welfare of others;
CGE4b -demonstrates flexibility and adaptability;
CGE4c -takes initiative and demonstrates Christian leadership;
CGE4d -responds to, manages and constructively influences change in a discerning manner;
CGE4e -sets appropriate goals and priorities in school, work and personal life;
CGE4f -applies effective communication, decision-making, problem-solving, time and resource management skills;
CGE4g -examines and reflects on one's personal values, abilities and aspirations influencing life's choices and opportunities;
CGE4h -participates in leisure and fitness activities for a balanced and healthy lifestyle.

A Collaborative Contributor who

CGE5a -works effectively as an interdependent team member;
CGE5b -thinks critically about the meaning and purpose of work;
CGE5c -develops one's God-given potential and makes a meaningful contribution to society;
CGE5d -finds meaning, dignity, fulfillment and vocation in work which contributes to the common good;
CGE5e -respects the rights, responsibilities and contributions of self and others;
CGE5f -exercises Christian leadership in the achievement of individual and group goals;
CGE5g -achieves excellence, originality, and integrity in one's own work and supports these qualities in the work of others;
CGE5h -applies skills for employability, self-employment and entrepreneurship relative to Christian vocation.

A Caring Family Member who

CGE6a -relates to family members in a loving, compassionate and respectful manner;
CGE6b -recognizes human intimacy and sexuality as God given gifts, to be used as the creator intended;
CGE6c -values and honours the important role of the family in society;
CGE6d -values and nurtures opportunities for family prayer;
CGE6e -ministers to the family, school, parish, and wider community through service.

A Responsible Citizen who

CGE7a -acts morally and legally as a person formed in Catholic traditions;
CGE7b -accepts accountability for one's own actions;
CGE7c -seeks and grants forgiveness;
CGE7d -promotes the sacredness of life;
CGE7e -witnesses Catholic social teaching by promoting equality, democracy, and solidarity for a just, peaceful and compassionate society;
CGE7f -respects and affirms the diversity and interdependence of the world's peoples and cultures;
CGE7g -respects and understands the history, cultural heritage and pluralism of today's contemporary society;
CGE7h -exercises the rights and responsibilities of Canadian citizenship;
CGE7i -respects the environment and uses resources wisely;
CGE7j -contributes to the common good.

Unit 2: Energy and Momentum

Time: 22 hours

Unit Description

Students learn the concepts of work, energy, and momentum, and the laws of energy and momentum for objects moving in two dimensions. They investigate these laws experimentally for both elastic and inelastic collisions, and then solve problems involving these laws using vectors, graphs, and free body diagrams. Students study Hooke's law and analyse it in quantitative terms. They also analyse planetary and satellite motion in terms of energy and energy transformations. As a conclusion, students investigate the economic and social costs and benefits of various types of protective equipment and safety devices used in the world around them.

Unit Synopsis Chart

Since each activity includes a cluster of expectations, various Achievement Chart categories may be assessed; however, one or more areas tend to have a greater emphasis. These categories have been indicated in bold type to clarify to the teacher which category should be weighted more heavily.

Activity	Time	Learning Expectations	Assessment Categories	Tasks
1. Energy Concepts 1.1 Diagnostic Concept Map 1.2 Problems and Qualitative Simulation Analysis 1.3 Hooke's Law Experiment	5 hours	EMV.01, EM1.01, EM1.03, EM1.05, EM1.08, EM2.02 SIS.04, .06, .07, .08, .09, .10, .11 CGE 2d, 3c, 4f, 5ae	**Knowledge** Inquiry Making Connections	- Brainstorming - Concept mapping - Present simulations - Problem solving - Analysis of problems
2. Energy Transformations 2.1 Energy Transformation and Conservation 2.2 Work-Energy Theorem 2.3 Analysis of Video Clips	4 hours	EMV.01, EM1.01, EM1.03, EM1.05 SIS.05, .06, .07, .08, .09, .11, .12 CGE 2c, 3c, 4f, 5ae	**Knowledge** Inquiry Communication Making Connections	- Analysis of issue - Class discussion - Problem solving - Teacher-directed lesson - View video clips - Analysis of video clip
3. Conservation of Momentum and Energy 3.1 Momentum and Impulse 3.2 Conservation of Momentum in One Dimension 3.3 Conservation of Momentum in Two Dimensions 3.4 An Investigation of Momentum and Energy Conservation	4 hours	EMV.01, EMV.02, EM1.01, EM1.02, EM1.03, EM1.04, EM1.05, EM2.01, EM2.02 SIS.01, .02, .03, .05, .06, .07, .08, .09, .10, .11 CGE 2c, 3c, 4f, 5ae	**Knowledge** **Inquiry** Communication	- Teacher-directed lesson - Mathematical problem solving - Computer simulations - Student designed experiments

Activity	Time	Learning Expectations	Assessment Categories	Tasks
4. Energy and Satellite Motion	3 hours	EMV.01, EM1.03, EM1.06, EM1.07 SIS .04, .06, .07 CGE 2c, 4f	**Knowledge** Inquiry	- Teacher-directed lesson - Student problem solving - Computer simulation of satellite motion
5. Energy and Protective Equipment and Devices in Automobile Safety	6 hours	EMV.03, EM1.03, EM1.05, EM3.01, EM3.02 SIS. 03, .04, .10, .12 CGE 2de, 3bcef, 4f, 5ade, 7hj	**Knowledge** **Inquiry** **Communication** **Making Connections**	- Criteria development - Brainstorming - Investigation of issues - Independent study - Tracking sheet - Presentations

Activity 1: Energy Concepts

Time: 5 hours

Description

Students review kinetic, gravitational potential, and thermal energy, and are introduced to spring energy. Students require a detailed understanding of these energy concepts as a basis for conservation of energy and momentum. Students brainstorm using various resources to review energy concepts and create a detailed concept map to include all information. The concept maps are used as a diagnostic assessment of their understanding. Based on this task the teacher can introduce or reinforce concepts as necessary. The energy concepts are further reinforced by completing problems and data analysis. A qualitative analysis of energy and its transformations can be provided from Internet simulations, freeze frame photography, or direct experimentation. Hooke's Law and the conservation of energy are introduced, and students design a laboratory investigation to experimentally verify Hooke's Law.

Strand(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE2d - writes and speaks fluently in one or both of Canada's official languages;
CGE3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE4f - applies effective communication, decision-making, problem-solving, time and resource management skills;
CGE5a - works effectively as an interdependent team member;
CGE5e - respects the rights, responsibilities, and contributions of self and others.

Strand(s): Energy and Momentum

Overall Expectations

EMV.01 - demonstrate an understanding of the concepts of work, energy, momentum, and the laws of conservation of energy and of momentum for objects moving in two dimensions, and explain them in qualitative and quantitative terms.

Specific Expectations

EM1.01 - define and describe the concepts and units related to momentum and energy;
EM1.03 - analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat) and the laws of conservation of momentum and of energy;
EM1.05 - analyse and explain common situations involving work and energy, using the work - energy theorem;

EM1.08 - state Hooke's Law and analyse it in quantitative terms;
EM2.02 - design and conduct and experiment to verify the conservation of energy in a system involving kinetic energy, thermal energy and its transfer (heat), and gravitational and elastic potential energy.

Scientific Investigation Skills
SIS.04 - locate, select, analyse, and integrate information on topics under study, working independently and as a part of a team, and using appropriate library and electronic research tools, including Internet sites;
SIS.06 - use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;
SIS.07 - analyse and synthesize information for the purpose of identifying problems for inquiry, and solve the problems using a variety of problem-solving skills;
SIS.08 - select and use appropriate S.I. units, and apply unit analysis techniques when solving problems;
SIS.09 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate scientific ideas, plans, and experimental results;
SIS.10 - communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research papers, and account for discrepancies between theoretical and experimental values with reference to experimental uncertainty;
SIS.11 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures.

Prior Knowledge & Skills

Grade 11 University Physics: Energy, Work and Power – concepts of gravitational potential energy, kinetic energy, thermal energy, skills of qualitative and quantitative analysis

Planning Notes

- The teacher may begin this activity with an invitation to students to raise their thoughts to the concept of God as the source of all energy, both material and spiritual. Students are encouraged to identify and paraphrase the message of one of the psalms that recognizes God in the grandeur and power of natural phenomena.
- All expectations for this unit are met by the activities in the profile. However, to complete these activities in an appropriate time requires adherence to the timelines outlined in this profile.
- Students are provided with various resources (Internet access, textbooks, periodicals) that include information regarding kinetic, potential, gravitational potential, thermal energy, and Hooke's Law.
- Students are provided with chart paper, markers, etc., to produce energy concept maps.
- Students should be aware of the roles required in small group learning (leader, recorder, facilitator, etc.).
- The teacher should create an example of a concept map to show the requirements (concept maps should include definitions, examples, equations, units required, and detailed descriptions of the connections between concepts).
- Students are provided with a peer assessment rubric for participation.
- The teacher should develop a checklist for the information to be included on the concept map in order to identify areas of weakness that need to be addressed in Activity 1.2.
- Students are provided with numerical questions to complete.
- Students are provided with data to analyse (applets, video, photographs, experimental data).
- The teacher may post the concept maps in the classroom as a source of reference throughout the unit.

Teaching/Learning Strategies

Activity 1.1: Diagnostic Concept Map

The teacher:

- provides all students access to resource materials for the preparation of the concept map;
- provides material for concept maps;
- reviews the requirements for a detailed concept map by providing an example;
- places the students in groups of varying strengths;
- ensures that all members of the group participate through a peer assessment and the teacher's anecdotal comments;
- assesses the concept maps and provides anecdotal feedback on areas of strength and weakness;
- posts concept maps in the classroom to reinforce information and may be added to as students acquire further information.

Students:

- use the information to create a detailed concept map exploring the concepts of kinetic, potential, gravitational potential, thermal, and spring energy, and Hooke's Law;
- ensure that all group members participate during the activity;
- complete the peer assessment.

Activity 1.2: Reinforcing Energy Concepts using Problems and Qualitative Simulation Analysis

The teacher:

- assesses the concept maps to determine the areas that require reinforcement using the checklist;
- provides a teacher-directed lesson to reinforce areas of weakness;
- provides questions (quantitative and qualitative) to reinforce concepts;
- introduces and discusses video clips/applets to provide an introduction to data analysis that occurs in Activity 2;
- reviews the equations for kinetic, potential, gravitational potential, and thermal energy as presented in SPH3U;
- reviews the concept of the conservation of energy;
- may have students design and perform a simple activity involving conservation of energy;
- provides solutions to the problems assigned.

Students:

- improve concept maps based on the teacher's feedback;
- complete and correct the assigned questions;
- follow and participate in a discussion of the video clips/applets;
- complete the activity involving conservation of energy.

Activity 1.3: Design an experiment about Hooke's Law

The teacher:

- reinforces the concept of spring energy and Hooke's Law;
- provides access to resources (Internet, textbooks, periodicals) with information regarding Hooke's Law;
- provides an example of an experiment that illustrates Hooke's Law;
- provides a detailed rubric or marking scheme for the evaluation of this experiment;
- checks students' laboratory procedures for safety before allowing students to carry out the procedure.

Students:

- review spring energy and Hooke's Law information;
- use the resources provided to develop a laboratory procedure, including safety precautions, that tests Hooke's Law and develops the Hooke's Law equation effectively from the data collected;
- test their procedure to ensure that the investigation obeys Hooke's Law;
- submit a detailed procedure, work cited and sample data for evaluation.

Assessment & Evaluation of Student Achievement

- Concept maps are diagnostic assessments for the teacher used to demonstrate areas that require reinforcement. A checklist (Appendix A) may be used to assess student performance in this task (EMV.01, EM1.01, EM1.08, SIS.04).
- Students can be assessed for knowledge and understanding and problem-solving skills by a paper-and-pencil quiz based on the questions assigned (EMV.01, EM1.01, EM1.05, EM1.08, SIS.06, .07, .08).
- Hooke's Law laboratory design can be assessed by a detailed rubric emphasizing the procedure developed, the sample data and the work cited (EMV.01, EM1.01, EM1.03, EM1.05, EM1.08, SIS.04, .06, .07, .08, .09, .10, .11).

Resources

Print

Giancoli, D.C. *Physics: Principles with Applications,* 2nd edition. Toronto: Prentice-Hall, 1985. ISBN 0-13-672627-5

Hirsch, Alan J. *Physics for a Modern World.* Toronto: John Wiley and Sons, 1986. ISBN 0-471-79747-2

Hobson, Art. *Physics: Concepts and Connections,* Second Edition. New Jersey: Prentice Hall, 1999. ISBN 0-13-095381-4

Kane, J.W. and M.M. Sternheim. *Physics,* 3rd edition. Toronto: John Wiley and Sons, 1988. ISBN 0-471-85221-X

Martindale, D.G. et al. *Fundamentals of Physics: An Introductory Course.* Toronto: D.C. Heath, 1987. ISBN 0-669-95113-7

Martindale, D.G. et al. *Fundamentals of Physics: A Senior Course.* Toronto: D.C. Heath, 1986. ISBN 0-669-95047-5

New American Catholic Bible. Wichita, Kansas: Catholic Bible Publishers, 1992.

Serway, Raymond, A. and Jerry S. Faughn. *College Physics.* Fort Worth: Saunders College Publishing, 1995. ISBN 0-03-003562-7

Serway, Raymond, A. *Physics for Scientists and Engineers with Modern Physics,* 4th Edition. Philadelphia: Sauders College Publishing, 1996. ISBN 0-03-015654-8

Spencer, P.T., K.G. McNeill, and J.H. MacLachlan. *Matter and Energy: The Foundation of Modern Physics,* 3rd edition. Toronto: Irwin Publishing, 1987. ISBN 0-7725-1558-1

Sternheim, Morton, M. and Joseph W. Kane. *General Physics.* New York: John Wiley and Sons, 1986. ISBN 0-471-92915-3

Wolfe, T.J.E., E. Brown, D. Parker, and F. Mustoe. *Physics Today 1.* Scarborough: Prentice-Hall Canada Inc., 1989. ISBN 0-13-669391-1

Zitzewitz, P. et al. *Merrill Physics: Principles and Problems.* New York: Glencoe/McGraw-Hill, 1995. ISBN 0-02-826721-4

Websites
Amercian Association of Physics Teachers – www.aapt.org
American Institute of Physics – www.aip.org/
Batesville High School (physics) – www.batesville.k12.in.us/physics
BBC Scotland Education Physics Review – www.bbc.co.uk/scotland/revision/physics/energy/
Ben Wiens Energy Science – www.benwiens.com
Contemporary College Physics Simulation library – http://webphysics.ph.msstate.edu/jc/library/
Glenbrook High School (physics) – www.glenbrook.k12.il.us/
How things work – www.howthingswork.virginia.edu
Hypertextbook(physics) – http://hypertextbook.com/physics/
Mind Net's Zona Land More Science than Math – http://id.mind.net/~zona/
Physics Classroom (Multimedia Physics Studio) – www.physicsclassroom.com/
Physics Central (Ask Lou Bloomfield) – www.physicscentral.com/
Physics Web (free downloads test question,simulations, labs) – www.physicsweb.com
Scientific American Ask the expert – http://www/sciam.com/askexpert/physics/index.html
Science Joy Wagon (conservation of energy lessons) – www.sciencejoywagon.com/physicszone/
Students' Alternate Conceptions – http://phys.udallas.edu/C3P/altconcp.html
The Physics of Everyday Stuff – www.bsharp.org/physics/stuff.swings.html
The Physics Teacher's Index – http://www.messiah.edu/
Thinkquest (conservation of energy) – http://library.thinkquest.org/

Online Videos and Simulations
American Institute of Physics (physics news simulations) – www.aip.org/physnews/graphics/date.html
NTNV Virtual Physics Library – http://phy.ntnu.edu.tw/java
Many other videos and simulations that relate to car collisions are listed at the end of Activity 5.

Appendices
Appendix A – Checklist for assessing Concept Map

Activity 2: Energy Transformations (Work-Energy Theorem)
Time: 4 hours

Description
In the following activity, students classify energy systems as open or closed, and analyse energy transformations using the work energy theorem. Demonstrations, group work and classroom discussions are used to develop the concepts and problem-solving skills. Students quantitatively describe energy transformations on the video clips used in Activity 1.

Strands & Learning Expectations
Ontario Catholic School Graduate Expectations
CGE 2c - presents information and ideas clearly and honestly and with sensitivity to others;
CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE 4f - applies effective communication, decision-making, problem-solving, time and resource management skills;
CGE 5a - works effectively as an interdependent team member;
CGE 5e - respects the rights and responsibilities and contributions of self and others.

Stand(s): Energy and Momentum

Overall Expectations

EMV.01 - demonstrate an understanding of the concepts of work, energy, momentum, and the laws of conservation of energy and of momentum for objects moving in two dimensions, and explain them in qualitative and quantitative terms.

Specific Expectations

EM1.01 - define and describe the concepts and units related to momentum and energy;
EM1.03 - analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat), and the laws of conservation of momentum and of energy;
EM1.05 - analyse and explain common situations involving work and energy using the work-energy theorem.

Scientific Investigation Skills

SIS.05 - compile, organize, and interpret data, using appropriate formats and treatments, including tables, flow charts, graphs, and diagrams (e.g., analyse the forces acting on an object, using free-body diagrams;
SIS.06 - use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;
SIS.07 - analyse and synthesize information for the purpose of identifying problems for inquiry, and solve the problems using a variety of problem-solving skills;
SIS.08 - select and use appropriate SI units and apply unit analysis techniques when solving problems;
SIS.09 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation (e.g., algebraic equations, vector diagrams, ray diagrams, graphs, graphing programs, spreadsheets) to communicate scientific ideas, plans, and experimental results;
SIS.11 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures;
SIS.12 - identify and describe science-and technology-based careers related to the subject area under study.

Planning Notes

- Prepare a demonstration and real-life examples of energy transformations. Identify possible misconceptions. For example, students often think that the speed of falling objects is proportional to height rather than time, e.g., students think falling objects dropped from a height (h) will travel at one half their maximum speed at a height h/2 above the ground.
- Review specific video clips and complete a sample simulation worksheet.

Prior Knowledge & Skills

Grade 11 University Physics - Energy, Work and Power (energy transformations)

Teaching/Learning Strategies

Activity 2.1: Energy Transformations and Conservation

The teacher:

- reviews the concept of energy transformation through a demonstration (for example a ball dropped from a height);
- reviews the types of energy discussed in Activity 1.1 (e.g., kinetic energy, gravitational potential energy, thermal energy);
- reviews the concept of total energy through the demonstration;
- divides the students into small groups and provides each group with a real-life example of an energy transformation to be analysed on the basis of energy types before, after, and during the transformation (for example, a car rolling down a hill, a pendulum swinging);

- ensures that a representative from each group presents the analysis to the class;
- leads a discussion on the results of the analyses and presents the students with the law of energy conservation;
- provides a variety of worked examples of the law of energy conservation applied to simple situations, for example, a roller coaster problem;
- outlines a common approach to problem solving using conservation of energy;
- leads a discussion comparing energy consumption per capita in countries with modern technologies to that of developing countries. Asks questions such as the following: 1) What will happen to the per capita energy consumption in developing countries as modern technologies become more wide spread? 2) How will these countries deal with the energy needs of modern technologies? 3) What will be the overall effect on the quality of life for the populations of these countries of introducing new technologies?;
- presents a specific example of a nation that has developed energy resources to meet the needs of their populations and the effect this has had on the people in the area (for example Belize or China).

Students:

- discuss within their groups the example presented to them on the basis of energy transformations;
- choose a student to present the analysis to the class;
- analyse with their groups the example on the basis of total energy;
- apply the law of energy conservation to worked examples and problems presented;
- research the impact on populations in developing countries of introducing new technologies and increasing the energy needed per person;
- produce a brief reflection paper on the moral ramifications of developing new energy sources in order to introduce new technology. Answer the question, “Who benefits and who suffers from these changes?”

Activity 2.2: Open and Closed Energy Systems (Work-Energy Theorem)

The teacher:

- introduces examples of energy transformations where the total mechanical energy is not constant, e.g., a swing that is being pushed;
- reviews the equation for work and the concept that a force can do work on an object or system;
- introduces the concept of open and closed energy systems;
- divides the students into groups and has each group analyse a different energy system. The analysis should be based on the following criteria: a calculation of the total energy before and after the energy transformation; the identification of any external forces that do work on the system; whether the work done by the external force increases or decreases the total energy of the system; and the classification of the energy system as open or closed;
- conferences with the groups to insure the analysis is being carried out based on the above criteria;
- leads a discussion on the results of the analysis and presents the students with the work-energy theorem;
- provides a variety of worked examples of the work-energy theorem applied to simple situations, e.g., a car being pushed up a hill;
- outlines a common approach to problem solving using the work-energy theorem.

Students:
- apply the mathematical relationships for total mechanical energy and work done by external forces through worked examples and other problems;
- analyse in groups an energy transformation in a system on the basis of the above criteria and classify the system as open or closed;
- participate in a classroom discussion of the results of their analysis;
- apply the work-energy theorem to worked examples and problems presented.

Activity 2.3: Work-Energy Theorem (Analysis of Video Clips)

The teacher:
- reviews the concepts of work, energy, conservation of energy and the work-energy theorem;
- provides access to a video clip for each student;
- presents a sample analysis of a video clip used in Activity 1 using the work-energy theorem; (this analysis will depend on the video clip used, e.g., the speed of a roller coaster could be determined as it travels down a hill);
- outlines the specific expectations of a rating scale for the analysis of each video clip on a work sheet;
- conferences with students regarding appropriate application of the work-energy theorem.

Students:
- apply the work-energy theorem to a specific energy transformation in a video clip;
- submit a worksheet for the analysis of the video clip.

Assessment & Evaluation of Student Achievement
- Individual student's analysis of the video is assessed for Knowledge/Understanding (EM1.01, 1.03, 1.05) using a rating scale.
- Individual problem-solving skills could be assessed for Knowledge/Understanding (EM1.01, 1.03, 1.05) using a paper-and-pencil quiz.

Resources
See Resources for Activity 1 for print and website resources as well as videoclip sources.

Cunningham, L.S. *The Catholic Heritage.* Crossroads, 1983.

Appendices
Appendix B – Sample Computer Simulation Work Sheet

Activity 3: Conservation of Momentum and Energy
Time: 4 hours

Description
In the following activity, students are introduced to the concepts of impulse, momentum and the conservation of momentum. Demonstrations, group work, and classroom discussions are used to develop concepts and problem-solving skills. The students design and perform an experiment to test the conservation of momentum and the work-energy theorem.

Strands & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE 2c - presents information and ideas clearly and honestly and with sensitivity to others;
CGE 3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE 4f - applies effective communication, decision-making, problem-solving, time and resource management skills;
CGE 5a - works effectively as an interdependent team member;
CGE 5e - respects the rights and responsibilities and contributions of self and others.

Strand(s): Energy and Momentum

Overall Expectations

EMV.01 - demonstrate an understanding of the concepts of work, energy, momentum, and the laws of conservation of energy, and of momentum for objects moving in two dimensions, and explain them in qualitative and quantitative terms;
EMV.02 - investigate the laws of conservation of momentum and of energy (including elastic and inelastic collisions) through experiments or simulations and analyse and solve problems involving these laws with the aid of vectors, graphs, and free body diagrams.

Specific Expectations

EM1.01 - define and describe the concepts and units related to momentum and energy;
EM1.02 - analyse, with the aid of vector diagrams, the linear momentum of a collection of objects and apply quantitatively the law of conservation of linear momentum;
EM1.03 - analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat), and the laws of conservation of momentum and of energy;
EM1.04 - distinguish between elastic and inelastic collisions;
EM1.05 - analyse and explain common situations involving work and energy using the work-energy theorem;
EM2.01 - investigate the laws of conservation of momentum and of energy in one and two dimensions by carrying out experiments or simulations and the necessary analytical procedures (e.g., use vector diagrams to determine whether the collisions of pucks on an air table are elastic or inelastic);
EM2.02 - design and conduct an experiment to verify the conservation of energy in a system involving kinetic energy, thermal energy and its transfer (heat), and gravitational and elastic potential energy (e.g., design and conduct an experiment to verify Hooke’s law; develop criteria to specify the design, and analyse the effectiveness, through experimentation, of an “egg-drop” container).

Scientific Investigation Skills

SIS.01 - demonstrate an understanding of safety practices by selecting, operating, and storing equipment appropriately and by acting in accordance with the Workplace Hazardous Materials Information System (WHMIS) legislation in selecting and applying techniques for handling, storing, and disposing of laboratory materials;
SIS.02 - select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., collect data accurately using stopwatches, photo gates, and/or data loggers when preparing an investigation concerning the law of conservation of energy);
SIS.03 - demonstrate the skills required to design and carry out experiments related to the topics under study, controlling major variables and adapting or extending procedures where required;
SIS.05 - compile, organize, and interpret data, using appropriate formats and treatments including tables, flow charts, graphs, and diagrams;
SIS.06 - use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;
SIS.07 - analyse and synthesize information for the purpose of identifying problems for inquiry and solve the problems using a variety of problem-solving skills;

SIS.08 - select and use appropriate SI units and apply unit analysis techniques when solving problems;
SIS.09 - select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation (e.g., algebraic equations, vector diagrams, ray diagrams, graphs, graphing programs, spreadsheets) to communicate scientific ideas, plans, and experimental results;
SIS.10 - communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research papers and account for discrepancies between theoretical and experimental values with reference to experimental uncertainty;
SIS.11 - express the result of any calculation involving experimental data to the appropriate number of decimal places or significant figures.

Planning Notes

- Select examples that illustrate momentum, impulse, and the conservation of momentum.
- Locate and test software to perform simulations of collisions in one and two dimensions.
- Have a variety and inventory of materials present and in working order that could be applied to the investigation (examples of these type of materials are ramps, air tracks, air table apparatus gliders, objects to roll or slide down the ramps, pendulum bobs, masses, springs, and pulleys).
- Ensure that measuring devices and recording timers, photo gates, or stop watches are available and in working order.
- Ensure that graphing calculators and calculator-based ranger (CBR) or calculator-based laboratory (CBL) motion detectors are available and in working order.
- Recognize that students often do not realize that momentum is a vector. They often think that conservation of momentum applies only to collisions and that momentum is not conserved in collisions with immovable objects.

Prior Knowledge & Skills

- Grade 12 University Physics Forces and Motion: Dynamics unit - The analysis of vector quantities
- Grade 11 and 12 University Physics Forces and Motion unit - Newton’s laws

Teaching/Learning Strategies

Activity 3.1: Momentum and Impulse

The teacher:

- introduces the concept and equation(s) for momentum through examples;
- provides a variety of sample calculations using the equation(s) for momentum;
- reviews Newton’s first law and asks students to consider how the momentum of an object might be changed;
- reviews Newton’s second law;
- derives the mathematical relationship for impulse using Newton’s second law;
- demonstrates a calculation of impulse using a force vs. time graph;
- provides a variety of worked examples using the relationship for impulse;
- outlines a common approach to problem solving using change of momentum and impulse.

Students:

- apply the mathematical relationships for momentum and impulse to worked examples and problems presented.

Activity 3.2: Conservation of Momentum (One Dimension)

The teacher:

- reviews Newton's third law;
- through a demonstration of a simple one dimensional collision, shows how action-reaction forces determine the final velocity of the objects after the collision;
- introduces the concept of the law of conservation of momentum by applying Newton's third law to a collision;
- provides a variety of worked examples using the law for conservation of momentum in one dimension;
- divides the students into groups and has each group analyse a different one dimensional collision; the analysis should use the conservation of momentum to determine the final or initial conditions of the objects involved in the collision;
- leads a discussion of each group's results;
- outlines a common approach to problem solving using the law of conservation of momentum.

Students:

- analyse, in groups, a collision through the law of momentum conservation;
- apply the mathematical relationship for conservation of momentum to worked examples and problems presented.

Activity 3.3: Conservation of Momentum in Two Dimensions (Simulations)

The teacher:

- reviews the resolution of a vector quantity into components;
- provides an example of a system of objects that has momentum in two dimensions;
- introduces the vector nature of the Law of Conservation of Momentum as it applies to a two-dimensional system;
- provides a variety of worked examples using the relationship for conservation of momentum in two-dimensions;
- demonstrates the use of a computer simulation to find the momentum before and after a two-dimensional collision;
- provides access to a simulation program and assigns each student a two-dimensional collision to analyse with the simulation;
- outlines the expectations of a collision simulation report to be submitted by students. The report should include calculations of momentum before and after the collision in two dimensions.

Students:

- apply the mathematical relationship for conservation of momentum in two dimensions to worked examples and problems presented;
- simulate and analyse a two-dimensional collision;
- submit a report of their analysis for assessment.

Activity 3.4: An Investigation of Momentum and Energy Conservation

The teacher:

- reviews the concepts of conservation of momentum, conservation of energy, and elastic collisions;
- outlines a method for the design of an experiment that investigates the conservation of momentum, the conservation of energy, and the transfer of energy to heat;
- reviews appropriate and safe use of the equipment available and experimental techniques used for the measurement of variables needed for the analysis;
- reviews the analysis of uncertainty in measurement and calculations;
- provides a list of equipment that is made available to the students;

- divides the students into small groups to design an experiment that will allow them to measure conservation of momentum, energy conservation, and the transfer of energy to heat;
- conferences with the groups to assess their plans and ensures the design will accomplish the expectations;
- supplies each group with the equipment requested;
- ensures students are aware of and follow procedures for the safe and correct use of the equipment;
- meets with each group while they are conducting their experiment to answer questions regarding the operation of equipment and the recording of data;
- reviews the criteria for a lab report with students and outlines the specific criteria for this report.

Students:

- contribute to a group design of an experiment to measure conservation of momentum, conservation of energy and the transfer of energy to heat;
- modify plans and refine the design if needed after conference with the teacher;
- submit a design for the experiment to be assessed in their logbooks;
- perform the experiment, measure the variables needed for the analysis;
- analyse the results of the experiment;
- complete a lab report and submit for evaluation.

Assessment & Evaluation of Student Achievement

- Individual student lab work can be assessed for Inquiry (SIS.01, .03) using a laboratory-skills checklist.
- Group lab design can be assessed for Inquiry (SIS.02, .03 EM2.02) using a laboratory-design checklist.
- Individual student's lab report is assessed for Communication and Inquiry (SIS.10, .11, EM1.02, 1.03, 2.01, 2.02) using a lab report rubric.
- Individual student's collision analysis report is assessed for Communication and Making Connections (SIS.07, EM1.02, 1.04) using a checklist.
- Individual problem-solving skills could be assessed for Knowledge/Understanding and Inquiry (EM1.01, 1.02, 1.03, 1.04 .1.05) using a paper-and-pencil quiz.
- Group one dimensional collision analysis could be assessed by peers for Inquiry and Communication (SIS.05, EM2.01) using a checklist.

Resources

See Resources for Activity 1 for print and website resources as well as videoclip sources.

Activity 4: Energy and Satellite Motion

Time: 3 hours

Description

Students are made aware of the general relationship involved in Gravitational Potential Energy using Newton's Universal Law of Gravity. They apply this relationship to determine the energy required to propel a spacecraft from the Earth's surface to a point out of the Earth's gravitational field (commonly called the binding energy).

Strands & Learning Expectations

Ontario Catholic School Graduate Expectations
CGE 2c - presents information and ideas clearly and honestly and with sensitivity to others;
CGE 4f - applies effective communication, decision-making, problem-solving, time and resource management skills.

Strand(s): Energy and Momentum

Overall Expectations
EMV.01 - demonstrate an understanding of the concepts of work, energy, momentum, and the laws of conservation of energy and of momentum for objects moving in two dimensions, and explain them in qualitative and quantitative terms.

Specific Expectations
EM1.03 - analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat), and the laws of conservation of momentum and energy;
EM1.06 - analyse the factors affecting the motion of isolated celestial objects and calculate the gravitational potential energy for each system, as required;
EM1.07 - analyse isolated planetary and satellite motion and describe it in terms of the forms of energy and energy transformations that occur (e.g., calculate the energy required to propel a spaceship from the Earth's surface out of the Earth's gravitational field and describe the energy transformations that take place; calculate the kinetic and gravitational potential energy of a satellite that is in a stable circular orbit around a planet).

Scientific Investigation Skills
SIS.04 - locate, select, analyse, and integrate information on topics under study, working independently and as a part of a team, and using appropriate library and electronic research tools, including Internet sites;
SIS.06 - use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena;
SIS.07 - analyse and synthesize information for the purpose of identifying problems for inquiry and solve the problems using a variety of problem-solving skills.

Prior Knowledge & Skills

- Grade 9 SNC1D The Study of the Universe - the concept of planetary and satellite motion
- Grade 11 SPH3U Energy, Work, and Power - concept of gravitational potential energy
- Grade 12 SPH4U Force and Motion: Dynamics - concept of centripetal force and uniform circular motion

Planning Notes

- Review the unit on Force and Motion studied earlier in order that students may have background knowledge about planetary motion and the forces involved.
- Book either a computer lab or library/resource centre with Internet access in order that students may view simulations about circular motion (if they haven't already done so as part of the previous unit).
- Identify possible misconceptions, such as that there is no gravitational force in space or that it is the Earth's spinning that causes gravity.

Teaching/Learning Strategies

The teacher:

- prepares a lesson reviewing the idea of gravitational potential energy near the Earth's surface and then extends the idea to space using the universal law of gravity;
- illustrates the derivation of the general equation for the gravitational potential energy in general in space using Newton's Universal Law of Gravity in order to show the application of mathematical models to the behaviour of a natural phenomenon;
- applies the concept of total mechanical energy as the combination of potential and kinetic energy to a satellite in orbit in order to show that the total energy of a satellite in orbit is a negative number and therefore "bound" to the planet that it is orbiting;
- defines the concept of the "binding energy" of a satellite as the additional kinetic energy that a satellite would need to escape the orbit of a planet;
- provides an opportunity for students to view a simulation of a satellite in orbit either by providing them with an appropriate computer simulation or allowing them to view an appropriate Internet site.

Students:

- solve various sample problems relating to objects in orbit around a planet;
- view simulations of satellites in orbit and determine binding energy of a satellite by adding additional kinetic energy to the satellite in order to free it of the planet's gravitational field.

Assessment & Evaluation of Student Achievement

Students knowledge and understanding of the energy concepts involved in satellites in orbit can be evaluated by means of a pencil-and-paper quiz (EM1.06, EM1.07)

Accommodations

Possible enrichment activities:

- research the energy required to put the International Space Station components into orbit;
- research the energy required to place a satellite into orbit around Mars or another planet;
- research the binding energy of a planet relative to the sun;
- ask students who have taken calculus in mathematics to use the concept of integration in order to derive the equations for gravitational potential energy in general using Newton's Universal Law of Gravity;
- students may learn about the ancient practice of studying the stars and the planets in an attempt to understand important events in human history. An example of this can be found in the Gospel of Matthew Ch.2: 1-12. The word "contemplation" comes from the joining of two words, con and templum. Templum refers to a slice of the sky that was focussed on by the ancient seer for the purpose of taking auspices and interpreting the actions of "supernatural beings."

Resources

See Resources for Activity 1 for print and website resources as well as videoclip sources.

Activity 5: Energy and Protective Equipment and Devices in Automobile Safety

Time: 6 hours

Description

In these activities, students examine all the aspects involved in the development of safety devices in automobiles from a moral perspective inspired by Gospel values and Church teachings. These aspects include: scientific benefit, economic and social impact and costs, benefits to society, testing of the devices, cost of development, and the process involved from development to having a safety device made mandatory.

Strands(s) & Learning Expectations

Ontario Catholic School Graduate Expectations

CGE2d - writes and speaks fluently in one or both of Canada's official languages;
CGE2e - uses and integrates the Catholic faith tradition, in the critical analysis of the arts, media, technology, and information systems to enhance the quality of life;
CGE3b - creates, adapts, and evaluates new ideas in light of the common good;
CGE3c - thinks reflectively and creatively to evaluate situations and solve problems;
CGE3e - adopts a holistic approach to like by integrating learning form various subject areas and experience;
CGE3f - examines, evaluates, and applies knowledge of interdependent systems (physical, political, ethical, socio-economic and ecological) for the development of a just and compassionate society;
CGE4f - applies effective communication, decision-making, problem-solving, time and resource management skills;
CGE5a - works effectively as an interdependent team member;
CGE5d - finds meaning, dignity, fulfilment, and vocation in work which contributes to the common good;
CGE5e - respects the rights, responsibilities and contributions of self and others;
CGE7h - exercises the rights and responsibilities of Canadian citizenship;
CGE7j - contributes to the common good.

Strand(s): Energy and Momentum

Overall Expectations

EMV.03 - analyse and describe the application of the concepts of energy and momentum to the design and development of a wide rage of collision and impact-absorbing devices used in everyday life.

Specific Expectations

EM1.03 - analyse situations involving the concepts of mechanical energy, thermal energy and its transfer (heat), and the laws of conservation of momentum and of energy;
EM1.05 - analyse and explain common situations involving work and energy using the work-energy theorem;
EM3.01 - analyse and describe, using the concepts and laws of energy and of momentum, practical applications of energy transformation and momentum conservation;
EM3.02 - identify and analyse social issues that relate to the development of vehicles.

Scientific and Investigation Skills

SIS.03 - demonstrate the skills required to design and carry out experiments related to the topics under study, controlling major variables, and adapting or extending procedures where required;
SIS.04 - locate, select, analyse, and integrate information on topics under study, working independently and as a part of a team, and using appropriate library and electronic research tools, including Internet sites;
SIS.10 - communicate the procedures and results of investigations and research for specific purposes using data tables, laboratory reports, and research paper and account for discrepancies between theoretical and experimental values with reference to experimental uncertainty;
SIS.12 - identify and describe science- and technology-based careers related to the subject area under study.

Prior Knowledge & Skills

- independent research skills;
- ability to properly reference materials, students can be referred to websites, or library/resource centre personnel to assist them in proper references;
- communication of ideas in a poster/presentation format.

Planning Notes

- Arrange for computers and Internet access in order to provide students with an opportunity to do the required research. Ethical use of the Internet should be reinforced with students throughout Activity 5.
- A template for a computer presentation software program format may be developed.
- Be aware that students sometimes think that momentum and kinetic energy are the same, or alternatively that momentum is the same as force.

Teaching/Learning Strategies

The teacher:

- places students in groups to develop criteria for the aspects involved in the development of safety devices through a brainstorming activity;
- provides feedback on the criteria developed from the brainstorming activity to ensure all criteria are addressed; the criteria for this research should be holistic and Catholic in perspective, stressing the importance of the common good in developing these devices;
- assists the students in choosing a safety device through a brainstorming activity that may include: air bags (front and side), seat belts (lap and shoulder), crumple zones, child seats, head rests, road barriers, computer modelling simulations, the development of external safety testing agencies, crash test dummies, Canadian safety standards;
- provides research tracking sheets for students;
- provides information regarding proper referencing of the materials used;
- provides a rubric (Refer to Appendix C) for project evaluation that outlines clearly the expectations for the project presentation.

Students:

- brainstorm the important aspects involved in safety product development;
- incorporate feedback from the teacher from the brainstorming session to ensure the research criteria include all important aspects;
- choose a single safety device/or safety aspect and research the development of this device/safety aspect in detail;
- present this information in a format set by the teacher, following the criteria set out in the rubric provided by the teacher.

Assessment & Evaluation of Student Achievement

- The poster project/presentation is assessed for Knowledge/Understanding, Inquiry, Communication, and Making Connections by means of a rubric. (EMV.03, EM1.03, .05, EM3.01, .02, SIS.04, .10).

Resources

Accident Reconstruction Resources – http://c-design.com/index.html

Accident Reconstruction Ring at AOL (choose Accident reconstruction) – http://www.webring.org

Advocates for Highway and Auto Safety – http://www.saferoads.org/

Basics of Accident Investigation – http://www.iacnet.net/IIFS/

Car Safety Timeline – http://www.allpar.com/ed/safety.html

European New Car Assessment Programme – http://euroncap.com/

Glenbrook High School see year end projects – http://glenbrook.k12.il.us/

How things work – www.howthingswork.virginia.edu

Insurance Institute for Highway Safety – http://hwysafety.org/

McHenry Software Accident Reconstructions – http://www.mchenrysoftware.com/genintro.html

National Highway Traffic Safety Administration – http://www.nhtsa.dot.gov/index.html
Stephen A. Estrin and Company – http://www.sa-estrin.com/fe2.htm
Students' Alternate Conceptions – http://phys.udallas.edu/C3P/altconcp.html
Summit engineering – http://www.summitengr.com/accident.htm
TEC-REC accident reconstructions – http://www.REC-TEC.com/index.html
The Bureau of Transportation Statistics (US statistics) – http://www.bts.gov/smart/
Traffic Accident Reconstruction Origin – http://tarorigin.com/index/html
Worlds in Motion lab experiments – http://members.aol.com/raacc/wim/

Online Videos and Simulations
Dean Zollman-Physics Modelling Video Collection – http://phys.ksu.edu/
Glenbrook High School Multimedia Physics Studio
– www.glenbrook.k12.us/gbssci/phys/mmedia/index.html
National Organization for Auto Safety and Victim's Aid (Japan) – http://www.osa.go.jp/
Steve Wagner's Home Page (accident reconstructions) – http://members.aol.com/StevenW201/index.htm
University of Michigan Engineering – Fun experiments, Air bags – http://www.eecs.umich.edu/
Vidshell – http://webphysics.tec.nh.us/vidsell/vidshell.html
Vidshell free downloads and information – http://192.233.237.47/vidshell/vidshell.html

Appendices
Appendix C – Rubric to Assess Safety Devices Project

Appendix A

Checklist for assessing Concept Map for Activity 1

Concept Map Checklist

1) Have the general concepts been linked outward to specific concepts?

   Yes _____ No _______

2) Are there detailed descriptions of the connections between the concepts?

   Yes _____ No _______

3) Have definitions been included with each concept?

   Yes _____ No _______

4) Have the correct equations been included with the appropriate concepts?

   Yes _____ No _______

5) Have appropriate examples been included to illustrate each concept?

   Yes _____ No _______

6) Have the units in each equation and concept been identified?

   Yes _____ No _______

7) Do each of the concepts deal with some form of energy?

   Yes _____ No _______

Appendix B

Computer Simulation Work Sheet for use with Activity 2.3

Topic: Conservation of Energy / Work Energy Theorem
Name: Sample
Site Address or Program: http/physics.weber.edu.DCRfiles/Energy/bungee4s.dcn

Description
A cartoon bungee jumper falls from a height and continues in motion as the cord pulls the jumper back up for another fall. The simulation records the jumpers gravitational potential energy, kinetic energy, spring potential energy and total energy. The program uses a mass of 65 kg for the jumper. It has options for slow motion and to include a transfer of mechanical energy to heat.

Types of Energy and Equations

1) Gravitational Potential Energy
GPE = mgh
m = mass (kg)
g = 9.8 N/kg
h = height above the bottom of the path (m)

2) Kinetic Energy
KE = $\frac{1}{2}mv^2$
m = mass (kg)
v = speed (m/s)

3) Spring (or Elastic) Potential Energy
EPE = $\frac{1}{2}kx^2$
k = spring constant (N/m)
x = displacement from equilibrium (m)

4) Total Energy = GPE + KE + EPE

Energy Transformation Description
Position 1) top of jump Total Energy = GPE
Position 2) between top and equilibrium Total Energy = GPE + KE
Position 3) between equilibrium and bottom of path Total Energy = GPE + KE + EPE
Position 4) at bottom of path Total Energy = EPE

Energy Conservation
Energy is conserved in this action. Each time the jumper returns to the original height. If the energy loss option is selected, the jumper transfers approximately 20% of the original total energy to heat each fall.

Appendix C

Rubric to Assess Safety Devices Project

Criteria/ Category	Level 1 (50-59%)	Level 2 (60-69%)	Level 3 (70-79%)	Level 4 (80-100%)
Knowledge/ Understanding				
(a) knowledge of facts and terms	- demonstrates limited knowledge of facts and terms	- demonstrates some knowledge of facts and terms	- demonstrates considerable knowledge of facts and terms	- demonstrates thorough knowledge of facts and terms
(b) understanding of relationships between concepts about energy and momentum and safety	- demonstrates limited understanding of relationships between concepts	- demonstrates some understanding of relationships between concepts	- demonstrates considerable understanding of relationships between concepts	- demonstrates thorough understanding of relationships between concepts
Inquiry - demonstration of research skills related to automobile safety devices	- shows few of the skills and strategies of inquiry in the research of the components of the issue	- shows some of the skills and strategies of inquiry in the research of the components of the issue	- shows most of the skills and strategies of inquiry in the research of the components of the issue	- shows all or almost all of the skills and strategies of inquiry in the research of the components of the issue
Communication				
(a) communication of information and ideas about energy, momentum, and safety	- communicates information and ideas with limited clarity and precision	- communicates information and ideas with moderate clarity and precision	- communicates information and ideas with considerable clarity and precision	- communicates information and ideas with a high degree of clarity and precision
(b) use of scientific terminology	- uses scientific terminology, symbols, conventions, and SI units with limited accuracy and effectiveness	- uses scientific terminology, symbols, conventions, and SI units with some accuracy and effectiveness	- uses scientific terminology, symbols, conventions, and SI units with considerable accuracy and effectiveness	- uses scientific terminology, symbols, conventions, and SI units with a high degree of accuracy and effectiveness
(c) use of poster as a form of communication	- demonstrates limited command of the poster; it is somewhat effective	- demonstrates moderate command of the poster; it is fairly effective	- demonstrates considerable command of the poster; it is effective	- demonstrates extensive command of the poster; it is very effective

Appendix C (Continued)

Criteria/ Category	Level 1 (50-59%)	Level 2 (60-69%)	Level 3 (70-79%)	Level 4 (80-100%)
Making Connections - understanding of social and economic issues	- shows limited understanding of social and economic issues involving safety devices	- shows some understanding of social and economic issues involving safety devices	- shows considerable understanding of social and economic issues involving safety devices	- shows thorough understanding of social and economic issues involving safety devices

Note: A student whose achievement is below Level 1 (50%) has not met the expectations for this assignment or activity.