Public District School Board Writing Partnership

Course Profile

Physics

Grade 11
University Preparation
SPH3U

• *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.

Acknowledgments

Public District School Board Writing Teams – Physics
Course Profile Writing Team
Arthur Prudham, Lead Writer, Waterloo Region District School Board (retired) and Science Co-ordinators and Consultants Association of Ontario (SCCAO)
Dudley Brown, Waterloo Region District School Board
Robert Callcott, York Region District School Board (retired)
Tom Card, Peel District School Board
Ed Doadt, Waterloo Region District School Board
Renaty Friedrich, Peel District School Board
Elizabeth Jarman, Simcoe County District School Board
Michelle Kane, York Region District School Board
Erika Kerhoulas, York Region District School Board
Paulette Luft, Peel District School Board (retired)
David Miller, District School Board of Niagara

Reviewers
David Arthur, Ontario Society for Environmental Education (OSEE)
Dan Blanchard, York Region DSB
Shawna Hopkins, DSB of Niagara and Science Co-ordinators and Consultants Association of Ontario (SCCAO)
Peter Stone, Simcoe County DSB
Dr. Stefan Zukotinski, University of Toronto

Lead Board
Peel District School Board
Allan Smith, Project Manager
Partner Boards
District School Board of Niagara, Kawartha Pine Ridge District School Board, Simcoe County District School Board, Waterloo Region District School Board, York Region District School Board

Associations
Ontario Society for Environmental Education (OSEE)
Science Co-ordinators and Consultants Association of Ontario (SCCAO)

Course Overview
Physics, Grade 11, University Preparation, SPH3U

Course Description

In this course students develop an understanding of the basic concepts of physics through an analysis of the interrelationships between physics and technology, and a consideration of the impact of technological applications of physics on society and the environment. Students study the laws of dynamics and explore different kinds of forces, the quantification and forms of energy (mechanical, sound, light, thermal, and electrical), and the way energy is transformed and transmitted. They develop scientific-inquiry skills as they verify accepted laws and solve both assigned problems and those emerging from their investigations. Each unit ends with an end-of-unit task, which not only facilitates assessment of the unit itself, but also leads the student to prepare for the final assessment tasks. The final assessment tasks, introduced at the start of Unit 1, include a practical component that uses the students' knowledge of physics principles developed throughout this course to make a labour-saving/useful device. The students must also report on this device with the inclusion of an explanation of the physics principles involved.

This Profile offers one set of suggestions for achieving the Learning Expectations of the SPH3U Guideline. Teachers must adapt the Profile to suit their circumstances and to match the students' needs while ensuring that all Learning Expectations of the Guideline are addressed fully.

Course Notes

Scientific Literacy for All Students

The paramount task of science education is to equip all students with scientific literacy – the combination of knowledge, skills and habits of mind that enable them to think creatively, reason logically, evaluate information critically, and communicate effectively. This is an essential base for making productive and ethical decisions, not only about scientific and technological issues but in all areas of life. This course is designed to enhance that scientific literacy, and awareness of destination, for students intending to study physics at the university level.

The Ontario Curriculum, Grades 11 and 12, Science notes that, "Achieving excellence in scientific literacy is not the same as becoming a science specialist." The focus in Grade 11 Physics is scientific literacy for all students, with preparation for further studies in physics and related disciplines by some students. The policy document goes on to note, "The newer aspects of the science curriculum – especially those that focus on science, technology, society, and the environment (STSE) – call for students to deal with the impacts of science on society and the environment, which includes both the natural environment and the workplace environment. This requirement brings in issues that relate to human values. Science can therefore not be viewed as merely a matter of "facts"; rather, it is a subject in which students learn to weigh the complex combinations of fact and value that developments in science and technology have given rise to in modern society," p. 4. This perspective is consistent with the vision advanced in this profile. The challenge in delivering the course is to find ways to bring to the classroom an STSE focus from which the facts and physics specific skills derive naturally.

Guideline Directions

The Ontario Curriculum, Grades 11 and 12: Science contains recommendations regarding teaching approaches and curriculum expectations that are reflected in this profile and should be evident in courses developed using this profile as a template p. 8-10).

- "The expectations in science courses call for an active, experimental approach to learning, and require *all students* to participate *regularly* in laboratory activities";

- "Where opportunity allows, students might be required, as part of their laboratory activities, to design and conduct research on a real scientific problem for which the results are unknown";
- "Where possible, *concepts should be introduced in the context of real-world problems and issues*";
- "In all courses, a list of expectations is given that precedes the strands. These expectations describe skills that are considered to be essential for scientific investigation (e.g., skills in research, in the use of materials, and in the use of units of measurement), and skills required for investigating possible careers in the subject area. These skills apply to all areas of course content and must be developed in all strands of the course. Assessment of students' mastery of these skills must be included in the evaluation of students' achievement of the expectations for the course." In this profile, these expectations will be called Science Investigative Skills. When developing detailed course plans, teachers use the SIS expectations as a primary guide.

The Goals of Grade 11 Physics

As in the Grade 1 to 8 Science and Technology courses, and the Grade 9 and 10 Science courses, SPH3U is based on three goals:

- To relate science to technology, society, and the environment;
- To develop skills, strategies, and habits of mind required for scientific inquiry;
- To understand basic concepts of science.

As a prerequisite for SPH4U, Physics SPH3U must develop a large number of basic concepts. Nevertheless, the activities and assessment tasks in this profile reflect a balance among the three goals. Teachers are encouraged to ensure that their detailed plans do not focus to excess on 'understanding basic concepts' at the expense of the other goals. In all science courses every attempt should be made to place learning in an STSE context – inquiry skills should be built through issues first, with content assembled later. In addressing STSE Expectations such as 'evaluate technologies…,' 'analyse relationship with issues…,' 'analyse costs and benefits…,' and 'analyse impacts…,' students should have opportunities to discuss issues, examine values and attitudes, and propose solutions and actions. In this profile, topics addressed include the application of physics principles in transportation (e.g., navigation, highway bridge construction), recreation (e.g., skiing, canoeing, music), and energy systems (e.g., electrical power systems).

Planning and Implementing Grade 11 Physics

- When planning and delivering SPH3U, try to introduce each activity with a question or story which connects the key concepts to be learned with a context from the world outside the school. Some questions that could be addressed include:
  - How does the study of forces and motion assist in automobile design?
  - How is wave theory involved in the design and manufacture of audio speakers and earphones?
  - How important is a knowledge of light and geometric optics to the manufacturers of eyeglasses and contact lenses?
  - How can a knowledge of energy work and power assist politicians in assessing the impact, both economic and environmental, of proposed energy supply systems?
- A number of activities in this profile have a research focus that requires accessing information beyond the laboratory or field trip. Students should be taught explicitly how to use all available sources of information – people, print, online sources and other media, both within the school and in the community. They should also be given opportunities to use those skills, and to overcome the frustrations that invariably accompany the location and acquisition of quality information. However, care must be taken that student time is spent primarily on processing information rather than accessing information, so that the search does not become an end in itself.

- The Expectations are central to all aspects of this Course Profile. The context in which each unit is delivered, the skills and concepts developed and the assessment tasks used must be interconnected, and linked to the Expectations. The assessment data accumulated throughout the course must be sufficient (in variety and number) to permit teachers to evaluate the consistent level of performance for each student in each of the categories in the Achievement Chart for Science.
- Some of the expectations in the guideline, and the SIS (Science Investigative Skills), are so critical to the development of scientific literacy that they are given special emphasis in learning activities and are often revisited (e.g., those related to graphing and problem solving). These Expectations are taught, assessed, evaluated and revisited using alternate instructional strategies in a cyclic process that stops only when students have achieved them. They describe curriculum priorities/enduring learning/core learning which students must be given opportunities to explore in depth rather than just to acquire familiarity.
- Each student interprets new information in terms of what he or she already knows. The student tries to make sense of what is taught by trying to fit it with his or her experience. Understanding a key concept results when the student has opportunities to develop skills and construct understanding through concrete experiences and then to create generalizations from those personal experiences (e.g., forces and motion affect drifting in a canoe; electric motors pervade our world – computer printers, kitchen appliances, diesel-electric locomotives). Teachers must be aware of the experiences that students have already had from their work prior to Grade 11, and use those as building blocks to new and more complex concepts. Students may also arrive with misconceptions from their experience that will interfere with their ability to understand new concepts. Identifying and eliminating misconceptions through concrete experiences may be required at times.
- Terminology, formulae and algorithms should be viewed by students as tools for solving problems and communicating ideas, not as problems to be solved, and should not dominate the curriculum. SPH3U is intended to promote scientific literacy and to build a background in a science discipline. It is important to emphasize key skills and concepts without obscuring them by expecting students to memorize a multitude of facts and formulae and equations.
- This Course Profile describes a physics course in which students are encouraged to ask their own questions, and in some cases to find their own answers by inquiry – through experiment, research or the innovation of a device or process. Fundamental to the skill set of a scientifically literate person/citizen is the ability to ask quality questions and to interpret the answers critically, including identifying unstated assumptions. For example, when the media report on an incident involving physics, students should have the opportunity to discuss the issue, identify assumptions, consider alternatives and assess the degree of bias in the report. They should consider the extent to which the general population is influenced by the report and whether that influence is modified in light of greater understanding of physics.
- In this Course Profile there is a reduced emphasis on traditional laboratory activities in which students are provided step-by-step instructions, and more emphasis on developing students' ability to devise and carry out components of procedures within well-defined limits. The teacher's role is to decide what knowledge and skills students must have for them to proceed safely and successfully in a laboratory setting, without reducing their part in the process to being followers of recipes with entirely predictable results. Many traditional laboratory exercises can be opened up by rewording statements into questions, and replacing detailed procedures with a teacher-led class discussion. This could be followed by a challenge that requires students to devise a procedure and have its safety confirmed before carrying it out. By making decisions regarding what data to collect and which format to use for reporting both data and results, students develop skills of inquiry and communication essential in science.

Course Format

Component	Percentage	Time
Units	70%	100 h
Final Evaluation	30%	10 h

Final Evaluation

Component	Time
Written Exam	2 h
Performance Task	8 h

Rationale for the Unit Sequence of the Course Profile

The Unit Sequence in this profile was chosen to enable students to build on the concepts of motion developed in Grade 10, use those concepts to develop a qualitative and quantitative understanding of energy, and then extend that understanding of energy into the wave nature of sound and light. Once the wave model has been established it can be used to clarify electromagnetic behaviour.

Units: Titles And Times

* Unit 1	Forces and Motion	24 hours
Unit 2	Energy, Work and Power	20 hours
Unit 3	Waves and Sound	18 hours
Unit 4	Light and Geometric Optics	18 hours
Unit 5	Electricity And Magnetism	20 hours
	Final Assessment Tasks	10 hours

* This unit is fully developed in this Course Profile.

Unit Overviews

Key to Abbreviations used in Unit Overview Charts	
AC = Achievement Chart which has these assessment categories: K = Knowledge/Understanding I = Inquiry C = Communication MC = Making Connections	LS = Learning Skills found on the Provincial Report Card which are: WI = Works Independently WH = Work Habits/Homework I = Initiative O = Organization TW = Team Work

Unit 1: Forces and Motion

Time: 24 hours

Unit Description

In this unit the technological applications of motion and societal influences on transportation and safety issues are studied. The students' develop an understanding of the relationship between forces and the acceleration of an object in linear motion through experimentation and analysis. The contributions of Galileo and Newton to the understanding of dynamics are considered. The end-of-unit task is a research-based investigation of the underlying principles involved in transportation and recreation. Students are also asked to brainstorm ideas for the practical component of the final assessment tasks – perhaps a labour saving device relating to transportation or recreation.

Unit Overview Chart

Activity/ Time	Activity Title/Focus	Expectations	Assessment AC	LS
1.1 4.0 h	Review of Straight Line Motion	FMV.01, FM1.01, FM1.02, FM1.03, FM3.02, FM3.03	I, MC	WI, TW, I, WH
1.2 3.5 h	Graphical Analysis	FMV.02, FMV.03, FM1.01, FM1.02, FM1.03, FM2.03, FM3.03	I, MC	O, I, WI, WH
1.3 4.5 h	Forces	FMV.01, FMV.02, FM1.04, FM1.05, FM1.07, FM1.08, FM2.01, FM2.02	I, C	I, TW, O
1.4 4.0 h	Vectors, Free-body Diagrams and Newton's Laws	FMV.01, FMV.02, FMV.03, FM1.06, FM1.08, FM2.03, FM2.04, FM3.02, FM3.03	K, MC	WH, O, I
1.5 4.0 h	Newton and Galileo	FMV.01, FMV.02, FMV.03, FM1.07, FM2.04, FM3.01	MC, C	WI, O, I, WH, TW
1.6 4.0 h	End-of-unit Task	FMV.03, FM3.02, FM3.03	K, I, MC, C	I, O, TW, WI, WH

Unit 2: Energy, Work and Power

Time: 20 hours

Unit Description

In this unit students will analyse the costs and benefits of various energy sources and energy-transformation technologies that are used around the world, and explain how the application of scientific principles related to mechanical energy has led to the enhancement of sports and recreational activities. Students will gain an understanding of the concepts of work, energy, energy transformations, efficiency, and power. They will design and carry out experiments and solve problems involving energy transformations and the law of conservation of energy. The end-of-unit task is a cost benefit analysis for various energy sources and transformations. Students are also asked to link this to the practical component of the final assessment tasks – perhaps a labour saving device that improves energy efficiency.

Unit Overview Chart

Activity/ Time	Activity Title/Focus	Expectations	Assessment AC	LS
2.1 2.5 h	The Work-Energy Connection	EWV.01, EW1.01	K, MC, C	TW, I
2.2 4.5 h	Measurement of Work	EWV.01, EW1.01, EW1.02, EW1.04	I, K, MC	WI, WH
2.3 4.5 h	Kinetic, Thermal, and Potential Energy	EWV.01, EW1.01, EW1.03	I, K, MC, C	WI, O, TW, I, WH
2.4 4.5 h	Conservation of Energy and Energy Transformations	EWV.01, EWV.02, EWV.03, EW1.01, EW1.03, EW1.05, EW2.01, EW2.02, EW2.03, EW3.02	I, C, K, MC	TW, O, WH, I, WI
2.5 4.0 h	Energy and Society	EWV.01, EWV.03, EW1.05, EW3.01	I, MC, C	I, WI, WH

Details of Activities

2.1.1 Introduction to final assessment task (and reference to final assessment tasks)
2.1.2 Brainstorm general interpretation of the words "work" and "energy" and how one might generate the other
2.1.3 Brainstorm ways (in everyday terms) that work is done.
2.1.4 Research/discuss (bubble map) different forms of energy
2.1.5 Focus the discussion to "energy is the ability to do work" and "work is a means to transfer energy".
2.1.6 Develop concept of force and distance: simple activities
2.1.7 **Assessment:** Checklist (Knowledge); Oral presentation (Communication)

2.2.1 Activity: through hypothetical example (e.g., fuel consumption of a car over distance) infer Energy = Force × Displacement (e.g., toy car activity)
2.2.2 Define: Work = Force × Displacement
Problem solving (with emphasis on the "meaning") and units.
Link problems to end-of-unit task.
2.2.3 Binding conditions: F and Δd are co-directional
Extension: Vector components of F in finding W (i.e., $W = F\Delta d\cos\theta$)
2.2.4 Special cases of zero work: (i) F = 0; (ii) .$\Delta d = 0$; (iii) $F \perp \Delta d$: simple activities.
2.2.5 Discuss the effect of time on work done. (i.e., Power)
Simple activities e.g., race to stack grocery shelves
2.2.6 Define: Power = Work/time
Problem-solving using $P=W/\Delta t$ (with emphasis on anecdotal interpretation) and units.
2.2.7 **Assessment**: Written quiz (Knowledge)

2.3.1 From $W = F\Delta d$ derive $E = 1/2mv^2$ and define "Kinetic Energy, E_k"
Solve problems (with anecdotal interpretations) and establish unit: one joule = one newton metre (1 J = 1N·m).
2.3.2 Through problem-solving examples discuss transformation of kinetic energy to thermal energy through friction. Link problems to end-of-unit task.
2.3.3 Research/discuss thermal energy as molecular motion and transfer of thermal energy as "heat". Simple activities e.g., sanding wood
2.3.4 Extension: students solve problems involving the transfer of thermal energy using the equation: $Q = mc\Delta T$
2.3.5 Discuss types of "stored" energy and define as "Potential Energy". Consider special case of gravitational potential energy E_g
2.3.6 From $W = F\Delta d$ derive $E_g = mg\Delta h$ and solve problems with anecdotal interpretations.
Simple lifting activities: relate to sports, transport.
2.3.6 Activity: Power of a student (stairs)
2.3.7 **Assessment:** Laboratory skills (Inquiry); Problem-solving (Inquiry, Knowledge)

2.4.1 Activity: Students design an investigation to determine the total mechanical energy of a system (e.g., hot-wheels track, pendulum, inclined plane) using probe-ware.
2.4.2 Discuss energy transformations in the previous activity and develop the Law of Conservation of mechanical energy: $E_t = E_k + E_g$
Problem solving with anecdotal interpretations.
2.4.3 Research/report: Improvement in sports performance using the principles and concepts of work, kinetic and potential energy and the law of conservation of energy.

2.4.4 Extend discussion to transformation of other forms of energy and establish the Law of Conservation of Energy in general (include references to energy transformation technologies used around the world and the economic and environmental impact). Analyse above examples for per-cent efficiency, where percent efficiency = (output energy/input energy) ×100%

2.4.5 **Assessment:** Laboratory design skills (Inquiry); Oral report on transformations (Communication)

2.5.1 End-of-unit Task: Construct a model demonstrating energy sources and transformations used in the world and perform a cost/benefit analysis including percent efficiency.
Assessment: Oral Report on project (Communications, Making Connections, Inquiry)

Unit 3: Waves and Sound

Time: 18 hours

Unit Description

Students will describe and explain ways in which mechanical waves and sound are produced in nature, and evaluate the contributions to entertainment, health, and safety of technologies that make use of mechanical waves and sound. Students will gain an understanding of the properties of mechanical waves and sound and the principles underlying the production, transmission, interaction, and reception of mechanical waves and sound. They will investigate the properties of mechanical waves and sound through experiments or simulations, and compare predicted results with actual results. The end-of-unit task is a report on the prevalence of sound in society and nature and the construction of a model of a technological device related to sound. Students are also asked to link this to the practical component of the final assessment tasks – perhaps an acoustic device that is labour saving.

Unit Overview Chart

Activity/ Time	Activity Title/Focus	Expectations	Assessment AC	LS
3.1 2.5 h	Origins of Waves	WSV.01, WSV.02, WS1.01, WS1.02, WS2.01, WS2.02	I, K	WH, I
3.2 3.5 h	Properties of Waves	WSV.01, WSV.02, WS1.01, WS1.04, WS1.06, WS2.01, WS2.02	I, C, K	TW, O, I
3.3 4.0 h	Sound as a Wave	WSV.01, WSV.02, WSV.03, WS1.01, WS1.03, WS1.06, WS1.07, WS2.01, WS2.02, WS3.03	I, K, MC, C	WI, O, WH, TW
3.4 4.0 h	Resonance	WSV.01, WSV.02, WSV.03, WS1.01, WS1.05, WS1.08, WS2.03, WS3.01	I, C, MC, K	WI, O, WH
3.5 4.0 h	Societal Impact of Waves and Sound	WSV.03, WS3.01, WS3.02	I, MC, C, K	WI, I, O, WH

Details of Activities

3.1.1 Introduction to final assessment task (and reference to final assessment tasks)

3.1.2 Activities: vibrations in hacksaw blade, slinky, wave machine, pendulum. Define/illustrate longitudinal wave, transverse wave, cycle, period, frequency, amplitude, phase, wavelength.

3.1.3 Derive $v = f\lambda$ from $v = \dfrac{\Delta d}{\Delta t}$

3.1.4 Design and conduct investigation to determine speed of waves in a medium (slinky) and factors that affect the speed.

Assessment: Laboratory skills (Inquiry)

3.2.1 Activity (slinky): reflection, interaction, transmission
3.2.2 Activity (slinky): constructive and destructive interference.
3.2.3 Analyse interference; develop Principle of Superposition
3.2.4 Activity (slinky): production of standing waves.
Summarize conditions for production of standing waves.
3.2.5 Activity (ripple tank): reflection, interference including standing waves. Relate to culminating activities.
3.2.6 Activity: design and conduct investigation to determine speed of waves in a medium (ripple tank).

Assessment: Laboratory report (Inquiry, Communication)

3.3.1 Demo/discuss sound as a disturbance through a medium (longitudinal wave).
3.3.2 Activity: determine speed of sound in air
3.3.3 Research/discuss: speed of sound in different media.
3.3.4 Analyse the speed of sound equation: $v = 332 + 0.6T$ and discuss molecular reason for temperature dependence.
3.3.5 Discuss/research conditions for standing sound waves.
3.3.6 Activity: Doppler effect in a ripple tank.
3.3.7 Activity: Doppler effect in sound waves. (car in parking lot)
3.3.8 Summarize frequency change and Doppler effect.
3.3.9 Research project: How can highway noise be reduced?
(or structure of Greek stadium e.g., Acropolis, and how it makes maximum use of sound)

Assessment: Written quiz (Knowledge); Laboratory skills (Inquiry); Research report (Making Connections, Communication)

3.4.1 Activity: resonance in a string pendulum.
3.4.2 Research/report: Collapse of Tacoma Narrows Bridge.
3.4.3 Activity: resonance in vibrating strings and air columns
3.4.4 Summarize conditions for resonance and relate to musical instruments. Link to end-of-unit task.

Assessment: Oral laboratory report (Inquiry, Communication) Checklist (Making Connections, Knowledge)

3.5.1 Research/report on the prevalence of sound in society (e.g., design of buildings) and nature (e.g., infrasonic, audible and ultrasonic communication, use and design of audio systems)
3.5.2 Construct a model of a technological device related to sound. (e.g., audio speakers and earphones)

Assessment: Oral report on model (Inquiry, Making Connections, Communications); Research thesis (Inquiry, Making Connections, Communications, Knowledge)

Unit 4: Light and Geometric Optics

Time: 18 hours

Unit Description

Students evaluate the contributions of optical devices to such areas as entertainment, communications, and health and other technologies. Students study the properties of light and the principles underlying the transmission of light through a medium and from one medium to another. They investigate the properties of light through experimentation, and illustrate and predict the behaviour of light through the use of ray diagrams and algebraic equations. The end-of-unit task is a multimedia report on a student designed, constructed and tested prototype of an optical device. Students are also asked to link this to the practical component of the final assessment tasks – perhaps an optical device that is labour saving.

Unit Overview Chart

Activity/ Time	Activity Title/Focus	Expectations	Assessment AC	Assessment LS
4.1 3.5 h	Refraction and Snell's Law	LGV.01, LGV.02, LG1.01, LG1.02, LG1.03, LG1.04, LG2.01, LG2.02, LG2.04	K, I, C	TW, O, WH, TW, I
4.2 3.5 h	Lenses	LGV.01, LGV.02, LG1.01, LG1.02, LG1.05, LG1.06, LG1.07, LG2.03, LG2.04	K, I, C	TW, O, WH, I
4.3 3.5 h	Applications I	LGV.01, LGV.03, LG1.01, LG1.02, LG1.06, LG 3.01, LG 3.02, LG 3.03	K, I, C, MC	WI, TW, O, WH, I
4.4 3.5 h	Applications II	LGV.01, LGV.02, LGV.03, LG1.01, LG1.02, LG1.06, LG2.05, LG3.01, LG3.03	K, I, C, MC	WI, TW, O, WH, I
4.5 4 h	End-of-unit Task	LGV.01, LGV.02, LGV.03, LG1.01, LG1.02, LG1.06, LG2.05, LG3.01, LG3.03	K, I, C, MC	WI, TW, O, WH, I

Details of Activities

4.1.1 Introduction to end-of-unit task (and reference to final assessment tasks)

4.1.2 Review reflection law (e.g., laser reflection from mirror on speaker) and introduce refraction (e.g., demonstration with laser and stream of water. Use caution with lasers).

4.1.3 Refraction experiment using a semi-circular prism on a unit circle and measuring the semi-chords to introduce Snell's Law. (Use caution with bright lights and dark rooms)

4.1.4 Mathematical analysis of Snell's Law.

4.1.5 Compare theory and empirical evidence for Snell's Law using a different medium.

4.1.6 Lab: investigate total internal reflection and critical angle or more than one medium. (Use caution with bright lights and dark rooms)

4.1.7 Solve problems using critical angles and refractive indices, and verify empirically (and refer to end-of-unit task).

4.1.8 Discussion of various naturally occurring phenomena. (e.g., diamonds, mirages, "wet" roads, rainbows (identify colours for colour impaired students))

Assessment: Laboratory Skills test, Written test (Inquiry, Knowledge and Understanding)

4.2.1 Student activity: focus three parallel rays using one rectangular and two triangular prisms to introduce both concave and convex lenses.

4.2.2 Lens and ray diagrams to find images/to find object (board work/worksheets)

4.2.3 Investigation to compare empirical evidence with the Thin Lens Equation and account for discrepancies.

4.2.4 Derivation of lens equations using similar triangles, distinguishing between converging and diverging lenses:

$$\frac{1}{d_o} + \frac{1}{d_i} = \frac{1}{f};\ \frac{h_i}{h_o} = -\frac{d_i}{d_o}$$

4.2.3 Compare theory and empirical evidence using previous activity and account for any discrepancies.

4.2.4 Solve problems using the lens equations (and refer to end-of-unit task).

Assessment: Assignment Checklist, Written test (Inquiry, Knowledge and Understanding)

4.3.1 With the aid of diagrams and props identify special optical devices and why each contains converging or diverging lenses.(worksheets/research/experiment). Refer to End-of-unit Task.
4.3.2 With the aid of diagrams and props explain how images are formed in entertainment and culture. (worksheets/research/experiment)

Assessment: Compare, contrast and evaluate the use of various methods of creating images in entertainment and culture. (research/brainstorm/discussion) (Inquiry, Making Connections)

4.4.1 Using research and brainstorming compare and contrast various technologies related to human perception (e.g., contact lenses, virtual reality goggles, night vision goggles)
4.4.2 Evaluate the effectiveness of various technologies related to human perception.

Assessment: Report on the effectiveness of a technology related to human perception (Making Connections, Communication)

4.5.1 Students design, construct, test and refine a prototype of an optical device. (research/brainstorm/experiment)

Assessment: Multimedia Report on the prototype of an optical device (Making Connections, Communication)

Unit 5: Electricity and Magnetism

Time: 20 hours

Unit Description

Students evaluate social, economic, and environmental costs and benefits associated with electromagnetic fields and electrical energy production and distribution in Canada. In doing so students gain an understanding of electromagnetic fields through a study of their production. Using a variety of instruments and tools, they develop skills using qualitative and quantitative analysis. Students apply their knowledge of electromagnetic fields to design and construct devices that perform a specific function. The end-of-unit task is a report on systems based on electromagnetic fields, including a timeline and references to environmental costs and benefits. Students are also asked to link this to the practical component of the final assessment tasks – perhaps an electromagnetic device that is labour saving.

Unit Overview Chart

Activity/ Time	Activity Title/Focus	Expectations	Assessment AC	Assessment LS
5.1 5.5 h	Electrical Concepts	EMV.01, EMV.03, EM1.01, EM1.02, EM3.02	K, C, I, MC	WI, TW, I, WH
5.2 5.5 h	Magnetic Fields	EMV.01, EMV.02, EMV.03, EM1.01, EM1.02, EM1.03, EM1.04, EM1.07, EM1.08, EM2.01, EM2.02, EM2.03, EM3.01	K, C, I, MC	TW, I, WI, O
5.3 2.5 h	Practical Applications of Magnetic Fields – The Transformer	EMV.01, EMV.02, EMV.03, EM1.01, EM1.04, EM1.05, EM1.07, EM1.08, EM1.09, EM2.03, EM3.01	K, MC, C	WI, WH, I, O
5.4 3 h	Practical Applications of Magnetic Fields – The Motor Principle	EMV.01, EMV.02, EMV.03, EM1.01, EM1.04, EM1.05, EM1.06, EM1.07, EM2.04, EM3.01	K, MC, C	WI, WH, I, O
5.5 3.5 h	End-of-unit Task	EMV.03, EM3.01, EM3.02	I, MC, C	I, O, TW, WI, WH

Details of Activities

5.1.1 Introduction to final assessment task (and reference to final assessment tasks)

5.1.2 Elementary charges (q^+ and q^-)
Discuss/analyse

5.1.3 Current (electron flow vs. electric current)
Discuss/analyse convention

5.1.4 Electric potential (direction of charge flow)
Discuss/analyse

5.1.5 Research/analyse history of elementary charge, current convention, and its relationship to electric potential

5.1.6 Research/analyse contribution of Nickola Tesla and where appropriate link to end-of-unit task.

Assessment: oral/written presentation (Communication, Knowledge)

5.2.1 Activity: finding the characteristics of magnetic field lines and their direction using iron filings and magnetic compasses.

5.2.2 Earth's magnetic field/reasons/history
Discussion/research

5.2.3 Demonstration/activity: what happens when a current flows through a straight or coiled conductor. What are the characteristics of the magnetic field produced (strength and direction)

5.2.4 Develop the solenoid right-hand rule from the straight conductor right-hand rule.
Discuss/applications

5.2.5 Activity: determining the direction of current flow when the magnetic field is changed near a conductor.

5.2.6 Demonstrate Lenz's Law and the production of AC

5.2.7 Compare direct current (DC) and alternating current (AC) in qualitative terms, and explain the importance of alternating current in the transmission of electrical energy.

5.2.8 Student activity: verification of Lenz's law using a changing magnetic field in a solenoid.

5.2.9 Research/analyse Tesla (AC) vs. Edison (DC)
Research the contributions of Faraday, Öersted, Gilbert, and where appropriate link to end-of-unit task

Assessment: lab skills, lab report (Inquiry, Communication)

5.3.1 Demonstration operation of a transformer.

5.3.2 Activity: Students discover the relationship between current, number of coils and voltage in a transformer and relate it to the transmission of electrical power to homes or in a household/industrial appliance.

5.3.3 Class discussion: basic parts and operation of transformers including a discussion on power and energy (kW·h).

5.3.4 Discuss/analyse mathematical equations involved in the use of a transformer.

5.3.5 Discuss/analyse the use of alternating current in a transformer and where appropriate link to end-of-unit task.

Assessment: oral lab report, quantitative analysis (Communication, Making Connections)

5.4.1 Demonstration: the motor principle

5.4.2 Considering the factors that affect the force on a current carrying conductor in a magnetic field deduce the right-hand rule.

5.4.3 Activity: construct motors/ammeters/loudspeakers and link to technological systems at home and work.

5.4.4 Challenge: students construct a motor and are assessed on it and their ability to make it start with electrical power only.

5.4.5 Discuss the relevance of the motor principle in society and where appropriate link to end-of-unit task.

Assessment: interview, lab skills, written lab report (Knowledge, Communication)

5.5.1 Research/report: analyse and describe the operation of technological systems based on the principles related to electromagnetic fields. Write a report/draw an illustration of additional technologies that may arise due to the technologies already present and describe their environmental costs and benefits. (e.g., electrical power systems)

5.5.2 Research/report: create a timeline for a technology that is based on the principles related to electromagnetic fields and show how they have changed the way we live. (Cathode ray [TV] tubes, medical equipment, loudspeakers, magnetic information storage, electrical power systems)

5.5.3 Brainstorm: students relate the physics principles considered in this unit to the labour saving device required in the final assessment.

Assessment: written/oral report (Making Connections, Inquiry)

Final Assessment Tasks

Time: 10 hours

By curriculum policy, the Final Summative Evaluation of the course accounts for 30% of the final grade recorded for the course. This summative evaluation is based on assessment of achievement in all four categories of the Achievement Chart for Science and of expectations from all units of the course.

This assessment of the students' achievement of the Expectations has two components. The first component is a written evaluation as a preparation for university. The second component uses the students' knowledge of physics principles developed throughout this course to make a labour-saving/useful device. The students must also report on this device with the inclusion of an explanation of the physics principles involved. These final assessment tasks represent another opportunity for students to demonstrate mastery of the Expectations.

Time	**Assessment**		**Assessment Activity**
	AC	**LS**	
2 h	K I MC C	WI O I TWW H	Written Component This component consists of a variety of assessment instruments, such as: multiple choice, extended response, short answer, laboratory based questions (e.g., design an experiment, analyse a procedure for errors), and data analysis (determine mathematical relationship between two variables from sample data). This also enables an assessment of learning skills.
8 h	K I MC C	WI O I TWW H	Practical Component a) Students make a labour saving/useful device based on the physics principles developed throughout the course. An example could be a device that is light detecting and automatically lowers acoustic curtains. b) Students make a multimedia/oral/written report on their labour saving/useful device with the inclusion of an explanation of the physics principles involved.

Teaching/Learning Strategies

Need for Variety and Balance

Since the over-riding aim of this course is to develop scientific literacy in all students, a wide variety of instructional strategies is needed to provide learning opportunities that accommodate a variety of learning styles, interests and ability levels.

In planning activities for physics class make sure that your students have:

- opportunities to work individually, in pairs and small groups, and in large groups;
- direct-instruction as well as open-ended exploration;
- opportunities to develop concepts themselves from observed data;
- tasks in which they define some of the parameters (such as scope or procedure);
- opportunities to acquire knowledge and apply that knowledge in a variety of contexts;
- opportunities to communicate using standard formats (such as lab reports) as well as opportunities to choose and develop the format.

Skills are developed through experience and refined with practice

Many of the Learning Expectations describe **Inquiry Skills**. Give students repeated opportunities to carry out genuine inquiries in which they are responsible for defining one or more of the components of the inquiry: the topic or question, the methodology, the mode of presentation, the criteria of success. Within Physics, students should have multiple opportunities to practise a variety of inquiry styles, including the following:

- **Research** involves accessing information that has already been gathered elsewhere, selecting what is needed, and analysing that information for patterns and meaning. This will require instruction and practice in techniques for effective use of library resources, searching the Internet and interviewing experts.
- **Experimentation** involves identifying controls and variables, designing the experimental procedure, observing and measuring and analysing the data for patterns and meaning. This may occur in laboratories or the field. Laboratory techniques and safety procedures must be taught and assessed.
- **Design/Innovation** in which knowledge is applied to define a problem or challenge, set criteria for a satisfactory solution, devise and execute a procedure, and assess the result.

Every inquiry should be driven by a clear question that is manageable and has relevance to the students. Students must be given instruction and repeated practice in: identifying and refining good inquiry questions; developing testable hypotheses; setting the parameters of the solutions to be sought; assessing results.

All forms of inquiry as well as other activities throughout the course develop **Communications Skills**. Although the traditional written report is one form of communication, students need to describe what they do and what they learn in other formats – poster presentations, computer presentations, video, music. Through various formats of cooperative learning they discuss, debate and reflect on their own thinking and learning.

In addition to key physical concepts, every learning activity should identify a technique or skills that will be taught or reinforced and assessed. Over the length of the course, all skills required to meet the Expectations should be practised repeatedly in a variety of contexts.

Use of Computer Technology

Computer applications should be taught and used whenever they enhance learning by enabling students to do something more efficiently or that they could not otherwise do. A wide variety of software tools should be used to record and display information, including word-processing (e.g., reports), spreadsheets (e.g., class data from measurements of acceleration and force, object and image distances in lenses), graphics (e.g., flow charts, concept maps, diagrams in place of written reports of investigations), databases (e.g., collection of data from replicated experiments, class data on energy sources and transformations), and presentation programs (e.g., an alternative for reporting on investigations, particularly by groups). Probe-ware should be used to collect data (e.g., to permit replications of force and motion experiments with sufficient accuracy for data analysis). Simulations may substitute for experiences but should not be used to replace direct experiences that are safe, ethical and available (e.g., object-image ray diagrams especially for virtual images, Doppler effect). The portability of calculator based laboratory systems makes them useful for work outside the classroom.

Learning Skills

While not evaluated for marks, Learning Skills - Works Independently, Teamwork, Organization, Work Habits/Homework, Initiative - are keys to success in school and beyond. As with other skills, they should be taught, practised, and assessed in the physics classroom. Variety is essential: individual assignments foster independence; small-group co-operative learning (including laboratory work done in pairs) provides opportunities to develop teamwork. Small Group Cooperative Small Group Learning (CSGL) structures are discussed in some detail in Appendix OV-3, beginning on p. 18 of the Overview to the Grade 9 Science, Essential, Course Profile. (http://www.curriculum.org/occ/profiles/9/9essential.htm#science). A summary of CSGL structures has been included as Appendix 1 in the Public Course Profile for Grade 11 Science, SNC3M.

Making Connections

The knowledge Expectations of this course have intrinsic worth as useful information, but they also serve as vehicles for developing other Expectations.

- Acquisition of knowledge through inquiry develops inquiry skills;
- Connecting physical concepts to social and environmental issues develops the habits of mind for Making Connections;
- Applying scientific knowledge to practical problems makes connections to technology; considering how scientific knowledge is acquired brings understanding of the role that technology plays in scientific discovery.

Assessment & Evaluation of Student Achievement

Assessment is a systematic process of collecting information or evidence about student learning. *Evaluation* is the judgment we make about the assessments of student learning based on established criteria.

The purpose of assessment is to improve student learning. This means that judgments of student performance must be criterion-referenced so that feedback can be given that includes clearly-expressed next steps for improvement. This can be facilitated by tools of varying complexity.

- Where completion or non-completion is the issue, a checklist is sufficient;
- Where quality of performance is easily identifiable, a rating scale can be used;
- For more complex tasks, the criteria may be incorporated into a rubric where levels of performance for each criterion are stated in language that can be understood by students. Rubrics describe performance of a generalized skill (such as Inquiry) or can be task-specific.

Checklists, rating scales and rubrics become powerful tools for improving learning when students understand the criteria and levels of performance before they undertake the task. Discussion of the criteria for success should be part of every learning task. Wherever possible, involve your students in the development of the rating scale or rubric (identifying criteria and setting levels of achievement in terms they understand).

Note: The following references are useful in expanding both teacher and student understanding of rubrics as a powerful tool in assessment.

- The Course Profile for SCH3U includes Appendix 1: Rubric Development with samples of generic rubrics which can be adapted for use in science courses across the curriculum. The appendix includes brief suggestions for teacher use of the contents, and the following sample/model rubrics. Each sample relates to a section of the Achievement Chart for Science and to the goals of this science course.
  - Rubric for Declarative Knowledge (Knowledge/Understanding of concepts, generalizations, facts – related to the first goal in this course)
  - Rubric for Procedural Knowledge (Knowledge/Understanding and Inquiry – related to the second goal in this course which focuses on the skills required for performance using manipulative, thinking and reasoning skills.)
  - Rubric for Collaborative Group Work (Learning Skills)
  - Partial Rubric for an Experimental Inquiry
  - Partial Rubric for a Research Inquiry
  - Rubric for a Written Report
- Task-specific rubrics See TSM 5C: Developing Task-Specific Rubrics, p. 16 of the Teacher Support Materials in Grade 10 Science, Public Profile, Academic.

Assessment must be embedded within the instructional process throughout each unit rather than being an isolated event at the end. Often, the learning and assessment tasks are the same, with formative assessment provided throughout the activity. In every case, the desired demonstration of learning is articulated at the beginning and the learning activity is planned to make that demonstration possible. When planning learning activities for Physics, this process of beginning with the end in mind helps to keep focus on the Expectations and to reduce the inclination to expand what is taught beyond what is required by the guideline.

Assessment, Evaluation and Reporting are tied to the Learning Expectations and Achievement Chart for Science, pp. 172-175 in *The Ontario Curriculum, Grades 11 and 12: Science, 2000*. Every learning activity and its assessment should collect data for making judgments about performance in one or more of the Achievement Categories: Knowledge and Understanding, Inquiry, Communications and Making Connections. Within each unit and across the course, teachers must collect sufficient data (in kind and number) to make valid judgments about each student’s performance in all Categories.

In the end, whether the evaluation of the assessment data is expressed as Levels of Achievement or as a percentage based on those Levels, that judgment must be based on each student’s performance based on the criteria, not relative to other students’ performances. Final evaluations should reflect the teacher’s informed, professional judgment of each student’s most consistent level of performance in each category of the Achievement Chart.

A wide and balanced range of assessment strategies is needed to accommodate the varied learning styles of all students, to meet the needs of students with special needs, and to encompass a broadened range of knowledge and skills Expectations.

There must be opportunities for students to demonstrate learning at all levels of the Achievement Chart. Strategies include:

- diagnostic, formative and summative assessments;
- performance tasks and pencil-and-paper instruments. Both are needed to assess the full range of Expectations;
- both teacher assessment and student (self and peer) assessment. With clearly articulated criteria, students become partners in the assessment process;
- both individual and group assessment. When students are engaged in group tasks it is appropriate to consider group interaction as an indicator of each student’s learning skills. However, assessment must focus primarily on each student’s individual demonstration of the Learning Expectations.

By curriculum policy, the Final Summative Evaluation of a course accounts for 30 per cent of the final mark recorded for the course. A recommended composition of that component is as follows:

- Written examination including a variety of question styles including multiple choice, short answer, lab-based questions, extended response, and problem solving, synthesis, analysis, and societal implications. An excellent reference for this component is the OTIP - Ontario Teacher Inservice Program, which was part of the OAC Physics Examination Review in which all schools in the province participated in the 1990s. [Contact your board's Superintendent of Program for information about the OAC TIP program if documents are not located in your school.] A laboratory practical examination could also be used to contribute to this portion of the final grade.
- Using the knowledge of physics principles developed throughout this course students make and report on a labour-saving/useful device. The report must include an explanation of the physics principles involved.

Accommodations

Students with special needs, whether identified formally or not, need additional supports to succeed in Grade 11 Physics. For each identified student, read the Individual Education Plan (IEP) for information about specific accommodations designed to compensate for specific disabilities. The following are examples of accommodations and aids that may be helpful for students. Where there are specific accommodations required in an activity, the suggestions are noted with the activity description.

- ensure that peer helpers are available when students are working in small groups
- provide handout sheets with sample calculations and specific skill instructions
- help students create data charts into which they record information.
- advise special education staff in advance when students are working on major assignments
- record key words on the board when students are expected to make their own notes
- allow students to report verbally to a scribe (teacher or student) who can then help in note making
- permit students a wide range of options for recording and reporting their work to utilize student strengths (e.g., drawings, diagrams, flow charts, concept maps)
- timelines may need to be extended to give students more time to process language and put their thoughts into words
- where an activity requires reading, give it in advance to students or provide a selection of materials at different reading levels

Students in English as a Second Language/English Literacy Development programs may require additional supports.

- have students keep a science dictionary of terms using pictures and first language words
- where an activity requires reading, give it in advance to students
- permit the use of a translation dictionary on assessments
- provide additional time on assessments for dictionary use and processing language
- have the teacher-librarian identify resources with appropriate reading level when research is required
- advise ESL/ESD staff in advance when significant written work is required

Resources

Note: The URLs for the websites have been verified by the writer prior to publication. Given the frequency with which these designations change, teachers should always verify the websites prior to assigning them for student use.

General References on Science Education

Armstrong, Thomas. *Multiple Intelligences in the Classroom*. Alexandria, VA: Association for Supervision and Curriculum Development. 1994. ISBN 0-87120-230-1

Brown, John L. *Observing Dimensions of Learning in Classrooms and Schools*. Alexandria, VA: Association for Supervision and Curriculum Development. 1995. ISBN 0-87120-255-7

Burke, Kay. *How to Assess Thoughtful Outcomes*. Palatine, Illinois: IRI/Skylight Publishing, Inc. 1993. ISBN 0-932935-58-3 (1-800-348-4474)

Herman, Aschbacher and Winters. *A Practical Guide to Alternative Assessment*. Association for Supervision and Curriculum Development. 1992. ISBN 0-87120-197-6

McDonald, Joseph P. et al. *Graduation by Exhibition: Assessing Genuine Achievement*. Alexandria, VA: Association for Supervision and Curriculum Development. 1993. ISBN 0-87120-204-2

Zemelman, Daniels and Hyde. *Best Practice: New Standards for Teaching and Learning in America's Schools.* Portsmouth, NH: Heinemann. 1993. ISBN 0-435-08788-6

General Internet Resources

Schools should develop and maintain web sites on which selected resources are listed, particularly those which have links to other science references. One site, with very extensive links, is The Internet Public Library (http://www.ipl.org – lower case necessary).

Other general science sites include:

American Association for the Advancement of Science - http://www.aaas.org/

Association for Supervision and Curriculum Development - http://www.ascd.org/ (a variety of high quality publications and videos on a wide variety of topics. Many principals and superintendents have memberships and can purchase materials at reduced rates. Also the home of *Educational Leadership* magazine)

Canadian government and research sites related to science and engineering http://www.nserc.ca/relate.htm

CBC Educational Resources - http://www.cbc.ca/insidecbc/educational/

Education Network of Ontario - http://www.enoreo.on.ca/

Education resources on the web (Canadian site) http://www.educ.uvic.ca/depts/snsc/pages/weblinks/weblinks.htm

EDU Web Index to find anything on the Ministry's web site http://www.edu.gov.on.ca/eng/webmap.html

Gateway to Educational Materials - http://www.thegateway.org/

Kathy Schrock's Guide for Educators - http://discoveryschool.com/schrockguide/

Midwest Mathematics and Science Consortium (MSC) - http://www.ncrel.org/msc/msc.htm

National Science Foundation (USA) - http://www.nsf.gov/

National Staff Development Council issues of implementation - http://www.nsdc.org/

Online Resources for Assessment - http://www.rmcdenver.com/useguide/assessme/online.htm

Ontario Ministry of Education (EDU) -- curriculum documents page http://www.edu.gov.on.ca/eng/document/curricul/curricul.html

Regional Education Laboratories in the USA focus on educational research http://www.sedl.org/RELs.html

Science Museum, London, England - http://www.nmsi.ac.uk/science_museum_fr.htm

Science Museum, Munich, Germany (Deutsches Museum) - http://www.deutsches-museum.de/e_index.htm

Science Teachers Association of Ontario (STAO) links to science sites
http://www.stao.org/hotlinks.htm

STAR Centre for Academic Renewal (Texas) - http://www.starcenter.org/

USA National Academy of Sciences - http://www.nas.edu/

Physics References

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

Wolfe, T. and J. Elgin. *Physics Today 1.* Prentice-Hall Canada Inc., 1989. ISBN 0-13-669391-1

General Physics Internet Resources

Glenbrook South The Physics Classroom
- http://www.glenbrook.k12.il.us/gbssci/phys/Class/BBoard.html
- http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html

Covers most Physics topics.

University of Guelph - http://eta.physics.uoguelph.ca/tutorials/index.html
A collection of tutorials.

Ghozx web site - http://www.ghozx.com
This is a general site maintained by David Miller, a teacher in Niagara Falls.

Science-Ebooks - http://www.science-ebooks.com/physics.htm
This site has a variety of links to other physics sites.

Java Applets on Physics - http://pathfinder.esu2.k12.ne.us/java/physics/physengl/physengl.htm
A variety of physics Java applets

University of Queensland - http://www.physics.uq.oz.au/people/mcintyre/PH145/optics/geommain.shtml
Geometric optics site

How Stuff Works - http://www.howstuffworks.com
General explanations of how technologies work.

Physics Demonstrations - http://sprott.physics.wisc.edu/demobook/intro.htm
A variety of physics demonstrations.

About: The Human Internet - http://physics.about.com/education/physics/library
Physics in the News

Canadian Association of Physicist - http://www.cap.ca
The association web site

The American Institute of Physics - http://www.aip.org
The association web site

Netscape Physics site - http://search.netscape.com/Science/Physics
Many links to physics concepts

Yahoo Physics site - http://dir.yahoo.com/Science/Physics/
Many links to physics concepts

Yahoo Nobel Prize winners
http://dir.yahoo.com/Society_and_Culture/Issues_and_Causes/Philanthropy/Organizations/Grant_Making_Foundations/Nobel_Foundation/Nobel_Prize_in_Physics/
Nobel Prize Winners

Encarta Encyclopedia - http://encarta.msn.com/category/CategoryMedia.asp?cat=69&pn=0
Many links to physics concepts

"What use is Physics to me, if I want a job?" is addressed at
- http://www.science.mcmaster.ca/scs

Specific Physics Topics Internet Resources

Yahoo Mechanics - http://dir.yahoo.com/Science/Physics/Mechanics/
Many mechanics links
http://dir.yahoo.com/Science/Physics/Mechanics/Amusement_Park_Ride_Physics/
Physics at the amusement park

Netscape optics - http://search.netscape.com/Science/Physics/Optics
Many links to optics concepts

Yahoo Lasers - http://dir.yahoo.com/Science/Physics/Lasers/
Many links to lasers

Yahoo Optical Engineering - http://dir.yahoo.com/Science/Engineering/Optical_Engineering/
Many links to optical engineering

Davidson College Applets - http://entropy.davidson.edu/alumni/MiLee/java/Final_Optics/optics.htm
Optics Bench a Java Script optics program for your web browser.

Molecular Expressions - http://www.micro.magnet.fsu.edu/optics/index.html
Science, Optics and You is a science curriculum package being developed for teachers, students, and parents.

Software Teaching of Modular Physics - http://www.ph.surrey.ac.uk/stomp/
STOMP computer based teaching

University of Oregon - http://guernsey.uoregon.edu/~phdemo/demo/Light_and_Optics/LO-Optics.html
Descriptions of twelve demonstrations of light and optics from the University of Oregon.

Netscape Sound
http://search.netscape.com/Science/Technology/Acoustics%2c_Ultrasound_and_Vibrationlinks to sound

Newtscape Electromagnetism - http://search.netscape.com/Science/Physics/Electromagnetism
many links to electromagnetism

Yahoo Magnetism - http://dir.yahoo.com/Science/Physics/Magnetism/
many links to magnetism

http://dir.yahoo.com/Science/Physics/Magnetism/Electromagnetism/
many links to electromagnetism

Netscape Energy - http://search.netscape.com/Science/Technology/Energy
many links to energy sites

IE rubric search-http://www.glenbrook.k12.il.us/gbssci/phys/projects/q1/tparub.html
rubric for physics investigation

Software

Interactive Physics 2000

Science Works

OSS Considerations

Students can apply and refine the skills, knowledge and habits of mind they acquire in SPH3U through Cooperative Education, work experience and service placements within the community. They also have the opportunity to explore various science related careers related to the course and consider them when they are developing their Annual Education Plan (AEP).

- A work site placement must be directly connected to the Expectations of SPH3U if it is to contribute to a student's perspective of future careers or educational opportunities. The wording in the document *Cooperative Education and Other forms of Experiential Learning* (*Ontario, Ministry of Education, 2000*) provides clear direction, and should be the focus of the personalized learning plans for students. "The personalized learning plan must include the following: the curriculum expectations of the related course that describe the knowledge and skills the student will extend and refine through application and practice at the workplace" (p. 23, emphasis added). The placement is not intended to introduce the student to the Expectations, but should connect closely enough that significant Expectations are clearly extended and refined in a workplace setting. Both workplace and community experiences may offer unique opportunities for students to achieve the goal of SPH3U "To relate science to technology, society, and the environment" and to gain experience in the *Science Investigative Skills* defined at the beginning of the course description in the guideline. The personalized placement-learning plan of a student who has an Individual Education Plan (IEP) must be developed with direct reference to the IEP.
- Students are required to complete 40 hours of community involvement activities prior to graduation. Volunteer work in elementary or secondary schools with science and technology teachers, with a board of education or municipal health and safety, physical plant maintenance (electrical, construction), or information technology department would provide connections to the goals of SPH3U while supporting the intent of the service to encourage students to develop awareness and understanding of civic responsibility and the role they can play in supporting and strengthening their communities.
- Students graduating from Ontario schools must be technologically literate. Through the study of SPH3U students must come to understand and apply technological concepts, to use computers in various applications, and to analyse the implications of technology on individuals and society.

Coded Expectations, Physics, Grade 11, University Preparation, SPH3U

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 (e.g., check all electrical equipment for damage prior to conducting an experiment);

SIS.02 · select appropriate instruments and use them effectively and accurately in collecting observations and data (e.g., collect data accurately using stopwatches, photogates, or data loggers);

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., investigate the relationships among force, mass, and acceleration);

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., interpret data, using graphs and graphical analysis techniques; explain, using a ray diagram, the operation of an optical instrument);

SIS.06 · use appropriate scientific models (theories, laws, explanatory devices) to explain and predict the behaviour of natural phenomena (e.g., use the kinetic molecular theory of matter to explain thermal energy and its transfer [heat]); use ray diagrams to predict the location and nature of images created by lenses);

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 (units of measurement of the *Système international d'unités*, or International System of 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., electrical engineer, computer technologist).

Forces and Motion

Overall Expectations

FMV.01 · demonstrate an understanding of the relationship between forces and the acceleration of an object in linear motion;

FMV.02 · investigate, through experimentation, the effect of a net force on the linear motion of an object, and analyse the effect in quantitative terms, using graphs, free-body diagrams, and vector diagrams;

FMV.03 · describe the contributions of Galileo and Newton to the understanding of dynamics; evaluate and describe technological advances related to motion; and identify the effects of societal influences on transportation and safety issues.

Specific Expectations

Understanding Basic Concepts

FM1.01 – define and describe concepts and units related to force and motion (e.g., vectors, scalars, displacement, uniform motion, instantaneous and average velocity, uniform acceleration, instantaneous and average acceleration, applied force, net force, static friction, kinetic friction, coefficients of friction);

FM1.02 – describe and explain different kinds of motion, and apply quantitatively the relationships among displacement, velocity, and acceleration in specific contexts;

FM1.03 – analyse uniform motion in the horizontal plane in a variety of situations, using vector diagrams;

FM1.04 – identify and describe the fundamental forces of nature;

FM1.05 – analyse and describe the gravitational force acting on an object near, and at a distance from, the surface of the Earth;

FM1.06 – analyse and describe the forces acting on an object, using free-body diagrams, and determine the acceleration of the object;

FM1.07 – state Newton's laws, and apply them to explain the motion of objects in a variety of contexts;

FM1.08 – analyse in quantitative terms, using Newton's laws, the relationships among the net force acting on an object, its mass, and its acceleration.

Developing Skills of Inquiry and Communication

FM2.01 – design and carry out an experiment to identify specific variables that affect motion (e.g., conduct an experiment to determine the factors that affect the motion of an object sliding along a surface);

FM2.02 – carry out experiments to verify Newton's second law of motion;

FM2.03 – interpret patterns and trends in data by means of graphs drawn by hand or by computer, and infer or calculate linear and non-linear relationships among variables (e.g., analyse and explain the motion of objects, using displacement-time graphs, velocity-time graphs, and acceleration-time graphs);

FM2.04 – analyse the motion of objects, using vector diagrams, free-body diagrams, uniform acceleration equations, and Newton's laws of motion.

Relating Science to Technology, Society, and the Environment

FM3.01 – explain how the contributions of Galileo and Newton revolutionized the scientific thinking of their time and provided the foundation for understanding the relationship between motion and force;

FM3.02 – evaluate the design of technological solutions to transportation needs and, using scientific principles, explain the way they function (e.g., evaluate the design, and explain the operation of, airbags in cars, tread patterns on car tires, or braking systems);

FM3.03 – analyse and explain the relationship between an understanding of forces and motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies (including terrestrial and space vehicles) and recreation and sports equipment.

Energy, Work, and Power

Overall Expectations

EWV.01 · demonstrate an understanding, in qualitative and quantitative terms, of the concepts of work, energy (kinetic energy, gravitational potential energy, and thermal energy and its transfer [heat]), energy transformations, efficiency, and power;

EWV.02 · design and carry out experiments and solve problems involving energy transformations and the law of conservation of energy;

EWV.03 · analyse the costs and benefits of various energy sources and energy-transformation technologies that are used around the world, and explain how the application of scientific principles related to mechanical energy has led to the enhancement of sports and recreational activities.

Specific Expectations

Understanding Basic Concepts

EW1.01 – define and describe the concepts and units related to energy, work, and power (e.g., energy, work, power, gravitational potential energy, kinetic energy, thermal energy and its transfer [heat], efficiency);

EW1.02 – identify conditions required for work to be done, and apply quantitatively the relationships among work, force, and displacement along the line of the force;

EW1.03 – analyse, in qualitative and quantitative terms, simple situations involving work, gravitational potential energy, kinetic energy, and thermal energy and its transfer (heat), using the law of conservation of energy;

EW1.04 – apply quantitatively the relationships among power, energy, and time in a variety of contexts;

EW1.05 – analyse, in quantitative terms, the relationships among per-cent efficiency, input energy, and useful output energy for several energy transformations.

Developing Skills of Inquiry and Communication

EW2.01 – design and carry out experiments related to energy transformations, identifying and controlling major variables (e.g., design and carry out an experiment to identify the energy transformations of a swinging pendulum, and to verify the law of conservation of energy; design and carry out an experiment to determine the power produced by a student);

EW2.02 – analyse and interpret experimental data or computer simulations involving work, gravitational potential energy, kinetic energy, thermal energy and its transfer (heat), and the efficiency of the energy transformation (e.g., experimental data on the motion of a swinging pendulum or a falling or sliding mass in terms of the energy transformations that occur);

EW2.03 – communicate the procedures, data, and conclusions of investigations involving work, mechanical energy, power, thermal energy and its transfer (heat), and the law of conservation of energy, using appropriate means (e.g., oral and written descriptions, numerical and/or graphical analyses, tables, diagrams).

Relating Science to Technology, Society, and the Environment

EW3.01 – analyse, using their own or given criteria, the economic, social, and environmental impact of various energy sources (e.g., wind, tidal flow, falling water, the sun, thermal energy and its transfer [heat]) and energy-transformation technologies (e.g., hydroelectric power plants and energy transformations produced by other renewable sources, fossil fuel, and nuclear power plants) used around the world;

EW3.02 – analyse and explain improvements in sports performance, using principles and concepts related to work, kinetic and potential energy, and the law of conservation of energy (e.g., explain the importance of the initial kinetic energy of a pole vaulter or high jumper).

Waves and Sound

Overall Expectations

WSV.01 · demonstrate an understanding of the properties of mechanical waves and sound and the principles underlying the production, transmission, interaction, and reception of mechanical waves and sound;

WSV.02 · investigate the properties of mechanical waves and sound through experiments or simulations, and compare predicted results with actual results;

WSV.03 · describe and explain ways in which mechanical waves and sound are produced in nature, and evaluate the contributions to entertainment, health, and safety of technologies that make use of mechanical waves and sound.

Specific Expectations

Understanding Basic Concepts

WS1.01 – define and describe the concepts and units related to mechanical waves (e.g., longitudinal wave, transverse wave, cycle, period, frequency, amplitude, phase, wavelength, velocity, superposition, constructive and destructive interference, standing waves, resonance);

WS1.02 – describe and illustrate the properties of transverse and longitudinal waves in different media, and analyse the velocity of waves travelling in those media in quantitative terms;

WS1.03 – compare the speed of sound in different media, and describe the effect of temperature on the speed of sound;

WS1.04 – explain and graphically illustrate the principle of superposition, and identify examples of constructive and destructive interference;

WS1.05 – analyse the components of resonance and identify the conditions required for resonance to occur in vibrating objects and in various media;

WS1.06 – identify the properties of standing waves and, for both mechanical and sound waves, explain the conditions required for standing waves to occur;

WS1.07 – explain the Doppler effect, and predict in qualitative terms the frequency change that will occur in a variety of conditions;

WS1.08 – analyse, in quantitative terms, the conditions needed for resonance in air columns, and explain how resonance is used in a variety of situations (e.g., analyse resonance conditions in air columns in quantitative terms, identify musical instruments using such air columns, and explain how different notes are produced).

Developing Skills of Inquiry and Communication

WS2.01 – draw, measure, analyse, and interpret the properties of waves (e.g., reflection, diffraction, and interference, including interference that results in standing waves) during their transmission in a medium and from one medium to another, and during their interaction with matter;

WS2.02 – design and conduct an experiment to determine the speed of waves in a medium, compare theoretical and empirical values, and account for discrepancies;

WS2.03 – analyse, through experimentation, the conditions required to produce resonance in vibrating objects and/or in air columns (e.g., in string instruments, tuning forks, wind instruments), predict the conditions required to produce resonance in specific cases, and determine whether the predictions are correct through experimentation.

Relating Science to Technology, Society, and the Environment

WS3.01 – describe how knowledge of the properties of waves is applied in the design of buildings (e.g., with respect to acoustics) and of various technological devices (e.g., musical instruments, audio-visual and home entertainment equipment), as well as in explanations of how sounds are produced and transmitted in nature, and how they interact with matter in nature (e.g., how organisms produce or receive infrasonic, audible, and ultrasonic sounds);

WS3.02 – evaluate the effectiveness of a technological device related to human perception of sound (e.g., hearing aid, earphones, cell phone), using given criteria;
WS3.03 – identify sources of noise in different environments (e.g., traffic noise in neighbourhoods adjacent to highways), and explain how such noise can be reduced to acceptable levels (e.g., noise can be reduced by the erection of highway noise barriers or the use of protective headphones).

Light and Geometric Optics

Overall Expectations

LGV.01 · demonstrate an understanding of the properties of light and the principles underlying the transmission of light through a medium and from one medium to another;
LGV.02 · investigate the properties of light through experimentation, and illustrate and predict the behaviour of light through the use of ray diagrams and algebraic equations;
LGV.03 · evaluate the contributions to such areas as entertainment, communications, and health made by the development of optical devices and other technologies designed to make use of light.

Specific Expectations

Understanding Basic Concepts

LG1.01 – define and describe concepts and units related to light (e.g., reflection, refraction, partial reflection and refraction, index of refraction, total internal reflection, critical angle, focal point, image);
LG1.02 – describe the scientific model for light and use it to explain optical effects that occur as natural phenomena (e.g., apparent depth, shimmering, mirage, rainbow);
LG1.03 – predict, in qualitative and quantitative terms, the refraction of light as it passes from one medium to another, using Snell's law;
LG1.04 – explain the conditions required for total internal reflection, using light-ray diagrams, and analyse and describe situations in which these conditions occur;
LG1.05 – describe and explain, with the aid of light-ray diagrams, the characteristics and positions of the images formed by lenses;
LG1.06 – describe the effects of converging and diverging lenses on light, and explain why each type of lens is used in specific optical devices;
LG1.07 – analyse, in quantitative terms, the characteristics and positions of images formed by lenses.

Developing Skills of Inquiry and Communication

LG2.01 – demonstrate and illustrate, using light-ray diagrams, the refraction, partial refraction and reflection, critical angle, and total internal reflection of light at the interface of a variety of media;
LG2.02 – carry out an experiment to verify Snell's law;
LG2.03 – predict, using ray diagrams and algebraic equations, the image position and characteristics of a converging lens, and verify the predictions through experimentation;
LG2.04 – carry out experiments involving the transmission of light, compare theoretical predictions and empirical evidence, and account for discrepancies (e.g., given the index of refraction, predict and verify the critical angle of incidence of a substance; given the focal length of a lens, predict and verify the position and characteristics of an image);
LG2.05 – construct, test, and refine a prototype of an optical device (e.g., construct at least one of the following: telescope, microscope, binoculars, periscope, device producing a mirage or a shimmering effect).

Relating Science to Technology, Society, and the Environment

LG3.01 – describe how images are produced and reproduced for the purposes of entertainment and culture (e.g., in movie theatres, in audio-visual and home entertainment equipment, in optical illusions);

LG3.02 – evaluate, using given criteria, the effectiveness of a technological device or procedure related to human perception of light (e.g., eyeglasses, contact lenses, virtual reality "glasses", infra-red or low light vision sensors, laser surgery);

LG3.03 – analyse, describe, and explain optical effects that are produced by technological devices (e.g., periscopes, binoculars, optical fibres, retro-reflectors, cameras, telescopes, microscopes, overhead projectors).

Electricity and Magnetism

Overall Expectations

EMV.01 · demonstrate an understanding of the properties, physical quantities, principles, and laws related to electricity, magnetic fields, and electromagnetic induction;

EMV.02 · carry out experiments or simulations, and construct a prototype device, to demonstrate characteristic properties of magnetic fields and electromagnetic induction;

EMV.03 · identify and describe examples of domestic and industrial technologies that were developed on the basis of the scientific understanding of magnetic fields.

Specific Expectations

Understanding Basic Concepts

EM1.01 – define and describe the concepts and units related to electricity and magnetism (e.g., electric charge, electric current, electric potential, electron flow, magnetic field, electromagnetic induction, energy, power, kilowatt-hour);

EM1.02 – describe the two conventions used to denote the direction of movement of electric charge in an electric circuit (i.e., electric current [movement of positive charge] and electron flow [movement of negative charge]), recognizing that electric current is the preferred convention;

EM1.03 – describe the properties, including the three-dimensional nature, of magnetic fields;

EM1.04 – describe and illustrate the magnetic field produced by an electric current in a long straight conductor and in a solenoid;

EM1.05 – analyse and predict, by applying the right-hand rule, the direction of the magnetic field produced when electric current flows through a long straight conductor and through a solenoid;

EM1.06 – state the motor principle, explain the factors that affect the force on a current-carrying conductor in a magnetic field, and, using the right-hand rule, illustrate the resulting motion of the conductor;

EM1.07 – analyse and describe electromagnetic induction in qualitative terms, and apply Lenz's law to explain, predict, and illustrate the direction of the electric current induced by a changing magnetic field, using the right-hand rule;

EM1.08 – compare direct current (DC) and alternating current (AC) in qualitative terms, and explain the importance of alternating current in the transmission of electrical energy;

EM1.09 – explain, in terms of the interaction of electricity and magnetism, and analyse in quantitative terms, the operation of transformers (e.g., describe the basic parts and the operation of step-up and step-down transformers; solve problems involving energy, power, potential difference, current, and the number of turns in the primary and secondary coils of a transformer).

Developing Skills of Inquiry and Communication

EM2.01 – conduct an experiment to identify the properties of magnetic fields (e.g., use magnetic compasses and iron filings to identify the properties of magnetic fields), and describe the properties that they find;

EM2.02 – interpret and illustrate, on the basis of experimental data, the magnetic field produced by a current flowing in a long straight conductor and in a coil;

EM2.03 – conduct an experiment to identify the factors that affect the magnitude and direction of the electric current induced by a changing magnetic field;

EM2.04 – construct, test, and refine a prototype of a device that operates using the principles of electromagnetism (e.g., construct an operating prototype of one of the following devices: electric bell, loudspeaker, ammeter, electric motor, electric generator).

Relating Science to Technology, Society, and the Environment

EM3.01 – analyse and describe the operation of industrial and domestic technological systems based on principles related to magnetic fields (e.g., electric motors, electric generators, components in home entertainment systems, computers, doorbells, telephones, credit cards);

EM3.02 – describe the historical development of technologies related to magnetic fields (e.g., electric motors and generators, cathode ray [TV] tubes, medical equipment, loudspeakers, magnetic information storage).

Unit 1: Forces and Motion

Time: 24 hours

Unit Description

In this unit the technological applications of motion and societal influences on transportation and safety issues are studied. The students develop an understanding of the relationship between forces and the acceleration of an object in linear motion through experimentation and analysis. The contributions of Galileo and Newton to the understanding of dynamics are considered. The end-of-unit task is a research-based investigation of the underlying principles involved in transportation and recreation, relying on the physics learned in the unit as well as leading into new fields of design and analysis. Students are also asked to brainstorm ideas for the final assessment task – perhaps a labour saving device relating to transportation or recreation.

Unit Synopsis Chart

Activity	Time	Expectations	Assessment	Task Focus
1.1 Review of Straight Line Motion	240 min	FMV.01, FM1.01, FM1.02, FM1.03, FM3.02, FM3.03	I, MC	Teacher directed lessons; student designed investigations; applications problem solving; use of probe-ware; introduction to graphical analysis of motion.
1.2 Graphical Analysis	210 min	FMV.02, FMV.03, FM1.01, FM1.02, FM1.03, FM2.03, FM3.03	I, MC	Students analyse a wide variety of data – anecdotal, given data sets, graphs, directly observed data.
1.3 Forces	270 min	FMV.01, FMV.02, FM1.04, FM1.05, FM1.07, FM1.08, FM2.01, FM2.02	I, C	Research on forces; teacher lesson; student-designed investigations on how forces affect motion.
1.4 Vectors Free-body Diagrams Newton's Laws	240 min	FMV.01, FMV.02, FMV.03, FM1.06, FM1.08, FM2.03, FM2.04, FM3.02, FM3.03	K, MC	Students draw vector diagrams and solve problems; students apply free-body diagrams and Newton's second law to solve practical problems.
1.5 Newton and Galileo	240 min	FMV.01, FMV.02, FMV.03, FM1.07, FM2.04, FM3.01	MC, C	Teacher assisted research on the Third Law and its historical and current applications in small groups; oral presentations.
1.6 End-of-unit Task	240 min	FMV.03, FM3.02, FM3.03	K, I, MC, C	Research and written/ oral reports on technology applications of forces and motion.

Unit Planning Notes

- Gather probe-ware, software and motion detecting hardware.
- Establish link between motion and transportation, recreation (political, economic, environment and safety).
- Prepare historical resources regarding Newton and Galileo.

Resources

University of Guelph Tutorial Collection - http://www.physics.uoguelph.ca/tutorials/
Many tutorials on physics.

Glenbrook South Physics Classroom - http://www.glenbrook.k12.il.us/gbssci/phys/Class/BBoard.html
Covers many topics, most with graphics.

The Multimedia Physics - http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html
The Multimedia Physics Studios consists of a collection of GIF animations and accompanying explanations

Ontario Science Centre, Science North, and other heritage sites and museums, which provide background on earlier transportation forms and recreation activities. The following website references all museums and heritage sites in Ontario by region
http://www.gov.on.ca/mczcr/english/culdiv/heritage/muinfo/htm

Misconceptions: the following websites provide background on common misconceptions
http://www.ced.appstate.edu/intercollege/3850/studwork/danoliv/
http://www.physics.uoguelph.ca/people/gfac/miscon97.htm

Software
Interactive Physics 2000

Science Works

Activity 1.1: Review of Straight Line Motion

Time: 240 minutes

Description

This activity allows students to review terminology and concepts of motion studied in Grade 10. To facilitate this, students design experiments involving motion, solve problems, generate and analyse graphs, and apply vector analysis. Students relate motion to transportation and leisure in order to begin preparation for the end-of-unit task.

Strands & Learning Expectations

Strand(s): Forces and Motion

Specific Expectations
FM1.01 - define and describe concepts and units related to force and motion
FM1.02 - describe and explain different kinds of motion, and apply quantitatively the relationships among displacement, velocity, and acceleration in specific contexts
FM1.03 - analyse uniform motion in the horizontal plane in a variety of situations, using vector diagrams
FM3.02 - evaluate the design of technological solutions to transportation needs and, using scientific principles, explain the way they function
FM3.03 - analyse and explain the relationship between an understanding of forces and motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies and recreation and sports equipment.

Prior Knowledge & Skills

- Students draw on the knowledge and skills gained in the motion units in Grade 10 Science, Academic. This includes graphing, problem solving, and laboratory inquiry skills.

Planning Notes

- In order to accommodate the laboratory investigation, teachers may wish to have a range of motion measurement devices prepared, such as sonic probe-ware, software programs (e.g., Science Works, Smart Pulley), ticker timers, stopwatches, metre sticks and metric tape measures. The students may also request air tracks and smooth ramps.
- Teachers could also prepare some examples of the link between motion and transportation/sports (for the end-of-unit task) as well as introductory ideas on the useful device required in the final assessment tasks. Schedule time to use the Library/Resource Centre or other location where students can have access to computer/Internet.

Teaching/Learning Strategies

1.1.1 Student Activity: Students are introduced to the two relevant culminating activities. The final assessment task requires that the students construct a labour saving/useful device, based on the physics principles studied throughout the course, and to report on the device. The End-of-unit Task (Activity 1.6) requires that the students relate the principles of science to technological improvements in transportation. It also asks how a study of Forces and Motion allows for educated decisions to be made in the field of transportation and recreation.

Teacher Facilitation: Lead students in a brainstorming session so they begin to formulate ideas on the culminating activities. No decision has to be made yet, but throughout the unit and course ask the students to refer back and refine these ideas. If students are unsure, the teacher may ask questions relating to air bags, headrests, seat belts, and other restraining devices used in cars and at amusement parks. A consideration of the use of internal combustion engines to provide “motion” in society allows for political, economic, and environmental discussions.

1.1.2 Student Activity: Working in small groups students design a series of small laboratory investigations which will demonstrate the determination of the velocity of an object, its position, and its acceleration under two different conditions:

i. constant velocity in a straight line
ii. constant acceleration in a straight line

Teacher Facilitation: Students may need help remembering some of the concepts and investigations covered in Grade 10, however by experimenting with their own designs students are given an opportunity to “construct” their own learning. In this introductory activity, allow students to make mistakes without fear of penalty, provided safety issues are addressed at all times. As indicated in the planning notes, have a range of measuring devices on hand, such as motion probe-ware, ticker timers, stopwatches, and metric tape measures. Discuss the vector nature of position, displacement, velocity, and acceleration even at this introductory stage.

1.1.3 Student Activity: Students and teacher brainstorm the derivation, from a velocity-time graph for constant positive acceleration, of the mathematical equations for motion.

$$\vec{v}_2 = \vec{v}_1 + \vec{a}\Delta t$$

$$\Delta\vec{d} = \vec{v}_2\Delta t - \frac{\vec{a}\Delta t^2}{2}$$

$$\Delta\vec{d} = \frac{(\vec{v}_1 + \vec{v}_2)}{2}\Delta t$$

$$\vec{v}_2^{\,2} = \vec{v}_1^{\,2} + 2\vec{a}\Delta\vec{d}$$

$$\Delta\vec{d} = \vec{v}_1\Delta t + \frac{\vec{a}\Delta t^2}{2}$$

Teacher Facilitation: Involve the students as much as possible in the derivation. If necessary give them hints about areas and slopes to “tease” out the relationships.

1.1.4 Student Activity: Students use an accepted strategy, such as the "GRASP" strategy found in many textbooks (**G**iven, **R**equired, **A**nalysis, **S**olution, **P**araphrase), to solve problems involving the equations of motion, but not just restricted to the equations. Problems are designed to require an anecdotal, as well as mathematical, response and wherever possible relate to societal issues, particularly those encompassing transportation and recreation.
Teacher Facilitation: Although some "plug and play" examples are useful for gaining experience with the equations, try to develop more multi-part questions that require the student to "think" rather than just react to the equation. Some examples might include stopping distances while braking, the use of 'picks' in skating, icy roads in Canada and the use of salt and sand.
1.1.5 Student Activity: Using probe-ware or ticker-tapes students measure the velocity, position, and acceleration of an object undergoing motion at constant acceleration and generate the corresponding graphs. Through an analysis of the graphs they review the basic graphical properties, viz.:

- velocity may be determined from the slope of a position-time graph
- displacement may be determined from the area under a velocity-time graph
- acceleration may be determined from the slope of a velocity-time graph

Analysis includes consideration of significant figures in calculations.
Teacher Facilitation: There will be a more detailed analysis in Activity 1.2 so use simple single stage graphs here. Students may need some help to generate smooth parabolic shapes when drawing position-time graphs for accelerated motion. The "PZSC" technique may help:
Plot the **P**oints; **Z**ero slope means **Z**ero velocity; **S**traight lines join points when velocity is con**S**tant; now fill in the **C**urved parts for **C**onstant acceleration.
Try to choose examples that involve the transportation and/or recreation theme.
1.1.6 Student Activity: Students brainstorm the distinction between average velocity and instantaneous velocity and practise using anecdotal and mathematical problems. (**Note:** this is a review of Grade 10). Students examine the vector nature of position, displacement, velocity, and acceleration through examples of displacement along the number line.
Teacher Facilitation: Emphasize that average velocity may be calculated by using the area under the velocity-time graph to determine the displacement, then dividing by the time interval. Discuss in terms of a trip to P.E.I. and back, for example. However, the instantaneous velocity is a description of the velocity at a point in time. Although tangents are used in Activity 1.2, some students will already have been introduced to their use in determining instantaneous velocity. If so, this is a good opportunity to discuss them. The vector nature of position, displacement, velocity, and acceleration should be established here.
1.1.7 Student Activity: Students discuss and summarize any further ideas they have developed regarding the relevance of the study of motion to the end-of-unit task and the final assessment tasks.
Teacher Facilitation: Allow for a free discussion but then require that the students write down a summary of the discussion.
1.1.8 Student Activity: An assessment of the Expectations and the Science Investigative Skills, through students' problem-solving and graphical analysis skills, is completed with emphasis on Knowledge, Inquiry and Making Connections.
Teacher Facilitation: This assessment can be achieved either through observations of student work during Activity 1.1, or through a separate exercise given at the end, or both. A scenario could be provided involving a transportation theme in which a graph is to be drawn, a mathematical problem is to be solved, and an account of political, environmental, or economic relevance is to be provided.

Assessment & Evaluation of Student Achievement

Activity 1.1.8 includes a suggested assessment outline, involving a possible scenario in which a graph could be drawn, strategies used to solve problems, and an evaluation of political, environmental, or economic impact prepared. Rubrics (or checklists) could be provided for the graph and impact analysis to enable self- and/or peer-assessment. A short quiz could assess the Knowledge component.

Rubrics could be used to determine
- how well students understand that the equations of motion are one way of describing motion
- the students' ability to use strategies such as "GRASP" to solve problems
- how well students' design experiments
- students' graphing abilities

Accommodations
- Encourage all students to participate in motion measurements. Examples could include skateboards, scooters, bicycles, and wheelchairs as long as safety precautions are followed, including School and Board Safety policies.
- Ask students who have either temporary or permanent physical exceptionalities to share their experiences on transportation systems.

Resources
Glenbrook South Physics Classroom
http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html#kinema (a collection of GIF animations and accompanying explanations of kinematics concepts)

Glenbrook South Physics Classroom
http://www.glenbrook.k12.il.us/gbssci/phys/Class/1DKin/1DKinTOC.html (an online physics classroom covering most high school concepts) http://www.glenbrook.k12.il.us/gbssci/phys/projects/q1/tparub.html (rubric for physics investigation)

Activity 1.2: Graphical and Vector Analysis
Time: 210 minutes

Description
Students analyse motion using graphing techniques including the measurement of the slopes of secants and tangents. Students use vector diagrams to analyse uniform motion in the horizontal plane in a variety of situations, using transportation and/or recreation themes where feasible.

Strands & Learning Expectations
Strand(s): Forces and Motion

Specific Expectations

FM1.01 - define and describe concepts and units related to force and motion;
FM1.02 - describe and explain different kinds of motion, and apply quantitatively the relationships among displacement, velocity, and acceleration in specific contexts;
FM1.03 - analyse uniform motion in the horizontal plane in a variety of situations, using vector diagrams;
FM2.03 - interpret patterns and trends in data by means of graphs drawn by hand or by computer, and infer or calculate linear and non-linear relationships among variables;
FM3.03 - analyse and explain the relationship between an understanding of forces and motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies and recreation and sports equipment.

Prior Knowledge & Skills
- Students draw on the knowledge and skills gained in the Grade 10 Science, Academic, Motion Unit, including graphing and the addition of vectors.

Planning Notes

- Prepare data sets and graphs for use by the students.
- Have probe-ware available for students to generate their own graph and data sets.
- Use the students' own background and experiences to obtain meaningful examples of types of motion that can be analysed.
- Students will require a "math set" (containing a ruler, protractor and possibly a compass for challenging problems) to aid them in drawing scale diagrams.
- It would be useful to discuss, with the mathematics department, the readiness of students to use trigonometry to solve vector diagrams (including the use of the cosine and sine laws).

Teaching/Learning Strategies

1.2.1 Student Activity: Given sets of data (or by generating their own data through probe-ware) students describe, anecdotally, the motion as it would be observed, and then translate the data into graphs, e.g., given data describing position over time, calculate the corresponding velocity then draw both position- and velocity-time graphs. Given graphs representing motion, students describe the motion anecdotally then sketch alternative graphs, e.g., from a velocity-time graph describe the motion as it would be observed, then sketch the corresponding position- and acceleration-time graphs without resorting to taking measurements from the graph.

Teacher Facilitation: This activity is designed to give the students a "feel" for alternative means of recording observed motion: anecdotal, data sets, graphs (and also equations as studied in Activity 1.1). Save the measurement of tangents etc. until the next activity. Use the transportation and recreation theme when supplying data sets so that students understand why they are learning this material.(e.g., the position of a downhill skier versus time).

1.2.2 Student Activity: Given (or by generating their own) a variety of position- and velocity-time graphs, students calculate the position, velocity, and/or acceleration using areas and slopes. Instantaneous velocity and acceleration may be determined from the slope of the tangent, while average velocity and acceleration may be determined from the slope of the secant. Each analysis is accompanied by an anecdotal description of the motion.

Teacher Facilitation: Include examples involving negative slopes and negative areas. Refer to the "PZSC" technique for drawing curved graphs described in Activity 1.1. Once again try to link to the end-of-unit task by using transportation and recreation themes.

1.2.3 Student Activity: Students use vector addition to determine the resulting motion of objects having two separate component motions, first in 1-dimension, then in 2-dimensions, and solve problems involving the resulting time of travel and displacement, e.g., a ferry crossing from Vancouver Island to the mainland under the action of both its own thrust and an ocean current. [Note that emphasis in Grade 11 is on 1-dimensional analysis. The more sophisticated 2-D examples should be saved for Grade 12.]

Teacher Facilitation: This is a good opportunity to use transportation and recreation themes, e.g., air travel, canoeing, and archery. A mixture of scale diagrams and trigonometry will give students a range of tools with which to approach problems.

1.2.4 Student Activity: An assessment of the Expectations through students' graphical and vector analysis skills is completed, with an emphasis on Knowledge, Inquiry, and Making Connections.

Teacher Facilitation: This assessment can be achieved either through the accumulation of a portfolio of students' graphs and vector analyses completed during Activity 1.2, or through a separate assignment given at the end, or both. A scenario might involve being given a velocity graph of an air flight, with the requirement to calculate average and instantaneous acceleration, and position, and to anecdotally describe the flight. In addition, students may be asked to comment on the economic and environmental significance of the flight (especially if it is a short one).

Assessment & Evaluation of Student Achievement

Activity 1.2.4 includes an assessment outline including a possible scenario in which students' graphing and vector analysing skills, as well as STSE awareness, can be assessed. Checklists could be used for self- and peer-assessment of graphs and vector analysis, and a rubric could be used to assess the students' statements of economic and environmental impact.

Accommodations

- Use the students' own background and experiences to obtain meaningful examples of types of motion that can be analysed.
- Some sensitivity is required when considering recreational themes with physically challenged students and those who may not have access to recreational sites.
- Allow sufficient time for the completion of vector diagrams.
- Anecdotal reports may be replaced by dramatizations.

Resources

University of Guelph tutorial - http://www.physics.uoguelph.ca/tutorials/vectors/vectors.html
University of Guelph tutorial in which the use of vectors in Physics is developed and demonstrated

Glenbrook South Multimedia Physics Studios
http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html#kinema
More GIF animations demonstrating physics concepts

Glenbrook South Multimedia Physics Studios
http://www.glenbrook.k12.il.us/gbssci/phys/mmedia/index.html#vectors
More GIF animations demonstrating physics concepts

Activity 1.3: Forces

Time: 270 minutes

Description

In this third activity students research the fundamental forces of nature in order to hypothesize which of these forces affect an object in motion. They go on to design and conduct an experiment to determine the factors that affect an object sliding along a surface. Students then state an hypothesis and design an experiment to determine which factors affect the acceleration of an object, leading up to Newton's Second Law.

Strands & Learning Expectations

Strand(s): Forces and Motion

Specific Expectations

FM1.04 - identify and describe the fundamental forces of nature;
FM1.05 - analyse and describe the gravitational force acting on an object near, and at a distance from, the surface of the Earth;
FM1.07 - state Newton's laws, and apply them to explain the motion of objects in a variety of contexts;
FM1.08 - analyse in quantitative terms, using Newton's laws, the relationships among the net force acting on an object, its mass, and its acceleration;
FM2.01 - design and carry out an experiment to identify specific variables that affect motion;
FM2.02 - carry out experiments to verify Newton's second law of motion.

Prior Knowledge & Skills

- Students draw on the knowledge and skills gained in the motion units in Grade 10 Science, Academic. This includes problem solving, laboratory inquiry skills, finding slope of a graph, proportionality and the determination of acceleration.

Planning Notes

- Access to the Internet and the learning resource centre of the school will help students in part 1.3.1 of this activity.
- In order to accommodate the laboratory investigations, teachers may wish to have a range of motion measurement devices prepared, such as sonic probe-ware, software programs ticker timers, stopwatches, metre sticks and metric tape measures. The students may also request air tracks and smooth ramps.
- Teachers could also prepare some examples of the link between force and transportation/sports (for the end-of-unit task) as well as introductory ideas on the useful device required in the final assessment task.

Teaching/Learning Strategies

1.3.1 Student Activity: Using the Internet, their text, or other resources students identify the four fundamental forces of nature (strong interaction, electromagnetic force, weak force, and gravitational force).
Teacher Facilitation: This activity is designed to give the students a small taste of "research". Book time on resource centre computers for the Internet research. Explain how search engines work. Outline school/board policies with respect to the use of computers and the Internet.
1.3.2 Student Activity: Students analyse the dependence of the force, acting between two magnets, on distance. Students draw an analogy between magnetism and gravity to validate the predictions of Newton regarding gravitational force acting on an object near, and at a distance from, the Earth's surface. Students examine the proportionalities:

$$\vec{F}_g \propto m_1, \quad \vec{F}_g \propto m_2, \quad \vec{F}_g \propto \frac{1}{d^2}, \quad \vec{F}_g \propto \frac{m_1 m_2}{d^2}, \textit{and finally the relationship}$$

$$\vec{F}_g = \frac{G m_1 m_2}{d^2}$$

Students solve sample questions involving Newton's Law of Universal Gravitation.
Teacher Facilitation: Students may need help remembering what proportionality is. You will need to introduce the symbol "$\propto$". Work through sample questions using the "GRASP" method. Provide simple Newton scales to establish $F_g \propto m$.
Instead of direct substitution in the equation for universal gravitation, encourage students to use "the mass factor," and the "distance factor," and their common sense to decide if it should be bigger or smaller.
1.3.3 Student Activity: Students and teacher brainstorm which factors might affect an object in motion (friction, heat, mass, pushing, pulling, etc.) A discussion of the role of "normal" force is included.
Teacher Facilitation: Allow any idea, not just the "right" answers. Some impractical ideas may generate very interesting discussions (refer to reference to misconceptions in the resources section at the beginning of this unit).
1.3.4 Student Activity: Students pick one factor and design and carry out a simple experiment to determine if that factor does indeed affect the motion. Students compare their results with each other.
Teacher Facilitation: Help, but do not direct, students with the design of the experiments. Encourage students to keep experimental design simple. Join students in a discussion of the results.

1.3.5 Student Activity: Students and teacher brainstorm which factors might affect the acceleration of an object (friction, heat, mass, pushing, pulling, etc.) leading to the design of an experiment to determine the relationship among *F*, *m* and *a*.
Teacher Facilitation: With some guidance students should understand that acceleration would increase with more force and less mass – but to what extent?
1.3.6 Student Activity: Students design and carry out an experiment to determine how force and mass affect acceleration, that is, proportionality statements:

$$\vec{a} \propto \frac{1}{m}, \quad and \quad \vec{a} \propto \vec{F}$$

Students solve linear $F = ma$ problems.
Teacher Facilitation: Be sure that the students design an experiment that is quantitative in nature. Help the students combine the resulting proportionality statements into $F = ma$. Articulate how one proceeds from a proportionality statement to an equation, with k=1 being a condition for the unit, newton. Prepare sample questions for students to work through.
1.3.7 Student Activity: Students discuss and summarize any further ideas they have developed regarding forces and the relevance of forces to the end-of-unit task and the final assessment task.
Teacher Facilitation: Allow for a free discussion but then require that the students write down a summary of the discussion.
1.3.8 Student Activity: Assessment of experimental design, observed laboratory skills and an oral laboratory report.
Teacher Facilitation: Prepare a rubric and/or checklist for assessment of experimental design, observed laboratory skills and oral laboratory report

Assessment & Evaluation of Student Achievement

Provide rubrics (or checklists) for the experiment design and performance to enable self- and/or peer-assessment (see Resources). In particular determine how well the students have understood the direct relationship between acceleration and force, and the inverse relationship between acceleration and mass, and how well their investigation was able to show these relationships.

Accommodations

- Partner students for laboratory investigations to allow for sharing ideas and assisting in completion of activities.
- Allow extra time to complete investigations

Resources

University of Tennessee - http://www.onlineastronomy.com/astr162/lect/cosmology/forces.html
Astronomy lecture series.

Astronomy 161 The Solar System
http://www.onlineastronomy.com/astr161/lect/history/newtongrav.html
The Universal Law of Gravitation.

Glenbrook South Physics Classroom

http://www.glenbrook.k12.il.us/gbssci/phys/Class/circles/u6l3c.html
Discusses Universal Gravitation; includes graphics.

http://www.glenbrook.k12.il.us/gbssci/phys/projects/q1/tparub.html
Rubric for physics investigation.

Activity 1.4: Vectors, Free-body Diagrams, and Newton's Laws

Time: 240 minutes

Description

In this fourth activity, students draw scale diagrams to show the addition of applied forces and to find F_{net}. Using the Pythagorean theorem and $F = ma$ students solve problems involving F_{net}. Note that emphasis in Grade 11 is on 1-dimensional analysis. More sophisticated 2-D examples should be saved for Grade 12. Finally, students, link ideas developed in this activity to transportation and recreation leading to the end-of-unit task and final assessment task.

Strand(s) & Learning Expectations

Strand(s): Forces and Motion

Specific Expectations

FM1.06 - analyse and describe the forces acting on an object, using free-body diagrams, and determine the acceleration of the object;
FM1.08 - analyse in quantitative terms, using Newton's Laws, the relationships among the net force acting on an object, its mass, and its acceleration;
FM2.03 - interpret patterns and trends in data by means of graphs drawn by hand or by computer, and infer or calculate linear and non-linear relationships among variables;
FM2.04 - analyse the motion of objects, using vector diagrams, free-body diagrams, uniform acceleration equations, and Newton's Laws of motion;
FM3.02 - evaluate the design of technological solutions to transportation needs and, using scientific principles, explain the way they function;
FM3.03 - analyse and explain the relationship between an understanding of forces in motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies, and recreation and sports equipment.

Prior Knowledge & Skills

- Students draw on the knowledge and skills gained in the motion units in Grade 10 Science, Academic. This includes problem solving, finding slope of a graph, proportionality statements and the determination of acceleration.

Planning Notes

- Students will require a "math set" (containing a ruler, protractor and possibly a compass for challenging problems) to aid them in drawing scale diagrams.
- Teachers may wish to have a range of software to aid with diagram demonstrations.
- Teachers also prepare some examples of the links between forces, vectors, free-body diagrams, Newton's laws and transportation/sports (for the end-of-unit task) as well as introductory ideas on the useful device required in the final assessment task.
- Discuss the use of trigonometry with the mathematics department.

Teaching/Learning Strategies

1.4.1 Student Activity: Using a "math set" students draw scale vector addition diagrams of applied forces to determine the net force in both magnitude and direction, beginning with 1-dimensional examples, then extending to 2 dimensions. Note that emphasis in Grade 11 is on 1-dimensional analysis. More sophisticated 2-D examples should be saved for Grade 12. Students link the concept of vector forces to transportation and recreation,(e.g., a skier on a hill).

Teacher Facilitation: This activity is designed to be hands-on. Students must be encouraged to bring proper equipment to class. Sample problems could be done on the overhead, rather than blackboard, in order to model proper use of actual equipment. Emphasize that direction is an important component of vector addition. Guide students in a brainstorming session on links between vector forces, and transportation and recreation (e.g., navigation, skiing, rocketry, etc.). Emphasize the importance of free-body diagrams for clarity in understanding concepts.

1.4.2 Student Activity – Extension: Students solve vector addition diagrams of applied forces using the Pythagorean formula.

Teacher Facilitation: These problems could be the same as some used in activity 1.4.1 to show why a mathematical treatment is preferred. Students may need remediation with $c^2 = a^2 + b^2$ and its application. Work through sample questions using the "GRASP" method. Use trigonometric solutions if feasible. Use free-body diagrams.

1.4.3 Student Activity: Students use $F = ma$ to solve a variety of real life problems (including both 1-dimensional and, as an optional extension, 2-dimensional situations) that lend themselves to the end-of-unit task. Free-body diagrams are drawn for each example. Students also design a set of sample $F = ma$ problems with solutions using the GRASP method.

Teacher Facilitation: Problems could include forces on automobiles, boats, skiers, rockets, canoes, etc. Students may need help solving linear equations. Discuss with students the minimum information required for sample questions. (e.g., two of *F*, *m* or *a*). Emphasize the concept of a free-body diagram, and use it to assist in problem-solving.

1.4.4 Student Activity: Students discuss and summarize any further ideas they have developed regarding vectors, free-body diagrams and Newton's Laws (in both 1 dimension and, as an optional extension, 2 dimensions) and their relevance to the end-of-unit task and the final assessment task.

Teacher Facilitation: Allow for a free discussion but then require that the students write down a summary of the discussion.

1.4.5 Student Activity: Written quiz/test

Teacher Facilitation: Question types must be of the same style as used in the activities. That is, this should be an authentic evaluation of the students' abilities with at least one student designed question with solution. An incentive could be built in for students' questions designed with a transportation or recreation theme.

Assessment & Evaluation of Student Achievement

A quiz or test can be given to determine if students know the concepts and can connect the concepts to the real world. (See activity 1.4.5) The quiz should include elements which:

- determine the students' ability to draw free-body diagrams
- use these free-body diagrams to perform vector addition of both 1-D and 2-D forces
- use either (or both) scale diagrams or Pythagorean/trigonometry calculations
- use application of $F=ma$ to determine the acceleration and explain the motion anecdotally
- relate the analysis of vectors, free-body diagrams and Newton's Laws to transportation and recreation.

Accommodations

- Allow ample time to complete diagrams
- Encourage students to use a pencil and an eraser for easy corrections

Resources

Ghozx.com - http://24.226.123.161/ghozx/SNC2D0/ip2000/ipindex.htm

The Interactive Physics 2000 page includes a vector addition module that is included in this general site maintained by David Miller, a teacher in Niagara Falls.

University of Kentucky - http://www.pa.uky.edu/~phy211/VecArith/
Interactive java applet for vector manipulation.

The Physics Classroom - http://www.glenbrook.k12.il.us/gbssci/phys/Class/vectors/vectoc.html
Lesson 1: Vectors - Fundamentals and Operations

The Physics Classroom - http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l3a.html
Lesson 3: Newton's Second Law of Motion

Activity 1.5: Applications of Newton's Third Law

Time: 240 minutes

Description

This activity allows students to review forces and motion, particularly Newton's Third Law of motion. By researching the contributions of scientists to the study of forces that cause motion students gain an appreciation for the scientific process and the individuals who helped us define our universe.

Strand(s) & Learning Expectations

Strand(s): Forces and Motion

Specific Expectations
FM1.07 - state Newton's laws, and apply them to explain the motion of objects in variety of contexts;
FM 2.04 - analyse the motion of objects, using vector diagrams, free-body diagrams, uniform acceleration equations, and Newton's laws of motion;
FM 3.01 - explain how the contributions of Galileo and Newton revolutionized the scientific thinking of their time and provided the foundation for understanding the relationship between motion and force.

Prior Knowledge & Skills

- Grade 10 Mathematics, Academic.
- Students who complete a computer technology course or courses that have extensive computer integration will find the skills they learned beneficial.

Planning Notes

- Teachers may wish to have one or more items to promote discussion and brainstorming sessions. These may include presentation software, print media, videos, etc. For discussion in small groups sheets of chart paper should be available.
- Schedule time in advance for the students to use the Library/Resource Centre where the students have access to computers/Internet.

Teaching/Learning Strategies

1.5.1 Student Activity: Students work in small groups designing activities that demonstrate action-reaction forces (Newton's Third Law). Students make a written/oral report on how each activity demonstrates the phenomenon.

Teacher Facilitation: Demonstrate, qualitatively, one example of the phenomenon. Supply materials requested by the individual groups for use in their activities with due consideration for safety. Encourage the students to quantitatively analyse the forces acting on two objects as they interact (equal and opposite). Moderate student involvement in the activity, and their analysis and reporting. This leads to the discussion of the scientists involved with the forces and laws that govern forces and motion.

1.5.2 Student Activity: Students work in pairs to research the historical contribution of Galileo and Newton to the study of forces and motion with respect to the application of these contributions to transportation and recreation.
Teacher Facilitation: This activity can use a Library/Resource Centre research period with access to the Internet. A brief lesson on successful Internet research and navigation should be given. Discuss the procedure for the development and submission of a research paper. Students should be urged to emphasize the scientists' contribution to the theories on force and motion and how these theories change how we view our world and the universe. If desired, misconceptions could be considered here in an historical context, (e.g., the Aristotle's concept that a force is required to maintain constant velocity; Galileo's experiment in dropping cannon balls from the Leaning Tower of Pisa to dispel the concept that heavier objects fall faster.)
1.5.3 Student Activity: An assessment of student achievement through research, presentation and reporting skills with an emphasis on Inquiry, Communication and Knowledge.
Teacher Facilitation: A checklist could be used for assessing Science Investigative Skills while a rubric would assist in assessing presentation/reporting skills. A quiz could be used to assess the students' understanding of Newton's Third Law.

Assessment & Evaluation of Student Achievement

Both a written (or oral) quiz, and a checklist (or rubric) to assess the experimental component, could be used to assess the students' understanding of Newton's Third law, with particular attention paid to the concept that the "action" and "reaction" forces act on *different* objects. For example students could be asked to explain the fallacy "If a horse pulls a cart, and Newton's Third Law requires that the cart pulls back with an equal force, how can anything ever move?" The historical research and presentation assignment lends itself to standard research and presentation rubrics.

Task	Tools	Assessment	Learning Skills
Research process	Self-assessment Checklist	Inquiry, Communication, Making Connections	Work habits
Oral/Written presentation	Rubric	Communication, Making Connections	Organization
Note making and summary of issues	Rubric	Knowledge, Communication, Making Connections	Works Independently

Accommodations

- Encourage students to research the contribution of other scientists (including non-western) who also contributed to the physics of forces and motion.
- Monitor research logs daily to help students stay on task.

Resources

The Physics Classroom - http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l4a.html
Lesson 4: Newton's Third Law of Motion

The Physics Classroom - http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l4b.html
http://www.glenbrook.k12.il.us/gbssci/phys/Class/newtlaws/u2l4b.html

Lesson 4: Newton's Third Law of Motion: Identifying Action and Reaction Force Pairs

Activity 1.6: End-of-unit Task

Time: 240 minutes

Description

In this activity students will evaluate and describe technological advances related to motion, and identify the effects of societal influences on transportation and safety issues. Students also relate the physics studied in this unit to the labour saving device required in the final assessment task. This end-of-unit task is designed to encourage students to use the information and skills they have learned in the unit as well as lead them into new areas of design and issue analysis.

Strand(s) & Learning Expectations

Strand(s): Forces and Motion

Specific Expectations

FM3.02 - evaluate the design of technological solutions to transportation needs and, using scientific principles, explain the way they function;
FM3.03 - analyse and explain the relationship between an understanding of forces and motion and an understanding of political, economic, environmental, and safety issues in the development and use of transportation technologies and recreation and sports equipment.

Planning Notes

- Teachers may wish to have one or more items to promote discussion and brainstorming sessions. These may include presentation software, print media, videos, etc. For discussion in small groups sheets of chart paper should be available.
- Schedule time to use the Library/Resource Centre and access to computers/Internet.

Prior Knowledge & Skills

- Students who have completed a computer technology course or courses that have extensive computer integration will find the skills they learned beneficial.

Teaching/Learning Strategies

1.6.1 Student Activity: Students work in pairs to research the scientific principles underlying the design of technological improvements in transportation. Students are free to choose any mode or aspect of transportation and deliver a report. Students are encouraged to relate the design back to what they learned about Galileo's and Newton's contributions to the study of forces and motion

Teacher Facilitation: Begin with a description or example of technological design and how this improved transportation. Promote discussion on transportation, its history and important moments etc., to help students brainstorm topics. Methodology of Internet search and library searches will help students locate information. Encourage creativity in student choices, such as automobile tire design, ABS braking, Concorde jet design, magnetic levitation trains.

1.6.2 Student Activity: Each pair of students submits a written report explaining how an understanding of forces and motion enables more educated political, economic, environmental, and safety decisions to be made in the transportation and recreation industries. Students should keep their focus on how force and motions affect these areas.

Teacher Facilitation: Provide the necessary tools and information for a successful Internet and library search. Lead the class in discussion to help students understand the perspective they should take in their research and a variety of topics or direction the students could follow (such as the development of safe ski equipment, automobile restraint devices and their compulsory use).

1.6.3 Student Activity: Students work in groups to relate the physics considered within this unit to the labour saving device require in the final assessment.

Teacher Facilitation: Lead the class in a discussion on how this could be linked to the final assessment task. Assist students with information gathering and building on their chosen topic. Devices to be considered may include garden tillers, lawnmowers, can openers, snow blowers.

Assessment & Evaluation of Student Achievement

Rubrics could be used to identify:

- how well the students identified an improvement in transportation technology
- how well they related the improvement to the contributions of Galileo and Newton
- how well the students articulated a connection between forces and motion and at least one (or more) political, economic, environmental, and safety decision (e.g., compulsory safety belts)

Task	Tools	Assessment	Learning Skills
Research process	Self-assessment Checklist	Inquiry, Communication, Making Connections	Working habits
Oral/Written presentation	Rubric	Communication, Making Connections, Inquiry	Organization

Accommodations

- Encourage students to research other scientists (including scientists from outside North America and Europe) who also contributed to the discovery and documentation of forces and motion.
- Encourage students to look for ways in which forces and motion touch their everyday lives
- Monitor research logs daily to assist students to stay on task.

Resources

Ministry of Transportation site - http://www.mto.gov.on.ca/english/
Links to road safety, publications, engineering and technology etc.

Ministry of the Environment site - http://www.ene.gov.on.ca/
Links to Ontario Drive Clean, air quality, smog alerts, etc.