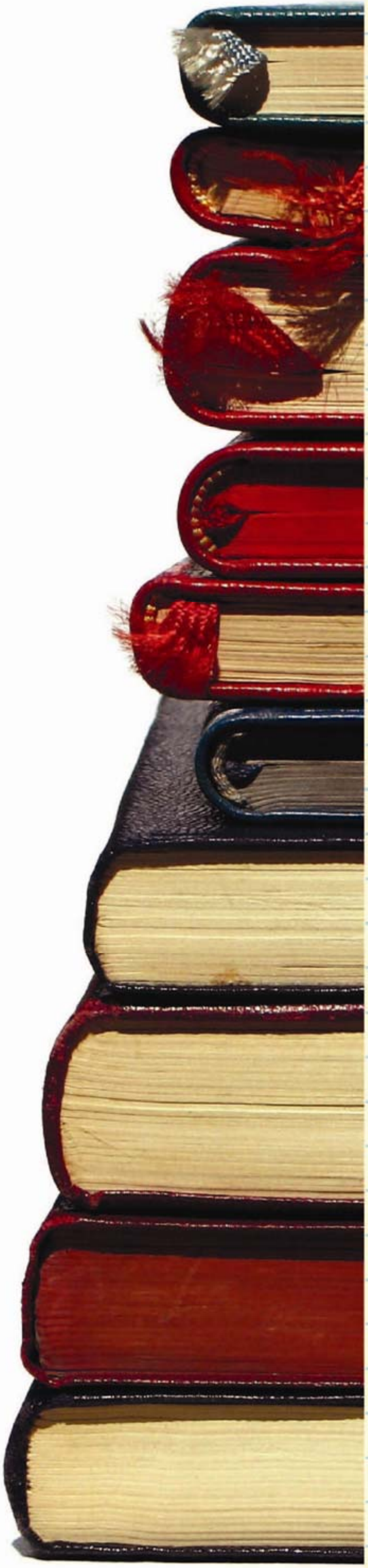

Comprehensive Curriculum

Revised 2008

Physics

Louisiana Department of
EDUCATION

Paul G. Pastorek, State Superintendent of Education

Physics

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Louisiana Comprehensive Curriculum, Revised 2008
Course Introduction

The Louisiana Department of Education issued the *Comprehensive Curriculum* in 2005. The curriculum has been revised based on teacher feedback, an external review by a team of content experts from outside the state, and input from course writers. As in the first edition, the *Louisiana Comprehensive Curriculum*, revised 2008 is aligned with state content standards, as defined by Grade-Level Expectations (GLEs), and organized into coherent, time-bound units with sample activities and classroom assessments to guide teaching and learning. The order of the units ensures that all GLEs to be tested are addressed prior to the administration of *i*LEAP assessments.

District Implementation Guidelines

Local districts are responsible for implementation and monitoring of the *Louisiana Comprehensive Curriculum* and have been delegated the responsibility to decide if

- units are to be taught in the order presented
- substitutions of equivalent activities are allowed
- GLES can be adequately addressed using fewer activities than presented
- permitted changes are to be made at the district, school, or teacher level

Districts have been requested to inform teachers of decisions made.

Implementation of Activities in the Classroom

Incorporation of activities into lesson plans is critical to the successful implementation of the Louisiana Comprehensive Curriculum. Lesson plans should be designed to introduce students to one or more of the activities, to provide background information and follow-up, and to prepare students for success in mastering the Grade-Level Expectations associated with the activities. Lesson plans should address individual needs of students and should include processes for re-teaching concepts or skills for students who need additional instruction. Appropriate accommodations must be made for students with disabilities.

New Features

Content Area Literacy Strategies are an integral part of approximately one-third of the activities. Strategy names are italicized. The link (view literacy strategy descriptions) opens a document containing detailed descriptions and examples of the literacy strategies. This document can also be accessed directly at http://www.louisianaschools.net/lde/uploads/11056.doc.

A *Materials List* is provided for each activity and *Blackline Masters (BLMs)* are provided to assist in the delivery of activities or to assess student learning. A separate Blackline Master document is provided for each course.

The *Access Guide to the Comprehensive Curriculum* is an online database of suggested strategies, accommodations, assistive technology, and assessment options that may provide greater access to the curriculum activities. The *Access Guide* will be piloted during the 2008-2009 school year in Grades 4 and 8, with other grades to be added over time. Click on the *Access Guide* icon found on the first page of each unit or by going directly to the url http://mconn.doe.state.la.us/accessguide/default.aspx.

Physics
Unit 1: Measurement and Symbolic Representation

Time Frame: Three weeks

Unit Description

This unit focuses on metric measurements of physical quantities. It also introduces methods used in inquiry. Skills addressed include recording data based on precision of devises used in taking measurements and relating this to significant digits, use of scientific notation, canceling units by dimensional analysis, determining accuracy and precision, generating graphs, and making calculations from experimental data.

Student Understandings

Inquiry is a logical sequential process used to solve problems related to experimental outcomes which helps students learn to use the methods, attitudes, and skills of scientists. This process includes forming a hypothesis, identifying variables, collecting and presenting data, and math calculations. Scientific equipment as well as student skill affects reliable measurement; all measurements should reflect the precision of the measuring devices and should be used to determine significant figures. For every activity, students should be able to identify safety issues. A copy of the Safety in the Physics Laboratory BLM should be given to each student and safety issues discussed. Students will produce products that include laboratory activities with written analyses and solutions to problems as described in Activities and Assessments.

Guiding Questions

1. Can the student differentiate between accuracy and precision?
2. Can students determine the precision of measuring devices and record data to reflect the proper number of significant digits?
3. Can students use scientific notation?
4. Can students cancel units to check for correct set-up of problems using dimensional analysis?
5. Can students identify proper safety procedures and equipment for specific experiments?
6. Can students collect data and use it to produce a graph?

Unit 1 - Grade-Level Expectations (GLEs)

GLE #	GLE Text and Benchmarks
Science as Inquiry	
1.	Write a testable question or hypothesis when given a topic (SI-H-A1)
3.	Plan and record step-by-step procedures for a valid investigation, select equipment and materials, and identify variables and controls (SI-H-A2)
4.	Conduct an investigation that includes multiple trials and record, organize, and display data appropriately (SI-H-A2)
5.	Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)
6.	Use technology when appropriate to enhance laboratory investigations and presentations of findings (SI-H-A3)
7.	Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role playing, computer simulations) (SI-H-A4)
9.	Write and defend a conclusion based on logical analysis of experimental data (SI-H-A6) (SI-H-A2)
10.	Given a description of an experiment, identify appropriate safety measures. (SI-H-A7)
Physical Science	
1.	Measure and determine the physical quantities of an object or unknown sample using correct prefixes and metric system units (e.g., mass, charge, pressure, volume, temperature, density) (PS-H-A1)
2.	Determine and record measurements correctly using significant digits and scientific notation (PS-H-A1)
3.	Determine accuracy and precision of measured data (PS-H-A1)
4.	Perform dimensional analysis to verify problem set-up (PS-H-A1)
5	Use trigonometric functions to make indirect measurements (PS-H-A1)
9.	Describe and measure motion in terms of position, displacement time, and the derived quantities of velocity and acceleration (PS-H-E2)
10.	Determine constant velocity and uniform acceleration mathematically and graphically (PS-H-E2)
11.	Plot and interpret displacement-time and velocity-time graphs and explain how these two types of graphs are interrelated (PS-H-E2)
12.	Model scalar and vector quantities (PS-H-E2)

Sample Activities

Introductory Activity: Safety SI GLE: <u>10</u>

Materials List: Safety in the Physics Laboratory BLM-one for each student

Since this is the first unit of the course, general safety concerns should be addressed before students begin inquiry activities. It is important that students understand exactly what the rules are and what consequences will result from failure to adhere to safety policies. Additionally, as part of future pre-lab discussions, specific safety precautions for each lab should be discussed.

Distribute a copy of the Introductory Activity, Safety in the Physics Laboratory BLM to each student. This document suggests an activity for students that can be utilized within the classroom, or the teacher may use some other means of providing instruction on safety to the students. Regardless of what method is used, it is imperative that students realize the importance of following safety guidelines within the science classroom.

Activity 1: Vocabulary Self-Awareness SI GLEs: <u>5</u>, <u>7</u>; PS GLEs: 9, 12

Materials List: Activity 1, Vocabulary Self-Awareness Chart BLM for each student

While *vocabulary self-awareness* (view literacy strategy descriptions) does not completely fit one specific GLE, there are elements used in the vocabulary list from each GLE. Students bring a wide range of word understandings to their science content readings. It is a valuable literacy strategy to ask students to identify what they know and what they need to learn in order to be comfortable with the unit's content vocabulary. This strategy calls for students to use a chart to organize the content vocabulary, including examples and models to clarify meaning, and to revisit their entries throughout the unit to practice and extend understanding.

Provide students with a list of key terms from the unit or ask them to locate the key terms. Ask students to rate their understanding of each word with a "+" (understand well) "√" (limited understanding or unsure or "–" (don't know). They will also write a definition of each word, give an example, and include an equation and identification of units, if appropriate. Over the course of the unit, students should return to the chart and add new information to it. The goal is to have all plus signs by the end of the unit. Examples are provided in the Vocabulary Self-Awareness Chart BLM.

Activity 2: Practicing Math Operations (SI GLE: 5; PS GLEs: 4, 5)

Materials List: teacher-generated pretest

A pretest to assess the students' math skills and weaknesses is an ideal way to begin this activity. A brief review of significant digits, scientific notation, and dimensional analysis before the pretest will help clarify teacher expectations. After the pretest, present example problems followed by students practice problems using scientific notation, significant digits, dimensional analysis, metric conversions, relative and percent error, and graphical analysis of data. Provide direct instruction, demonstrations, and guided practice followed by individual practice in areas revealed as weaknesses by the pretest.

Activity 3: Density of Marbles and Volume of the Textbook (SI GLE: 5; PS GLE: 1, 2)

Materials List: for each student group - Lab Report Format and Rubric: Density and Volume BLM, triple beam balance, metric ruler, graduated cylinder, water, marbles, weighing pan, and a calculator

The purpose of this activity is to learn or review the use of precision and accuracy in measurement, to relate precision to significant figures, and to relate accuracy to relative and percent error. At the beginning of each activity, students are to record the precision of all measuring devises and use this information for recording data. (For example, a standard triple beam balance is calibrated to 0.1 g or tenths place and estimated to hundredths.) All readings must reflect this degree of precision. These skills are used throughout the course.

Students should be given a copy of the Lab Report Format and Rubric: Density and Volume BLM before the lab so that they can meet the rubric expectations as they develop their own lab report. Unless otherwise directed, students are to write lab reports in their science laboratory notebooks. Working in pairs, ask students to determine experimentally the density of a group of marbles (or any other small objects of the same composition) using water displacement to find the volume of the marbles, a balance to find their mass, and a metric ruler to measure the length, width, and height of their textbook. Direct students to record data on their student-generated lab report in their lab notebooks. After data have been collected and calculations have been made, students may share data and results as a class.

This is a good opportunity to discuss and practice the value of eliminating extremely high and low values within data sets. Discuss the results in terms of precision of the measuring devices used. Stress that the precision of the measuring devices must be reflected in the number of significant digits recorded in the data table and the final calculated answers. Discuss how relative and percent error may be calculated. Remind students that units must be manipulated along with numbers. Students should come up with the suggestion that an average of the class results may be used to calculate error.

Activity 4: Determining Period of a Timer and the Graph of Freefall Motion (SI GLEs: 4, 5, 6: PS GLE: 9, 10, 11)

Materials List: for each student group - ticker timer or graphing calculator with motion detector, stopwatch (for ticker timer), small mass (100 g), graph paper or graphing calculator, Lab Report Format and Rubric: Using Ticker-Timer to Graph Free-Fall BLM

The purpose of this activity is to provide students with several inquiry techniques. These include using timing devices, collecting data, and converting data tables to graphs that allow for analysis of data. Students should realize that the time interval between dots is constant and that if the distance is changing, it must mean that the rate of motion is changing. This activity is a good introduction to concepts of linear motion developed in Unit 2. If ticker timers are not available and a graphing calculator and motion detector are, these may be substituted. Provide students with a copy of the Lab Report Format and Rubric: Using Ticker-Timer to Graph Free-Fall BLM. This assures that they can meet the rubric expectations as they develop their own lab report. Use a ticker timer and stop watch to determine the period of the timer. Have students, working in groups of three or four, set up the timer and pull the ticker tape through the timer at a constant rate, recording the time with a stopwatch. Repeat for several trials until consistent results are achieved. Explain to students that the frequency (f) of the timer is the number of times it vibrates per second indicated by the dots on the tape and that the period (T) is the reciprocal of the frequency ($T = 1/f$).

Have students attach a small mass to the end of a length of ticker tape and allow it to freefall through the timer. Ask students to examine the markings and compare them to the previous tapes made as the tape moved at constant speed. Direct students to generate a displacement/time graph for each kind of motion. They may use pencil and paper or a graphing calculator or graphing software if available. Discuss the meaning of the graphs; point out that the slope of a graph equals rise over run which in this case is displacement over time or the velocity ($v = d/t = y/x$). It is important that students understand that in physics, a graph of motion represents the equation for that motion. This means that when graphing motion, time should be plotted on the "x" axis.

Activity 5: Using the Inquiry Process to Design a Lab (SI GLEs: 1, 3, 4, 6, 9, 10; PS GLEs: 1, 2, 3)

Materials List: for each student group of two - 4 identical beakers, thermometer or calculator with heat probe, stop watch or clock with second hand, ice, hot water (below 60^0 C for safety purposes), graph paper (or graphing software), safety goggles, beaker tongs or insulated mitt for handling hot water, Science Rubric: Graphic Organizer BLM, Science Format and Rubric: Design a Lab BLM

The purpose of this activity is to give students experience in planning and carrying out a simple controlled experiment that involves one independent variable and requires accurate and precise data collection and processing. Remind students to look at the calibration of the thermometers and stopwatches and to determine how many significant digits to record in each data set. Both the Science Rubric: Graphic Organizer BLM and the Science Format and Rubric: Design a Lab will help students plan and organize the activity. Discuss with students the concept that temperature change indicates a transfer of heat energy. Explain that this activity uses the measure of the rate of heat transfer to explore the elements of scientific inquiry. Allow time for students to identify appropriate safety measures that should be followed for this activity. (Since transfer of hot water in glass beakers is required, they should stress the use of insulated mitts to handle hot beakers in addition to safety goggles.)

Provide each pair of students a set of 4 identical beakers, a thermometer, a stopwatch or a clock with a second hand, ice, and a source of hot water. Ask students to plan and conduct an experiment that involves water at four different temperatures and demonstrates the scientific process for a controlled experiment. Students will construct a question such as "How will temperature differences affect the rate of heat transfer?" Discuss formulating a question, stating a hypothesis, setting up an experiment with only one independent variable, collecting and displaying data, analysis of data, and reaching conclusions. Once the experimental design is complete, the students' plan must be approved by the teacher to assure the safety of the set-up and procedure. Recording the water temperatures every three minutes for fifteen or twenty minutes will give a good range of temperature change to plot a graph. If calculator or computer interfaced probes are available, have students use these to collect data. They may also use graphing software to generate the graphs. It is important that students look at the accuracy and precision of their measured data so that measurements and calculations match the calibration of the measuring instruments. Students should realize that the change in temperature is the dependent variable and the time is the independent variable.

Sample Assessments

General Guidelines

Assessment techniques should include the use of scale drawings, models, sketches of lab set-ups, laboratory investigations with reports for which students have been given the grading rubric in advance, performance-based assessments including projects and oral and written research reports, reflective assessment including group discussion and analysis of laboratory work, and traditional summative assessments including paper-and-pencil quizzes and tests. Assessments could include the following:

- Students should be monitored during activities and the teacher should make note of pertinent observations. This may be done in the form of journaling, anecdotal notes, skills rubric, and observation rubric.
- All student-generated work should be evaluated.
- Use a rubric to assess student proficiency in all laboratory techniques and skills, including social/group skills.

- A format for writing laboratory reports should be provided by the teacher. Students should write reports including analysis of the significance of the activity as it relates to the concept being studied.
- When appropriate, students should be given the opportunity to help develop grading rubrics.
- For multiple-choice items on written tests, allow students to justify their responses. This may identify poorly written test items as well as student misconceptions.
- Students should be given opportunities to evaluate their own work and progress through journaling and/or as part of their laboratory reports.

General Assessments

- The student will collect data reflecting the precision of measuring devices used.
- The student will solve problems using dimensional analysis to set up solutions and calculate units.
- The student will analyze and discuss laboratory results, noting accuracy, precision, safety elements, and sources of error.
- The student will state a research question or hypothesis, identify a variable, and collect and process data to answer the question.

Activity-Specific Assessments

- Activity 2: Student will produce samples of solved mathematics problems as described in Activity 2. A teacher-generated traditional summative assessment in the form of a paper-and-pencil test is appropriate.

- Activity 3: Students should include in their conclusions a self-evaluation based on their success in recording the correct number of significant digits in their data and calculations. They should discuss specific errors they made. A rubric appropriate for Activity 2 is included. See Lab Report Format and Rubric: Density and Volume BLM.

- Activity 4: A rubric appropriate for assessment of Activity 4 is included. See Lab Report Format and Rubric: Using Ticker-Timer to Graph Free-Fall BLM.

- Activity 5: The document entitled Science Format and Rubric: Design a Lab BLM is appropriate as an assessment of the student-designed activity.

Resources

- NSTA SciLinks Site - *Create a Graph* - Enter numbers for various graphs to be generated.
  www.SciLinks.org

- Rubric Generators:

  http://rubistar.4teachers.org/index.php

  http://teach-nology.com/web_tools/rubrics

  http://www.colorado.edu/physics/phet/web-pages/simulations-base.html

Physics
Unit 2: Forces and Linear Motion

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Time Frame: Approximately six weeks

Unit Description

The focus on this unit is the study of forces that produce linear motion. Four kinds of forces are identified and their relative strengths are addressed. Activities include calculating and graphically determining velocity and acceleration, plotting and interpreting graphs of linear motion, and solving for missing variables in kinematics equations—including momentum problems.

Student Understandings

Forces produce interactions among particles of matter; these interactions may result in motion in a straight line. Velocity is constant motion in a given direction. Newton's first law describes this motion. Acceleration results from unbalanced forces according to Newton's second law. Objects in motion have momentum, which describes the relationship between mass and velocity and is linked to Newton's law of inertia. Products to demonstrate student understandings include data collection and analysis with graphs that model various types of motion and assessment of problem solving skills.

Guiding Questions

1. Can students list and differentiate among the different kinds of forces?
2. Can students calculate speed, acceleration, and momentum of objects using mathematical formulas?
3. Can students create graphs of constant speed and acceleration?
4. Can the student interpret distance versus time, acceleration vs. time, and velocity vs. time graphs?
5. Can students derive simple acceleration vs. time and velocity vs. time graphs from observation of a moving object?
6. Can students discuss what factors determine the way objects move?
7. Can students explain how momentum is different from velocity and acceleration?
8. Can students examine experimental results to determine whether or not they follow the rules of evidence?

Unit 2 - Grade-Level Expectations

GLE #	GLE Text and Benchmarks
Science as Inquiry	
1.	Measure and determine the physical quantities of an object or unknown sample using correct prefixes and metric system units (e.g., mass, charge, pressure, volume, temperature, density) (PS-H-A1)
4.	Conduct an investigation that includes multiple trials and record, organize, and display data appropriately (SI-H-A2)
5.	Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)
6.	Use technology when appropriate to enhance laboratory investigations and presentations of findings (SI-H-A3)
7.	Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)
8.	Give an example of how new scientific data can cause an existing scientific explanation to be supported, revised, or rejected (SI-H-A5)
10.	Given a description of an experiment, identify appropriate safety measures (SI-H-A7)
11.	Evaluate selected theories based on supporting scientific evidence (SI-H-B1)
13.	Identify scientific evidence that has caused modifications in previously accepted theories (SI-H-B2)
14.	Cite examples of scientific advances and emerging technologies and how they affect society (e.g., MRI, DNA in forensics)
16.	Use the following rules of evidence to examine experimental results: (a) Can an expert's technique or theory be tested, has it been tested, or is it simply a subjective, conclusive approach that cannot be reasonably assessed for reliability? (b) Has the technique or theory been subjected to peer review and publication? (c) What is the known or potential rate of error of the technique or theory when applied? (d) Were standards and controls applied and maintained? (e) Has the technique or theory been generally accepted in the scientific community? (SI-H-B5) (SI-H-B1) (SI-H-B4)
Physical Science	
1.	Measure and determine the physical quantities of an object or unknown sample using correct prefixes and metric system units (e.g., mass, charge, pressure, volume, temperature, density) (PS-H-A1)
2.	Determine and record measurements correctly using significant digits and scientific notation (PS-H-A1)
3.	Determine accuracy and precision of measured data (PS-H-A1)
4.	Perform dimensional analysis to verify problem set-up (PS-H-A1)
7.	Relate gravitational force to mass and distance (PS-H-E1)

9.	Describe and measure motion in terms of position, displacement time, and the derived quantities of velocity and acceleration (PS-H-E2)
10.	Determine constant velocity and uniform acceleration mathematically and graphically (PS-H-E2)
11.	Plot and interpret displacement-time and velocity-time graphs and explain how these two types of graphs are interrelated (PS-H-E2)
13.	Solve for missing variables in kinematics equations relating to actual situations (PS-H-E2)
23.	Apply the law of conservation of momentum to collisions in one and two dimensions, including angular momentum. (PS-H-F2)
24.	Apply the concept of momentum to actual situations with different masses and velocities (PS-H-F2)

Sample Activities

Remind students at the beginning of the unit that they are to continue to utilize their *vocabulary self-awareness chart* (view literacy strategy descriptions).

Activities 1 and 2 below afford students an opportunity to collect and analyze data for objects moving at variable speeds and acceleration at a constant rate and to conceptually link several activities into new understandings. Students will record their predictions, thoughts, new insights, and reflections in the form of a *science learning log* (view literacy strategy descriptions). This is different from a traditional lab report since it is written in journal format and prompts students to compare results from several activities. *Learning log* entries may be written in the student laboratory notebook since the writing prompts are frequently related to concepts being explored in the laboratory activities.

Activity 1: Graphical Analysis of Constant Speed and Acceleration (SI GLEs: 1, 4, 5, 6, 7; PS GLEs: 9, 10, 11)

Materials List: Part One: for each student group - a constant velocity battery operated cart or toy battery operated car, meter sticks, measuring tape to mark off distance intervals, a stopwatch, graph paper or a computer interfaced graphing calculator (As an alternative, use real automobiles moving along a street.) Part Two: an adjustable ramp and a ball, science learning logs

Part One**:** For this activity, use constant velocity battery-operated carts, toy battery-operated cars, or if your school is located on a long busy street, students can collect data utilizing cars that drive past. If collecting data on real cars, caution students about safety on the street.

Use a tape measure to position student pairs at ten-meter intervals. Have one student select the cars to be timed and to give a “start” signal. One student in each pair can operate the stopwatch while the other records the time it takes for each car to reach them; several trials are needed, as students will initially make many errors in timing. When students return to whole group, have the recorders to post their times on the board and discuss the data. Eliminate obvious timing errors and incomplete data sets. Select four different speeds and have students graph these trials and discuss the motion illustrated by the graphs. If students are using battery-operated cars, divide them into groups of five. Line up meter sticks along the floor or hallway and have one student release the car a short distance ahead of the first meter stick and give the start signal as the car reaches the first meter stick. The remaining students should time the car for 2.0, 4.0, 6.0, and 8.0 seconds and note the distance traveled during their particular interval. Several trials are necessary for consistent results. Students should record their results in their science *learning logs*. (view literacy strategy descriptions)

Part Two**:** Instruct student groups to set up a ramp and time a ball rolling down the ramp, adjusting the ramp angle so that it takes a little more than five seconds for the ball to roll the entire distance. Instruct students to time and mark with tape the distance traveled during each one-second interval. If a calculator or computer interfaced motion detector is available, use this for data collection.

Direct students to plot two distance versus time line graphs and convert the distance/time graphs to velocity/time graphs and the Part Two graph to an acceleration versus time graph. Use graphing software if it is available; some software packages are capable of making the graph conversions, but students can do at least one set of these manually. Observations and results should be recorded in their science *learning logs.*

Activity 2: Analysis of Free-Fall Motion (SI GLEs: 1, 4, 7, 10; PS GLEs: 1, 2, 3, 4, 7, 9, 10, 11)

Materials List: Part One: two balls of equal size but very different masses; Part Two: several identical balls, stopwatches, a long tape measure or long piece of string, access to library or online research tools, science learning logs

Part One**:** Following a brief description of this activity, students are to identify necessary safety procedures. These may include safety associated with the hazards of falling objects.

Obtain two balls of equal size but very different masses. Pass them around the room so that students realize one is much more dense that the other. Ask students to make predictions about the motion of the balls if they are dropped at the same instant from the same height. Have them write their predictions in the form of an *opinnionaire* (view literacy strategy descriptions). The teacher should provide a statement such as, "Aristotle believed that heavier objects fall faster than lighter objects. Students may select SA (strongly agree), A (agree), D (disagree), or SD (strongly disagree). Students need to clearly state reasons for their opinion. Ask them to relate their opinion to any prior knowledge or experience. Be sure they record their predictions and reasons in their science *learning logs* (view literacy strategy descriptions). Drop the balls from the highest height possible such as a second story window, the top of bleachers, or from the highest accessible point in the classroom. Ask students to discuss in their science *learning logs* whether or not their predictions were correct.

Part Two**:** Obtain several identical balls such as golf or tennis balls. Have a student drop the balls one at a time while other students time each fall with stopwatches. Ask students to suggest methods for determining the height of the drop, from the highest point to the ground.. Students should post their results and discuss data, eliminating obvious timing errors. Use the remaining data to calculate a value for acceleration due to gravity. Stress the use of dimensional analysis and significant figures in calculations. Using the constant for acceleration due to gravity, have students calculate percent error. Ask students to go back to the Unit One free fall activity and reexamine the graphs they generated. They should compare the graphs of Activity 1, parts one and two and the graph of free fall motion and record their comparisons in the form of a science *learning log* entry. Discuss the fact that although the velocity changes during free-fall, acceleration due to gravity does not change.

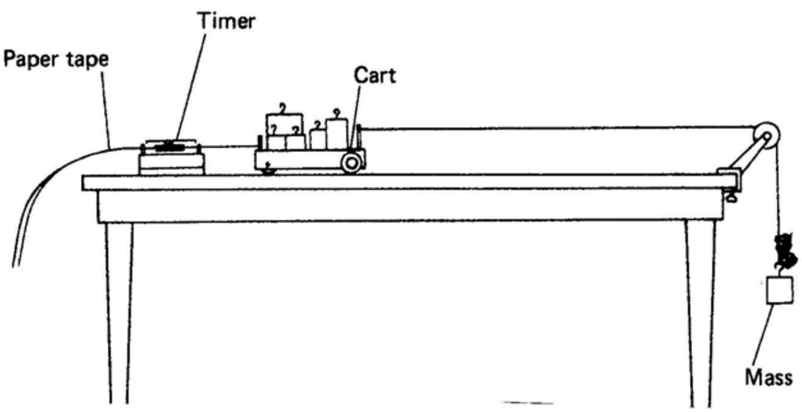
Students should research Galileo's experiments with free-falling objects and include a summary as background for their science *learning log* entry. They should include a discussion of his methods for collecting data and what equipment he used. In their reflections, they should compare Aristotle's beliefs concerning free-falling objects with Galileo's and compare Galileo's results with their own.

Activity 3: Investigation of Newton's Second Law and the Role of Friction (PS GLEs: 9, 13)

Materials List: for each student group - a cart, assorted masses, a pulley, string, ticker timer, ticker tape or (if available) a graphing calculator or computer and motion detector, science learning logs

Discuss the safety issues of moving carts and falling masses; students should make sure the carts do not fall from counters and that the suspended masses do not fall onto feet. Students should wear close-toed shoes.

During this activity, students will consider the role of friction as well as the relationship between mass and acceleration. Students may both graphically and mathematically analyze motion as it relates to Newton's second law.



Newton's second law may be demonstrated by using freefalling masses attached by string to one end of a cart and passed over a pulley. The other end of the cart is attached to a strip of ticker tape running through a ticker timer. If a graphing calculator or computer and a motion detector are available, these give excellent results since they can generate the graphs as data is collected. Most conventional laboratory manuals and electronic laboratory manuals contain a detailed description of this activity. Instruct students to determine first what size mass will just move the cart at constant speed; this will be converted to newtons (N) to give the frictional force of the cart system. Ask students to use two different additional masses to produce acceleration of the cart. Acceleration data are to be plotted on one graph which will clearly show the effect of increasing mass on acceleration. Calculations should confirm this relationship. Students should record their data in their science *learning logs* (view literacy strategy descriptions).

Activity 4: Observations of Newton's Three Laws during an Elevator Ride (SI GLE: 10; PS GLEs: 2, 3, 9, 13)

Materials List: elevator access, bathroom scale, platform, string, pulley wheel, spring scale, mass, science learning logs

The objective of this activity is to explore aspects of Newton's three laws as they apply to an everyday occurrence, an elevator ride, which everyone has experienced. If traveling from the school building, discuss proper conduct in public places, walking in traffic, and the dangers of opening and closing elevator doors. Ask students to form small groups to *brainstorm* (view literacy strategy descriptions) the workings of an elevator and the kinds of data they can collect related to the motion of an elevator. In the first part of the activity, students should explore the role of models in making scientific inquiries and come up with a design that is a working model of an elevator. Have students record their ideas in their science *learning log* (view literacy strategy descriptions) to share with the whole class.

Part One: Students will construct a model of an elevator. It requires minimally a platform supported on each corner by string that can be passed over a pulley wheel, a spring scale to measure apparent changes in weight and a mass appropriate for the sensitivity of the spring scale. Encourage students to come up with their own designs. Students can practice pulling the "elevator" up and down until they get a feel for accelerating, decelerating, and moving at constant speed. They can then record weight readings in newtons at the bottom while stationary, while accelerating upward from the bottom, traveling at constant speed, decelerating at the top, and while stationary at the top, then repeating these changes on the way down. This allows students to observe visual changes in force as motion changes. It also allows them to quantify inertia of an object at rest and during constant motion; in addition, it allows them to compare differences in inertia during acceleration and deceleration according to Newton's first law. Newton's second law is clearly demonstrated by the observation that acceleration and deceleration accompany a change in force. The idea that force pairs, as described in Newton's third law, are equal at constant speed and unbalanced when speed is changing can account for the apparent changes in weight and provide a link among the three laws.

Part Two is dependant upon access to an elevator. If you have access to a building with an elevator, this offers a great opportunity to study Newton's laws in a real-life setting. Guide the discussion so that students will determine the factors and variables to consider, including apparent weight changes of riders, changes in motion of the elevator, time to complete the ride, and height of the building. (Someone will probably come up with the idea of measuring the stairs to determine how high each floor is.) This activity is best done in groups of four students at a time and riding up and down on the elevator. One student stands on a bathroom scale and the others record stationary weight at the top and bottom, weight changes as the elevator accelerates and decelerates, and the time of the ride. Use the data to discuss Newton's three laws. Ask them as part of their conclusion to apply these laws to other real-life applications.

This is a good time to introduce the use of free body diagrams to represent equal and opposite forces and opposite unbalanced forces. Newton's third law dealing with equal and opposite forces can help students account for the whole elevator system, including the tension on the elevator support cable, the mass of the elevator, the acceleration due to gravity which is always constant, and the acceleration due to the force applied by the elevator motor which changes.

Student observations and data should be recorded in their science *learning logs*.

Activity 5: Components of Momentum. (SI GLEs: 10, 14; PS GLEs: 23, 24)

Materials List: force carts, heavy weights, meter sticks, stop watch, video clip of seatbelt physics or resources for researching practical applications of momentum, science learning logs

This activity will allow students to expand their experience with inertia and transfer that knowledge to the concept of momentum. Before the lab activity, ask students to make a list of safety precautions that should include the lifting of heavy objects, avoiding striking other students on the ankles with rolling carts, and resisting the temptation to use force carts as skates. As an introduction, show students a video clip of seatbelt physics, child car seat safety, or safety features in automobiles such as break away seats and collapsible bumpers. If such a video is not available, provide students the opportunity to search for practical applications of momentum and devise a method of conducting an activity to test their findings.

The teacher should provide force carts and bricks or other heavy weights to study momentum. Ask students to come up with as many combinations of collisions as possible to analyze the components of momentum. Some possible combinations are a light cart hitting a stationary light cart, a light cart hitting a heavy stationary cart, a heavy cart hitting a stationary light cart, a heavy cart hitting a stationary heavy cart, two moving light carts colliding head-on, and two heavy carts hitting head-on. Instruct students to develop a system for using the same force each time; for example, they may push the moving cart a set distance each time. It is also important that the carts travel in a straight line. Students should observe that there are differences in speed and distance traveled among the various collisions. Students need to record distances traveled after collisions and relative speeds of each cart after collision. The times may also be recorded and used to calculate speed for momentum calculations. All observations and results should be recorded in their science *learning logs* (view literacy strategy descriptions).

The conclusion includes a discussion of the transfer of momentum as demonstrated by the changes in velocity and distance traveled by the different carts. The students may also summarize practical applications of momentum. The teacher modeling conservation of momentum problems, including angular momentum, logically follows this activity. Practice problems should be assigned.

Activity 6: Probing the History of Gravitational Theory. (SI GLEs: 7, 8, 11, 13, 16)

Materials List: Internet or other research tools in school library, Rules of Evidence to Examine Experimental Results BLM, The History of Gravitational Theory Rubric BLM, Oral Presentation Rubric BLM

Give students a copy of each of the BLMs. Ask students to form groups and, using the questions posed on the Rules of Evidence to Examine Experimental Results BLM, to research Newton's and Einstein's theories of gravity in order to determine as many answers as possible. Encourage them to include other scientists who made significant contributions to the theories, as well. They should begin by organizing their research with a *graphic organizer* (view literacy strategy descriptions) in the form of a Venn diagram comparing and contrasting the two theories. The LPB Cyberchannel video listed in the resource section is an excellent source of information that may be shown to the class and discussed, or students may conduct their own search from the Internet or written text, CD ROMs, and videos available in their school library. Findings may be presented orally to the class.

Activity 7: Solving Problems (SI GLE: 5; PS GLEs: 2, 4, 10, 11, 13, 23, 24)

Materials List: set of practice problems and solutions, student-generated checklist for evaluating "professor know-it-alls"

In preparation for a unit paper and pencil test, ask students to make a list of all the possible types of problems they have studied during this unit including calculations from observations during inquiry activities. They should include analysis of motion graphs and conversion of distance/time graphs to velocity/time graphs. Instruct them to form groups to develop solution strategies for each problem type. Tell them each group will be called upon to act as a team of *professor know-it-alls* (view literacy strategy descriptions) to discuss one particular kind of problem. For example, one group might be experts in problems involving Newton's second law. They would explain these problems and answer classmates' questions. Make available a teacher generated or textbook set of the required problems and solutions that they can use as a guide if they have difficulties. Remind students to show all work, to use unit analysis to cancel units, and to round all answers to the correct number of significant digits. Classmates may record how well the "experts" presented their problem in terms of criteria the students select as meaningful. Areas for evaluation may be clarity of explanation, lack of errors, correct canceling of units, and correct use of significant figures.

Sample Assessments

General Guidelines

Assessment techniques should include the use of scale drawings, models, sketches of lab set-ups, laboratory investigations with reports for which students have been given the grading rubric in advance, performance-based assessments including projects and oral and written research reports, reflective assessment including group discussion and analysis of laboratory work, and traditional summative assessments including paper-and-pencil quizzes and tests. Assessments could include the following:

- Students should be monitored during activities and the teacher should make note of pertinent observations. This may be done in the form of journaling, anecdotal notes, skills checklist and/or observation rubric.
- All student-generated work should be evaluated.
- Use a rubric to assess student proficiency in all laboratory techniques and skills, including social/group skills
- A format for writing laboratory reports should be provided by the teacher. Students should write reports including analysis of the significance of the activity as it relates to the concept being studied.
- When appropriate, students should be given the opportunity to help develop grading rubrics.

- For multiple-choice items on written tests, allow student to justify their responses. This may identify poorly written test items as well as student misconceptions.
- Students should be given opportunities to evaluate their own work and progress through journaling and/or as part of their laboratory reports.

General Assessments

- The student will collect data and construct and analyze distance versus time graphs of motion.
- The student will interpret motion graphs.
- The student will describe the different kinds of forces and relate them to motion of objects.
- The student will discuss how momentum is different from velocity and acceleration.
- The student will use graphs and mathematical formulas to solve motion problems.
- The student will use research tools to collect information beyond classroom instruction.

Activity-Specific Assessments

- Activity 1: Students will write lab reports to include their purpose, a description of the procedures, data tables, and graphical analysis of the data. In the conclusion, they should identify and discuss differences between constant speed, variable speed, and acceleration. They will also calculate velocity using the portions of the graphs identified as representing constant speed, variable speed, and acceleration.

- Activity 6: Activity 6 affords an opportunity for using three different assessment tools: a teacher evaluation of an oral presentation, a peer evaluation of an oral presentation, and an evaluation of the content of a research project. There are sample rubrics for these evaluations in the BLM section: Rules of Evidence to Examine Experimental Research BLM, The History of Gravitational Theory Rubric BLM, and the Oral Presentation Rubric BLM.

- Activity 7: Instruct student groups of "professor know-it-alls" to prepare problem solutions they can share with the class when they are called upon. When the first group goes to the front of the room, the student audience will ask them questions about their particular type of problems. The "experts" will be responsible for answering questions and working problems correctly. Groups will be expected to supply feedback to one another in the form of notations on their student generated evaluation checklist. A group grade can then be assigned based how well the student audience feels the presenters meet the criteria.

Resources

- NSTA SciLinks Site - The Galileo Project is a good site to research Galileo's life. Seatbelt physics is a good site for studying momentum.
  www.Scilinks.org

- Videos - Constant Motion: Gravity and Friction: Elements of Physics: Motion, Force and Gravity; Newton's Three Laws; Einstein's Theory of Gravity.
  www.lpb.org/cyberchannel

- The Physics Classroom - Free of charge but use restricted to on line usage through live Internet connection. Newton's laws, free body diagrams, freefall, types of forces, right triangle trig, misconceptions, position/time graphs, kinematics problems including solutions. Includes animations and video footage.
  www.physicsclassroom.com

- HippoCampus is a great site for students to study on their own, review concepts, and practice problem solving. It is very user friendly and is free.
  www.hippocampus.org

Physics
Unit 3: Motion in Two Dimensions and Periodic Motion

Time Frame: Approximately six weeks

Unit Description

The focus of this unit is the analysis of projectile, circular and harmonic motion, plus the use of vectors to resolve forces exerted at angles. Making calculations using trigonometric functions is included. Both graphical and mathematical methods are addressed.

Student Understandings

Newton's laws apply to motion in two dimensions. Projectile motion has both horizontal and vertical components that are independent of one another. Projectiles may be launched horizontally or at an angle. Periodic motion consists of uniform circular motion that includes centripetal force and Newton's law of universal gravitation. It also includes simple harmonic motion of objects such as a pendulum or a spring. Since forces are not always exerted in a straight line, it is necessary to resolve non-linear forces into vector components. Products to demonstrate student understandings include data collection, manipulation and analysis, self assessment of progress, and assessment of problem-solving skills.

Guiding Questions

1. Can students distinguish between and give examples of scalar and vector quantities?
2. Can students use triangle trigonometry and scale drawings to resolve vector problems?
3. Can students solve centripetal force and acceleration problems?
4. Can students find horizontal and vertical components of projectiles and use these to find distance, time in the air, and launch angles?
5. Can students analyze the periodic motion of a pendulum and a spring?
6. Can students resolve torque problems using force and torque arms?
7. Can students assign relative strengths to fundamental forces?

Unit 3 - Grade-Level Expectations

GLE #	GLE Text and Benchmarks
Science as Inquiry	
1.	Write a testable question or hypothesis when given a topic (SI-H-A1)
3.	Plan and record step-by-step procedures for a valid investigation, select equipment and materials, and identify variables and controls (SI-H-A2)
4.	Conduct an investigation that includes multiple trials and record, organize, and display data appropriately (SI-H-A2)
5.	Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)
6.	Use technology when appropriate to enhance laboratory investigations and presentations of findings (SI-H-A3)
7.	Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)
9.	Write and defend a conclusion based on logical analysis of experimental data (SI-H-A6) (SI-H-A2)
10.	Given a description of an experiment, identify appropriate safety measures (SI-H-A7)
15.	Analyze the conclusion from an investigation by using data to determine its validity (SI-H-B4)
Physical Science	
4.	Perform dimensional analysis to verify problem set-up (PS-H-A1)
5.	Use trigonometric functions to make indirect measurements (PS-H-A1)
6.	Explain the role of strong nuclear forces and why they are the strongest of all forces
7.	Relate gravitational force to mass and distance (PS-H-E1)
8.	Compare and calculate electrostatic forces acting within and between atoms to the gravitational forces acting between atoms
12.	Model scalar and vector quantities (PS-H-E2)
13.	Solve for missing variables in kinematic equations relating to actual situations (PS-H-E2)
14.	Add and resolve vectors graphically and mathematically to determine resultant/equilibrant of concurrent force vectors (PS-H-E3)
15.	Calculate centripetal force and acceleration in circular motion (PS-H-E3)
16.	Analyze circular motion to solve problems relating to angular velocity, acceleration, momentum, and torque (PS-H-E3)
17.	Analyze simple harmonic motion (PS-H-E3)
18.	Demonstrate the independence of perpendicular components in projectile motion and predict the optimum angles and velocities of projectiles (PS-H-E3)

Remind students at the beginning of the unit that they are to continue to utilize their *vocabulary self-awareness chart* (view literacy strategy descriptions).

Sample Activities

Activity 1: Identifying Relative Strengths of Fundamental Forces (PS GLEs: 6, 8)

Materials List: pencil and paper, textbook or other research tool

Students explored the four fundamental forces in Unit 2. As an introductory activity to this unit, ask students to work in groups to build a *graphic organizer* (view literacy strategy descriptions) in the form of a flow chart or concept map that lists the four fundamental forces, their function, and from their function, to deduce their relative strengths. The chart or map should also include everyday examples of these forces.

Several of the following activities lend themselves to *directed reading-thinking activity, DR-TA* (view literacy strategy descriptions). *DR-TA* is an interactive teaching process in which students' prior knowledge is activated then they are asked to make predictions about the content. As the content is read, studied, and explored, students are asked to determine whether their predictions can be confirmed or not. Students make new predictions and search for confirmation throughout the lesson or exploration of the content. At the beginning of Activities 2, 3, and 4, before giving the reading assignment and before the activity is begun, ask students what they know about the topic. Student ideas and information may be recorded on the board or on paper. Then ask students to predict the outcome of the activity. Once the activity has been completed and the passage in the text has been read, have students confirm or revise their predictions. Discuss at what points students used inductive reasoning and where they used deductive reasoning.

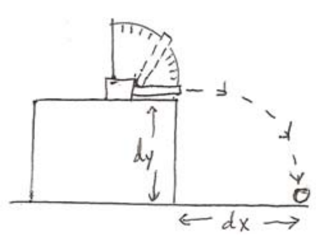
Activity 2: Analysis of Projectile Motion (SI GLEs: 4, 5, 7, 10; PS GLEs: 5, 13, 18)

Materials List: student-built (from PVC pipes and wood blocks) or purchased spring-loaded or rubber band powered cannon, ping pong balls, protractor, meter stick, safety goggles, set of problems

Prior to starting the investigation, have students identify and address appropriate safety measures.

Using the *DR-TA* (view literacy strategy descriptions) process, help students generate a list of prior experiences or studies that are related to projectile motion.

In this activity, students will fire a spring-loaded or rubber band powered cannon that shoots ping-pong balls and has adjustable angles. This cannon may be built from PVC pipes and blocks of wood, or a projectile launcher with adjustable angles may be purchased from a science supply company.



First, have students position the cannon on a desktop and fire horizontally until they get consistent results. Then they can measure the height of the desk from the floor, *y*, and the horizontal displacement, *x*. They may then calculate time in the air using y = $y = \frac{gt^2}{2}$ and use this time to calculate horizontal velocity of the ball using $v_x = \frac{x}{t}$. Second, ask students to make predictions in their lab notebooks regarding how the changing the angle of launch will affect the distance the projectile will travel. Then have students fire the cannon at three different angles, 25^o, 45^o and 65^o. Again they will need to fire several times until they get consistent displacement of the ball at each angle. Have students measure the distance traveled by the ball at each angle. Assuming that the muzzle speed of the ball is constant, students may now calculate total time in the air and vertical height to which the ball rose. Continuing the *DR-TA* process, be sure students compare their results with the literature results; it is a common misconception that a greater angle should result in a greater distance and students may try to make this happen, particularly if that was their prediction. Once this activity is completed, provide guided practice in solving horizontal and angular projectile problems. Individual practice in problem solving should also be assigned.

Activity 3: Factors that Affect the Period of a Pendulum. (SI GLEs: 1, 3, 4, 5, 7, 9, 15; PS: 17)

Materials List: string and bob, stopwatch, ring stand, protractor, soft drink can or paper cup attached to a string, set of pendulum problems

During this activity, students will study simple harmonic motion. Discuss with students what they know about the function of a pendulum and what factors they believe might affect the period of a pendulum. Again, using the *DR-TA* (view literacy strategy descriptions) process, ask students to write a hypothesis regarding at least one of these factors. Challenge students to design an investigation to test the hypothesis. Guide them toward testing the length of the pendulum, the mass of the pendulum, and/or the angle at which the pendulum is released. An empty soft drink can or paper cup attached to a string makes an excellent pendulum bob; variable amounts of water may be added to change the mass of the container. If available, washers on a string also make an inexpensive and easy to assemble pendulum. Either of these may be suspended from a ring stand. Students should ask the teacher to check the experimental design before beginning the experiment.

Ask students to design a data table for recording their selected independent and dependent variables. Remind them that they must test only one independent variable at a time. Better results are obtained if the time is recorded for three complete swings of the pendulum and the time is divided by three; it is also advisable to do multiple trials for the first few experimental setups, since students may have trouble with the stopwatches. They can eliminate extreme high and low values. Ask students to evaluate their times to determine which variables affected the period of the pendulum and to be sure to defend their conclusions based on their experimental data.

Next, give the reading assignment and introduce the pendulum equation. Continuing the *DR-TA* process, ask students to go back to their hypothesis and data to determine whether or not their results are confirmed by the literature. Have them use data involving variable lengths to calculate acceleration due to gravity. Some additional pendulum problems should be assigned.

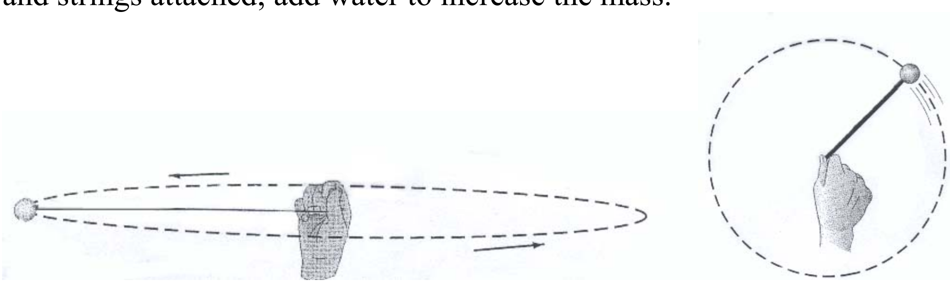
Activity 4: Centripetal Force (SI GLEs: 5, 10; PS GLEs: 7, 13, 15)

Materials List: can or cup tied to a meter-long string, science learning log, safety goggles

Following an overview of the activity, have students identify the safety issues that should be addressed. Discuss the danger of flying objects that could result from students letting go of the containers. If you have concerns about possible flying missiles, have students tie the strings securely to their wrists before spinning.

Centripetal force is a troublesome concept because of its being an inward-directed force. A large majority of students cannot easily conceptualize that the force on an object traveling in a circular path is being pulled inward and would simply obey Newton's first law and move off in a straight line if the inward force were removed. Again, using the *DR-TA* (view literacy strategy descriptions) process, discuss students' prior knowledge and experience with circular motion. Many of them may mention the "outward force" experienced when going around a curve in a car. This is a good example of inductive reasoning convincing them that centripetal force is outward-directed.

Assemble some soft drink cans or paper cups with holes punched in the sides near the top and strings attached; add water to increase the mass.



This is a good place to use *split-page notes* (view literacy strategy descriptions). Ask students to divide the current page in their science *learning log* (view literacy strategy descriptions) into a left and right column. In the column on the left, have students draw their three circles, two vertical and one horizontal. (See the sketches above; the left is horizontal and the right is vertical.) Instruct students to go outside and spread out far away from one another and swing the cans vertically and then horizontally and note differences; they will be asked to draw arrows indicating directions of forces and to describe differences observed between horizontal swinging and vertical swinging. Once everyone has completed adequate swinging and observation, assemble the students in a group and ask one student to move far away from the group and remove the container from his/her wrist, swing it in a vertical path and simply let go of the string as the object travels in its circular path. Repeat this a few times with different students.

Back inside, ask students to complete the drawings and explanations of the forces. Circulate through the room to be sure everyone has an arrow on the string itself and not just on the circular path of the object. Also make sure they have an arrow indicating exactly where the object traveled when the string was let go. Once everyone has identified the forces they think are in action, ask someone who labeled the force on the string as outward to push on the string while another student holds the can. It is immediately apparent that there can be no outward force on the string and that the object was spinning because it was being pulled inward by the hand holding the string. Now students will be open to learning about center-directed forces. After the reading assignment and teacher explanations are complete, students should return to the science *learning logs* where they did the sketches and labeling of their conception of what and where the forces are. Using the right column of the s*plit-page notes*, they may revise their drawings and explain the misconceptions that are now apparent in the original drawings. The page setup would look like this:

Study of Centripetal Force	
Student Original Drawings	Revised drawing and explanation of misconception

If time permits and the equipment is available, students can conduct a quantitative investigation to develop the equation for centripetal force. Most physics lab manuals describe this activity done with a rubber stopper and washers on a string. This activity should include calculations that confirm the centripetal force equation. Students are familiar with Newton's second law, $F = ma$, and they know that the circumference of a circle is $C = 2\pi r$. They also know that speed is $v = d/t$, making $v = 2\pi r/t$. Once they think of the time to travel around a circle as being the period of revolution, they should be receptive to examining the centripetal force equation. Follow-up problems should be assigned.

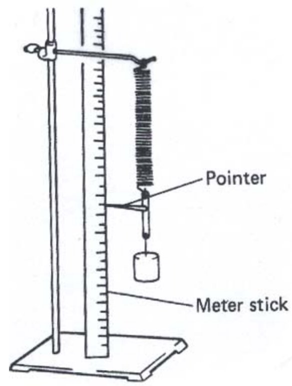
Once split-page notes are completed, be sure to demonstrate for students how they can study from them by covering one column and using information in the other to try to recall the covered information. Students should also be given time to quiz each other over the content of their notes in preparation for tests and other class activities.

Once students have an understanding of centripetal force, proceed to a study of Newton's law of universal gravitation.

Activity 5: Hooke's Law and Elastic Constants (SI GLEs: 4, 6; PS GLE: 17)

Materials: for each group- safety goggles, Hooke's Law apparatus (if not available, ruler, stretchy cord or rubber bands), masses, graphing software or graph paper, ring stand with clamp, set of sample problems

Hooke's Law lends itself well to demonstrate not only simple harmonic motion but also to demonstrate how proportionality constants are derived. It also can be used to point out to students the elastic limits of laboratory equipment, such as spring scales, that quickly loose their precision if their elastic limit is exceeded.



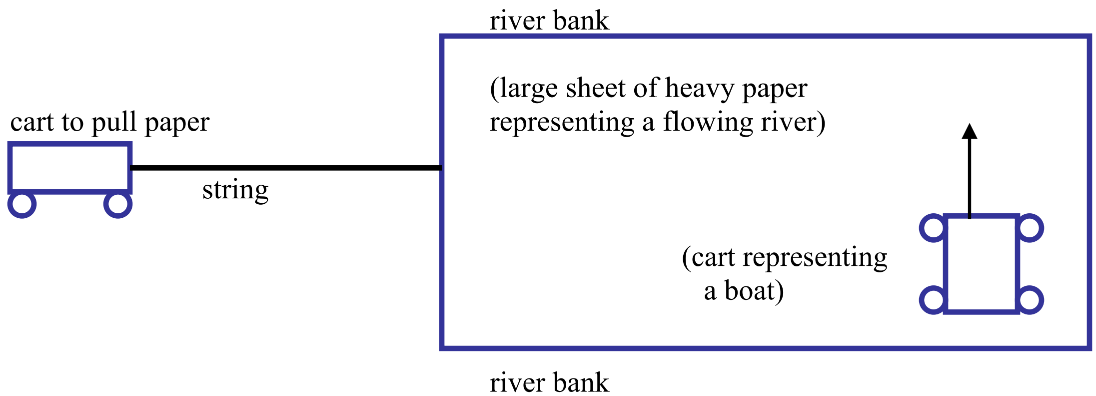
If Hooke's Law apparatus is available, have students assemble and record elongation versus force for at least four different masses. If the apparatus is not available, students should use rulers and rubber bands, elastic tie cords, or any bungee-type elastic. Instruct students to attach their elastic material to a stationary object such as a ring stand with a clamp. Use a ruler or meter stick to measure expansion when four different masses are attached to the bottom end of the elastic. The magnitude of the masses will need to be adjusted to produce measurable expansion and will vary with the nature of the elastic material. Ask students to use the collected data to plot an elongation versus force graph and to calculate the elastic constant using $F = k\Delta L$, where F = force in newtons, which is mass in kilograms x acceleration due to gravity or $F = mg$, k is the proportionality constant and ΔL is change in length measured in meters. If available, have students use a graphing software program to generate the graph. As with all activities, related guided practice in problem solving and sample problems for individual problem solving should be given to reinforce the math concepts involved.

Activity 6: Boat Crossing a River (SI GLEs: 4, 7, 15; PS GLEs: 5, 13, 14)

Materials**:** for each student group- a meter stick, two battery operated constant velocity cars, a stopwatch, chalk or tape for marking positions, a protractor and a two-meter long piece of heavy paper such as bulletin board paper, Lab Report: River Crossing BLM, set of vector problems

This activity allows students to work with a model of a boat crossing a river. They will be able to observe how the flow of the "river" changes the course of the "boat". They will also gain experience with using similar triangles to solve vector problems. Working in groups of three or four, students should observe and record the path of a boat moving across a flowing river. In the second part of the activity, they also need to assume the role of ferry driver and attempt to aim the boat at an angle that will allow it to come ashore perpendicular to the starting point. Students should refer to their Lab Report: River Crossing rubric as they work, so that they include all required components.

Boat Crossing a River



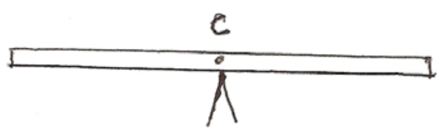
Students should first find the velocity of each car. Instruct students to first set one car on the paper and attach the other to the front center of the paper to record the velocity of the river. They will need to mark with chalk or tape the starting and stopping positions. To find the velocity of the boat, students should run the second car across the paper perpendicular to the edge representing the riverbank. Now the students should line up the boat perpendicular to the river and send it straight across as the river flows, recording the time and distance downstream the boat comes ashore. It requires coordination of effort; therefore, several trials may be necessary.

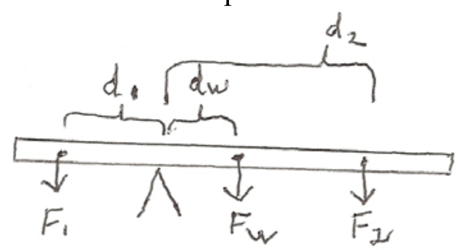
Second, have students predict at what angle the boat should be released in order for it come ashore directly across from its origin. Most students will select the same angle the boat took in the moving river, as this is a common misconception. If they are careful in the data collecting, they should find that indeed the angles are not the same. Also, if any group selected the faster car as the river, it will be impossible to get the boat to come ashore directly across from its origin. This provides an opportunity to discuss fast moving streams and the power of flood waters. Once data is collected, students may construct similar triangles for time, displacement, and velocity and calculate missing sides. Additional vector problems of forces at right angles and the use of similar triangles to solve vectors should be assigned.

Activity 7: Experimental Determination of Torque (SI GLEs: 4, 5; PS GLEs: 4, 16)

Materials: for each group - a meter stick, triple beam balance, a pivot, two different masses between 200g and 500g and a method of suspending the masses from the meter stick, Lab Report Evaluation Form BLM, safety goggles, set of torque problems

This activity allows student to study forces that are applied to lever arms to produce the rotational motion known as torque. They will also review the concept of center of gravity. Ask students to refer to their Lab Report Evaluation Form as they work through the activity; this will assure they are addressing all required elements of the lab. Instruct students to find the center of gravity of a meter stick by balancing it on the pivot, adjusting it until it is parallel to the horizontal. Ask them to find the mass and convert it to newtons. Students need to set the meter stick off center and attach a weight to the short side, adjusting it until the meter stick is once more in a state of equilibrium.



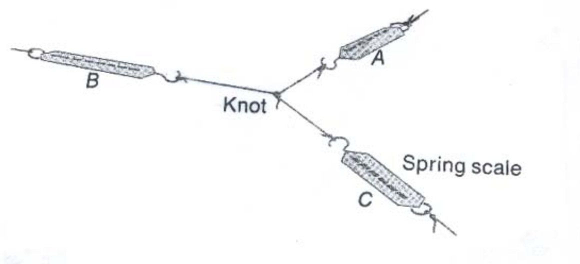


They should draw a sketch and label the setup including the location of the pivot, the center of gravity of the meter stick, and the placement of the suspended masses. Once again setting the meter stick off center, have them attach a mass to each side and adjust it until the meter stick is parallel. Instruct them to sketch and label this setup. The collected data may be used to calculate torque. Students may need to be reminded that torque arms are measured from the pivot. They will observe that a longer torque arm produces a greater rotation if masses are equal. Multiplying the mass (converted to newtons) x the torque arm (measured in meters) gives the unit of newton-meter. Guide students to link this to the fulcrum and lever, a simple machine they have studied in previous courses. They should also relate torque to other everyday applications such as jack handles, hydraulic pumps, and the action of pistons used to turn wheels. Assign additional torque problems for guided and individual practice after completing this activity.

Activity 8: Three Forces Acting Concurrently on a Point (SI GLEs: 4, 5, 7; PS GLE: 12)

Materials: for each group - 3 spring scales, string, a protractor, paper for drawing, scissors if string is not pre-cut, ruler, calculator, science learning logs

Each student group will need three spring scales that are calibrated to read the same. This activity is best done by suspending a mass from each one and adjusting the reading. Three pieces of string with a loop on one end and the other three ends tied together will secure the spring scales. (See sketch below.) As two or more students extend the springs and hold them perfectly still, an additional student may record force readings and draw lines along the strings so that the angles may be measured later. Have students conduct two trials using different forces and angles and record all data in their science *learning logs* (view literacy strategy descriptions). Once readings are taken, the springs may be removed and the angles measured and recorded.

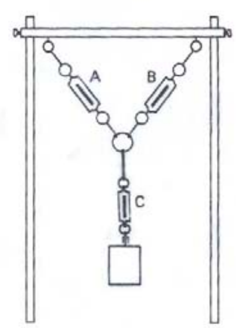


Since the system is in a state of equilibrium as the readings are recorded and the angles drawn, a tip-to-tail drawing should produce a triangle. Unless students are familiar with using scale drawings and trigonometry to solve problems, the teacher should model these before students begin their data analysis. If the first trial is a triangle, there is no need to draw the second trial. Some students may have difficulty with tip-to-tail drawings. If so, the teacher may model, resolving each force into *x* and *y* components to find the resultant.

Activity 9: Newton's Third Law (SI GLEs: 7, 10; PS GLEs: 5, 14)

Materials: 2 ring stands with clamps, meter stick, 3 spring scales, protractor, a mass, science learning logs

Discuss the laboratory procedure and ask students to identify safety concerns. These should include the importance of stabilizing their set-up and avoiding dropping the weights on their feet. Students will measure force changes at 30^o, 60^o, 90^o, and 120^o angles. Again using three spring scales that are calibrated to read the same, have students set up the three spring scales by suspending two from a meter stick supported by two ring stands. If the ring stands are placed on two student desks, the spring scales and attached mass can hang freely from the meter stick. Attach the third spring scale to the others, suspend a mass to it, adjust the angle, and record the angle and the forces from the scales.



Repeat for three other angles. Students should record all data in their science *learning logs* (view literacy strategy descriptions) and may use the data collected to calculate the vector sum of two forces acting on a point; students should draw free body diagrams showing equal and opposite force pairs and use the downward force as the accepted value for percent error calculations. Students should use both graphical analysis (to-scale models) and trig calculations to analyze their results.

Activity 10: Problem Solving (SI GLE: 5; PS GLEs: 4, 5, 7, 13, 14)

Materials List: student-generated review problems

Ask students to generate a list of problem types and accompanying equations they have used throughout the unit. Students should then select (from their textbook or some other source) a set of representative problems to practice in preparation for a summative assessment in the form of a paper-and-pencil test. Remind students to show all work using dimensional analysis and to round final answers to the correct number of significant digits. Confirm that they choose one of each kind, including Newton's law of universal gravitation that quantifies the relationship among force, mass, and distance. Students may form groups to evaluate each others' completed work. In addition, have each group demonstrate one problem solution to the entire class.

Sample Assessments

General Guidelines

Assessment techniques should include the use of scale drawings, models, sketches of lab set-ups, laboratory investigations with reports for which students have been given the grading rubric in advance, performance-based assessments including projects and oral and written research reports, reflective assessment including group discussion and analysis of laboratory work, and traditional summative assessments, including paper-and-pencil quizzes and tests. Assessments could include the following:

- Students should be monitored during activities and the teacher should make note of pertinent observations. This may be done in the form of journaling or an observation rubric.
- All student-generated work should be evaluated.
- Use a rubric to assess student proficiency in all laboratory techniques and skills, including social/group skills.
- A format for writing laboratory reports should be provided by the teacher. Students should write reports including analysis of the significance of the activity as it relates to the concept being studied.
- When appropriate, students should be given the opportunity to help develop grading rubrics.
- For multiple-choice items on written tests, allow student to justify their responses. This may identify poorly written test items as well as student misconceptions.
- Students should be given opportunities to evaluate their own work and progress through journaling and/or as part of their laboratory reports.

General Assessments

- The student will distinguish between and give examples of scalar and vector quantities.
- The student will use triangle trigonometry and scale drawings to resolve vector problems.
- The student will solve problems involving centripetal force and acceleration, torque problems using force and torque arms, and the use of horizontal and vertical components of projectiles to calculate distance, time, and launch angle.
- The student will analyze the periodic motion of a pendulum and a spring.

Activity-Specific Assessments

- Activity 6: Since this activity requires sketches of the lab set-up, math calculations of similar triangles, analysis of results, and a discussion of real world applications, it requires a rubric that is custom designed. Because students should be involved in the assessment process, including rubric development, demonstrate the building of a rubric that contains the elements to be evaluated. A possible rubric is included as Lab Report: River Crossing BLM.

- Activity 7: An appropriate rubric should be used to evaluate the torque activity. A rubric appropriate for the torque activity is Lab Report Evaluation Form BLM. It includes a component that allows the students to evaluate their own performance.

- Activity 9: This activity involves procedures that cannot be evaluated effectively by a generic rubric. For example, it requires a discussion of Newton's third law of equal and opposite force pairs as an introduction. Additionally, it requires both mathematical and graphical analysis of the data. This provides an excellent opportunity for students to generate a rubric. Pull up an Internet site that assists in rubric generation and work through it, based on student input.

Resources

- The Physics Classroom - Unit Three explores vectors and vector addition, including a boat crossing a river.
  www.physicsclassroom.com

- NSTA SciLinks - *Vectors-Motion and Forces in Two Dimensions* explains vectors and presents visual diagrams of them. *Things that Spin* illustrates how the motion of various objects is different.
  www.scilinks.org

- Resources for projectile motion:
  http://www.msu.edu/~brechtjo/physics/cannon/cannon.html
  http://physics.usask.ca/`pywell/HighSchool/Fun/Projectile/projectile.html

Physics
Unit 4: Energy Transformation and Conservation

Time Frame: Approximately five weeks

Unit Description

The focus of this unit is energy transformation and conservation. Conversions among thermal, chemical, magnetic, electrical, and mechanical energy types are examined. In addition, mechanical advantage and efficiency of simple machines are explored.

Student Understandings

Students should understand that everything is either matter or energy. Energy may be converted from one form to another, and energy must be available when work is done. Energy consumption may be quantified and must follow laws of conservation. Work done over time is power. Simple machines may be used to make work easier but do not reduce the total amount of work done. Students will demonstrate understandings through inquiry and problem solving activities that include energy consumption, conversion, and conservation.

Guiding Questions

1. Can students discuss the relationship among work, power, and energy and solve problems demonstrating these relationships?
2. Can students explain and solve problems demonstrating energy being transformed from potential to kinetic energy?
3. Can students list ways individuals consume energy?
4. Can students calculate mechanical advantage and efficiency of simple machines?
5. Can students explain why energy is so expensive even though energy comes ultimately from the sun?
6. Can students apply energy and work transformations to real life situations?
7. Can students discuss why we have energy shortages?

Unit 4 Grade-Level Expectations

GLE	GLE Text and Benchmarks
Science as Inquiry	
2.	Describe how investigations can be observation, description, literature survey, classification, or experimentation (SI-H-A2)
4.	Conduct an investigation that includes multiple trials and record, organize, and display data appropriately (SI-H-A2)

GLE #	GLE Text and Benchmarks
5.	Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)
6.	Use technology when appropriate to enhance laboratory investigations and presentations of findings (SI-H-A3)
7.	Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)
8.	Give an example of how new scientific data can cause an existing scientific explanation to be supported, revised, or rejected (SI-H-A5)
12.	Cite evidence that scientific investigations are conducted for many different reasons (SI-H-B2)
14.	Cite examples of scientific advances and emerging technologies and how they affect society (e.g., MRI, DNA in forensics) (SI-H-B3)
Physical Science	
4.	Perform dimensional analysis to verify problem set-up (PS-H-A1)
5.	Use trigonometric functions to make indirect measurements (PS-H-A1)
19.	Explain quantitatively the conversion between kinetic and potential energy for objects in motion (e.g., roller coaster, pendulum) (PS-H-F1)
20.	Calculate the mechanical advantage and efficiency of simple machines and explain the loss of efficiency using the dynamics of the machines (PS-H-F1)
21.	Explain and calculate the conversion of one form of energy to another (e.g., chemical to thermal, thermal to mechanical, magnetic to electrical) (PS-H-F1)
22.	Analyze energy transformations using the law of conservation of energy (PS-H-F2)
23.	Apply the law of conservation of momentum to collisions in one and two dimensions, including angular momentum (PS-H-F2)
24.	Apply the concept of momentum to actual situations with different masses and velocities (PS-H-F2)

Remind students at the beginning of the unit that they are to continue to utilize their *vocabulary self-awareness chart* (view literacy strategy descriptions).

Sample Activities

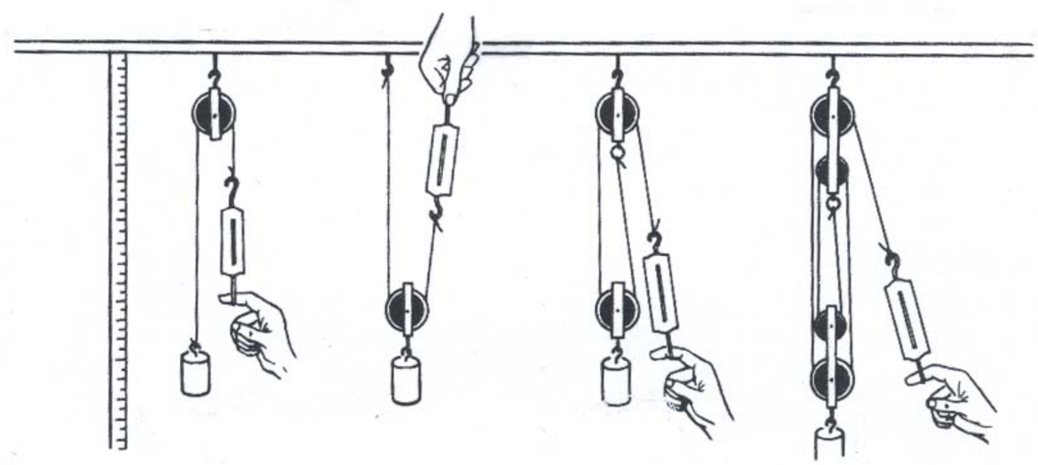
Activity 1: Pulley Lab (SI GLEs: 4, 5; PS GLE: 20)

Materials List: Two single pulleys, two double pulleys, at least two different metric masses, about 2 m of string, a spring scale and a meter stick, Process Guide for Simple Machines BLM, set of problems

If students need a review of simple machines, the following websites are excellent resources: www.mos.org/sln/Leonardo/InventorsToolbox.html and http://science.howstuffworks.com/pulley1.html.

Discuss with students the concept of *efficiency of machines*. Point out that no real machine can be one hundred percent efficient since some mechanical energy is converted to heat energy due to friction. Remind them that all machines, no matter how complex, are a combination of up to six simple machines, and the design determines the mechanical advantage and thus its efficiency. Challenge students to do a literature search for efficiency values for various machines such as bicycles, automobile engines, lever systems of the human body, and even plants carrying out photosynthesis.

Ask students to describe some uses of pulleys that they have seen; some of them may have visited a science museum where they used a "come along pulley" to raise themselves above the ground. Set-ups for pulleys are illustrated in most physics lab manuals. Student groups will need two single pulleys, two double pulleys, at least two different metric masses, about 2 m of string, a spring scale, and a meter stick. Instruct students to set up pulleys with one, two, and four lifting strands. Remind them to pull vertically and at constant speed as they determine the force and distance for work input and work output.



Following a teacher demonstration of calculations, have students calculate the mechanical advantage and efficiency of each pulley system and be sure to explain that loss of efficiency exists because energy has to be used to overcome friction. Students should run multiple trials. As an application, ask the students to draw a diagram of a system with a mechanical advantage of six that could be used to lift a boat. Teacher modeling of problem solving and the assignment of additional problems involving simple machines should follow this activity.

Note: The Process Guide for Simple Machines BLM can be used as an assessment for this activity.

Activity 2: Personal Energy Audit (SI GLEs: 5, 6, 7, 12, 14; PS GLEs: 21)

Materials List: Lab handout from the Riverdell website, science learning logs

Begin the activity by discussing the hazards of high voltage electricity with your students and stress that they need parental supervision when investigating their home electrical wiring and appliances. Next, view the LPB Cyberchannel (www.lpb.org/cyberchannel) video, *The Planet Electric*, or a similar video, that explains electrical power generation. Follow this with a discussion of the cost of generating power and the difficulties of meeting the huge demand for affordable energy worldwide, even with emerging technologies. Ask students to compare and contrast the quality of life for people in the world today who do and do not have electric power as part of their daily lives.

This activity presents a great opportunity to explore the idea that scientists conduct investigations for many different reasons. Discuss the various reasons for the students' conducting the energy audit: to heighten their awareness of personal energy use, to discover how their energy needs are met locally, to study factors in their home construction and landscaping that affect energy consumption, and to realize their personal contribution to carbon dioxide which is linked by many scientists to global warming. Include in the preliminary discussion what the source of the students' home electricity is (coal, oil, nuclear, hydroelectric, etc), why their form of electric power is expensive, and what specific impact their particular power source has on the environment. Ask students to determine how much they are charged by their supplier for a kilowatt-hour of electricity. If your students live in an area where nuclear reactors are used to produce power, the following web site would be of interest to them: http://www.eia.doe.gov/fuelnuclear.html.

Provide students with directions for recording data in their science *learning logs* (view literacy strategy descriptions) to complete an audit of the amount of energy their household uses in a typical week; they can convert this to a month and actually compare their estimate with the electric bill for that month. It is necessary for students to locate their electric meters and to discuss with parents any measures taken during construction to reduce heating and cooling costs, such as insulation, North-South placement of windows, tree planting, and energy efficient appliances. They can also use their data to calculate how much carbon dioxide their electricity consumption adds to the atmosphere for a given time period. The lab handout explains how to do this calculation. This handout entitled Personal Energy Audit may be obtained from www.riverdell.k12.nj.us/staff/molnar/labenergyuseaudit.htm. Additional information and suggestions may be found at www.enviroliteracy.org. Students may open the energy link and select the form of energy used for their local generation of electricity. If there are students who live in housing where their utilities are paid and do not have access to meters, they may use the meter readings of relatives or share a classmate's data.

The teacher should introduce and model various problem solutions involving energy conversions that include the conversion of heat from mechanical to electrical energy; these problems will also include work and power conversions. Provide guided practice in problem solving.

Activity 3: Power Lab (SI GLEs: 2, 7, 8; PS GLEs: 4, 5, 19, 21, 23, 24)

Materials List: bathroom scale, access to stairs or some elevation change such as a hill or sloping sidewalk, stopwatch, set of work and power problems, Lab Report Format and Rubric: Experimental Determination of Student Horsepower BLM, learning logs

This activity allows students to look at the history of our awareness of energy conversions and to apply James Watt's work to an everyday occurrence. Ask student groups to research the work of Count Rumford, James Joule, Thomas Newcomen, James Watt, and Sadi Carnot and record their findings in their science *learning logs* (view literacy strategy descriptions). They will find some interesting information about how our ideas of energy have changed over the centuries, such as the caloric theory being replaced as recently as the mid-nineteen hundreds with the kinetic-molecular theory. They may also discover that the idea of energy being converted from one form to another is a relatively recent one. Their information should be incorporated into an introduction to the lab activity. Also discuss the idea that investigations are not just experimentation but can involve descriptive components as well as literature research.

Explain to students that this activity is a model that demonstrates James Joule's definition of horsepower. Have a few student volunteers weigh themselves on a metric bathroom scale (or convert pounds to newtons) and run up a flight of stairs while another student times their ascension. Students will need the vertical height and may remember from the elevator lab in a previous unit that the height of one step on the stairs multiplied by the number of steps can be used to calculate this height. Students may then calculate the horsepower of each of the stair climbers with multiple trials. If there are no stairs at your school site, use a sloping sidewalk, a hill, or any kind of elevation that raises the students above the ground. The angle of incline may be estimated and used along with the length of the slope to calculate the rise (remind students that potential energy is based on vertical distance of the object above the ground). If there are no slopes available, provide students with a data set so they can complete the lab with paper-and pencil only. This will help them with the concept of work and give them experience in using horsepower units. All data collection and processing should be recorded in their science *learning logs.* The BLM grading rubric is suitable for scoring their work.

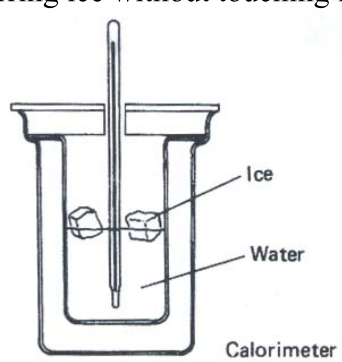
At the end of the activity, the teacher should continue to expand the explanation of energy conversions and energy conservation begun in Activity 2, including potential energy and kinetic energy conversions and conservation of momentum and energy following collisions. This may include conversion of kinetic energy to mechanical energy and to light, heat, and sound. Provide students with a writing prompt for a *learning log* entry which will require them to summarize their new knowledge about the historical evolution of our understanding of the nature of energy and energy transformations. Problem solving strategies with appropriate dimensional analysis and use of significant figures should also be modeled. Follow-up problems should be assigned.

Activity 4: Heat of Fusion (SI GLEs: 5, 6; PS GLEs: 4, 22)

Materials List: calorimeter cup, room temperature water, thermometer or computer-interfaced temperature probe, magnifying lens, ice cubes, triple beam balance, set of thermodynamics problems, closed insulated container or access to freezer

Remind students to take care when using thermometers since they are fragile glass. Also remind them that these alcohol thermometers must be stored upright when not in use. An introductory explanation by the teacher on temperature and heat including specific heat capacity, the first two laws of thermodynamics, and latent heats of fusion and vaporization should precede this activity.

Begin the activity with a discussion of the first law of thermodynamics (conservation of energy) as it applies to a closed system and how the use of a calorimeter is based on this law. Based on the principle of energy conservation during heat transfer, ask students to brainstorm effective methods of collecting data to minimize errors. They should mention heat loss or gain during transfer of materials and problems with reading the temperature changes precisely. If they have done specific heat activities in previous classes, students will probably recall getting high experimental errors. Ask them to suggest remedies that may reduce error. Some possible solutions are to use hand-held magnifying lenses when reading the thermometer, having two students take readings to confirm the temperature, and having a method of transferring ice without touching it with hands.



Students will need a calorimeter cup, thermometer, water, ice, and a triple-beam balance. If a refrigerator with a freezer compartment is available, record the temperature of the freezer compartment so the initial temperature of the ice is known. Otherwise, put the ice in a closed insulated container, let the temperature stabilize and then check it with a thermometer. For precise results, it should not be assumed that the beginning temperature of the ice is 0°C. Instruct students to find the mass of the empty cup, the cup plus 200 ml of water, and after the system stabilizes, the initial temperature. Then they will quickly transfer about 40 grams (two cubes) of ice to the calorimeter cup and allow it to melt; they can then take the final temperature and weigh the cup to find the mass of the ice. If a calculator or computer interfaced heat probe is available, it may be used to collect temperature changes. Students should complete at least two trials, three if time permits. The data should be recorded in the student *learning log* (view literacy strategy descriptions) and may be used to calculate the heat of fusion of ice. Since the calculation of heat of fusion is complicated, it may be necessary for the teacher to work through an example calculation before students attempt the lab calculations. It is important that the teacher model the use of dimensional analysis to minimize errors during calculations. In the conclusion of their lab write-ups, students need to discuss how the use of the calorimeter demonstrates the first law of thermodynamics. Additional related problems should then be assigned.

Activity 5: Converting Sunlight to Heat – How Modern Technology Enhances the Study of the Greenhouse Effect and Global Warming (SI GLE: 7, 8, 14; PS GLEs: 21)

Materials list: Research tools such as Internet, library resources, textbooks

Students are presented with the *SQPL* topic (view literacy strategy descriptions):

> *Current technological advances support (or do not support) a cause/ effect link between greenhouse gases and global warming.*

The position taken is not important to the activity; it is the development of a question-provoking process that is important. Using *split-page notes* (view literacy strategy descriptions), ask students to develop some questions that they will need to answer in their literature search. Some obvious ones would be "What is global warming?", "What are greenhouse gases?", "How can sunlight be converted to heat?", "What are the modern technologies used?", "What kinds of models are used to study global warming and greenhouse gases?", etc. Questions may be shared by writing them on the board, and then students may transfer them to the left side of the split-page note columns. As they begin their investigation, they should answer the questions in the right hand columns. The class should stop periodically to share information they have found. The NOAA website http://www.ncdc.noaa.gov/oa/climate/globalwarming.html is an excellent place to start, as it leads to many other valuable links.

The outcome of the exercise should be to better student understanding of how scientists use technology to study and develop support for controversial topics.

Activity 6: Problem Set (SI GLE: 5; PS GLEs: 4, 19, 20, 21)

Materials List: student list of math concepts with equations

As part of the unit review, ask students to assist in compiling a list of all the concepts that have required a mathematical solution; then ask them to suggest possible equations for solving each problem type. Provide students with a set of practice problems that are representative of the concepts addressed. These should include mechanical advantage and efficiency of simple machines, energy conservation, and work, power, and energy.

Sample Assessments

General Guidelines

Assessment techniques should include the use of scale drawings, models, sketches of lab set-ups, laboratory investigations with reports for which students have been given the grading rubric in advance, performance-based assessments including projects and oral and written research reports, reflective assessment including group discussion and analysis of laboratory work, and traditional summative assessments including paper-and-pencil quizzes and tests. Assessments could include the following:

- Students should be monitored during activities and the teacher should make note of pertinent observations. This may be done in the form of journaling or an observation rubric.
- All student-generated work should be evaluated.
- Use a rubric to assess student proficiency in all laboratory techniques and skills, including social/group skills
- A format for writing laboratory reports should be provided by the teacher. Students should write reports including analysis of the significance of the activity as it relates to the concept being studied.
- When appropriate, students should be given the opportunity to help develop grading rubrics.
- For multiple-choice items on written tests, allow students to justify their responses. This may identify poorly written test items as well as student misconceptions.
- Students should be given opportunities to evaluate their own work and progress through journaling and/or as part of their laboratory reports.

General Assessments

- The student will collect data reflecting the precision of measuring devices used.
- The student will collect data from a real world setting and use it to analyze real energy consumption.
- The student will do calculations using dimensional analysis to set-up and solve work, power, energy, mechanical advantage, and efficiency problems.
- The student will analyze and discuss laboratory results, noting safety elements, accuracy, precision, sources of error, and strategies to improve the activity.
- The student will discuss energy sources and production.

Activity-Specific Assessments

- Activity 1: The Process Guide for Simple Machines BLM can be used to assess this activity. It promotes applied thinking and reasoning about the use of simple machines in real world applications.

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- Activity 2: Students' personal energy consumption audits may be assessed in the form of a checklist. This may be generated through student input as part of the pre-lab discussion of the activity.

- Activity 3: A lab report graded with a rubric is appropriate for the activity. See Lab Report Format and Rubric: Experimental Determination of Student Horsepower BLM.

- Activity 5: Prepare a unit test based on assigned problems and concepts studied. This should include (a) multiple choice items, (b) math problems involving work, power, energy transformations and conservation of energy, mechanical advantage, and efficiency of simple machines and (c) discussion questions related to the history, research, and environmental impact of energy production.

Resources

- NSTA SciLinks - *Heat Engines: Thermodynamics* explains how heat is transferred and includes diagrams. *Potential Energy* gives math formulas and example problems for potential and kinetic energy and includes www.scilinks.org.

- Nuclear Power Plants - learning or reviewing how a nuclear plant works.

  http://www.nrc.gov/reading-rm/basic-ref/students.html

Videos

- www.lpb.org/cyberchannel
  Physics: A World in Motion: Conservation of Momentum and Energy
  Physics: A World in Motion: Collinear conservation of Momentum
  The Planet Electric (Describes how electricity is generated.)

Physics
Unit 5: Interactions of Energy and Matter/ Waves

Time Frame: Approximately five weeks

Unit Description

The focus of this unit is the nature of waves and the function of waves as a means of energy transfer. The components, properties, and behavior of mechanical and electromagnetic waves are analyzed. The function of mirrors and lenses is included.

Student Understandings

There are two methods of energy transfer: the first is by transfer of matter such as pounding a nail with a hammer or moving electrons through a wire and the second is by wave motion which can quickly transfer large amounts of energy with no transfer of matter. All waves share common characteristics and properties and behave in predictable ways, obeying laws of motion. Mechanical waves and electromagnetic waves have a number of differences, as well. Students will describe the nature of waves, methods of energy transfer, and the components of waves. They will be able to sketch and label wave components and interactions and solve problems related to wave behavior and motion.

Guiding Questions

1. Can students describe the nature of waves?
2. Can students explain why waves are critical to energy transfer?
3. Can students differentiate among wave types?
4. Can students diagram and give examples of wave interactions with other waves and with matter including constructive and destructive interference, behavior of waves at boundaries, and the Doppler effect?
5. Can students do calculations for reflection and refraction of waves?
6. Can students label the parts of a wave?
7. Can students solve problems involving the movement of sound and electromagnetic waves through different media?

Unit 5 - Grade-Level Expectations

GLE #	GLE Text and Benchmarks
Science as Inquiry	
2.	Describe how investigations can be observation, description, literature survey, classification, or experimentation (SI-H-A2

3.	Plan and record step-by-step procedures for a valid investigation, select equipment and materials, and identify variables and controls (SI-H-A2)
5.	Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)
GLE #	**GLE Text and Benchmarks**
6.	Use technology when appropriate to enhance laboratory investigations and presentations of finding (SI-H-A3)s
7.	Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)
8.	Give an example of how new scientific data can cause an existing scientific explanation to be supported, revised, or rejected (SI-H-A5)
9.	Write and defend a conclusion based on logical analysis of experimental data (SI-H-A6) (SI-H-A2)
11.	Evaluate selected theories based on supporting scientific evidence
14.	Cite examples of scientific advances and emerging technologies and how they affect society (e.g., MRI, DNA in forensics) (SI-H-B3)
15.	Analyze the conclusion from an investigation by using data to determine its validity
Physical Science	
4.	Perform dimensional analysis to verify problem set-up (PS-H-A1)
25.	Determine the relationships among amplitude, wavelength, frequency, period, and velocity in different media (PS-H-G1)
26.	Evaluate how different media affect the properties of reflection, refraction, diffraction, polarization, and interference (PS-H-G1)
27.	Investigate and construct diagrams to illustrate the laws of reflection and refraction (PS-H-G1)
28.	Draw constructive and destructive interference patterns and explain how the principle of superposition applies to wave propagation (PS-H-G1)
32.	Compare properties of electromagnetic and mechanical waves (PS-H-G3)
33.	Solve problems related to sound and light in different media
34.	Compare the properties of the electromagnetic spectrum as a wave and as a particle (PS-H-G3)
35.	Analyze the Doppler effect of a moving wave source (PS-H-G3)

Remind students at the beginning of the unit that they are to continue to utilize their *vocabulary self-awareness chart* (view literacy strategy descriptions).

Sample Activities

Activity 1: Snakey Spring Lab (SI GLE: 7; PS GLEs: 25, 26)

Materials List: large snakey spring, safety glasses, 30 cm piece of string, science learning logs, Observation of Wave Interactions in a Snakey Spring BLM

As an introduction to the unit, the nature and composition of waves should be presented. Provide the students with a copy of the Observation of Wave Interactions in a Snaky Spring BLM so they can use it as a guide to assure all parts of the lab are completed. A large flexible snakey spring (similar to a *Slinky*®) is needed for the activity; a large oversized model is available through science supply houses. The major safety concern for this activity is not student injury as the elasticity of the springs produces very little force. The danger is to the springs themselves; caution the student holders that if they let go of the extended springs, they will very likely become entangled beyond repair. This activity requires two students to manipulate the spring while the rest of the class observes and collects data. A class of 20 students can observe more effectively if divided into two groups with two springs and two pairs of spring holders. To one end of each spring, securely tie a piece of string about 30 cm long. This will represent a medium change. Before venturing into the selected space where the activity will be conducted, ask students to be sure to observe the following:

(a) one pulse moving down the line and being reflected when hand-held on both ends
(b) one pulse moving down the line and being reflected when one end is held by the string
(c) two pulses generated at opposite ends at the same time; one pulse moving to the right and one moving to the left – what happens the instant they meet and what happens after they pass? (If students have trouble seeing this, generate one large pulse, the other small.)
(d) two pulses generated at opposite ends at the same time; both pulses on the same side – what happens at the instant they meet and what happens after they pass?
(e) Generate a longitudinal wave pulse by bunching up one end of the spring and releasing it; observe the difference between transverse and longitudinal waves.

Have two students move several meters apart and sit on the floor. Show them how to generate a single pulse by pulling the spring to the side and releasing it. Students should record all observations for transverse pulses and then generate longitudinal waves to observe the difference. During the process, ask them to attempt to produce pulses that travel at different speeds. After students have completed observations, proceed with presentation of diagrams of wave interactions and have them discuss in their conclusions the discrepancies between what they thought they observed and what the literature says they should have observed. Some students may want to repeat the pulse interactions to confirm literature descriptions. This is a good opportunity to point out to students that making a single set of observations alone may not be adequate when studying a new phenomenon. It is often necessary to look at the literature explanation and repeat the experiment before valid conclusions are reached. Remind them of the previous difficulties with centripetal force observations. Have students record their observations in their science *learning logs* (view literacy strategy descriptions) and turn in with the copy of the Observation of Wave Interactions in a Snaky Spring BLM. It may be used by the teacher as the grading rubric.

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This activity should be followed by a thorough explanation of the nature, composition, and behavior of waves. Students will have observed that a medium change will affect the special orientation of waves and that the speed cannot be changed within a particular medium. Use this as a basis for introducing the effect of different media on wave properties. Calculations for frequency, period, and velocity should be modeled followed by a problem assignment. Science *learning log* entries should include sketching and labeling waves to show amplitude and wavelength.

Activity 2: Plane Mirror Demo (SI GLE: 7; PS GLE: 27)

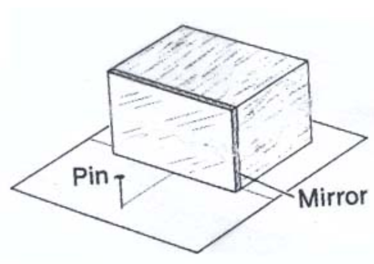
Materials List: large plane mirror, flashlight, string, protractor, ruler

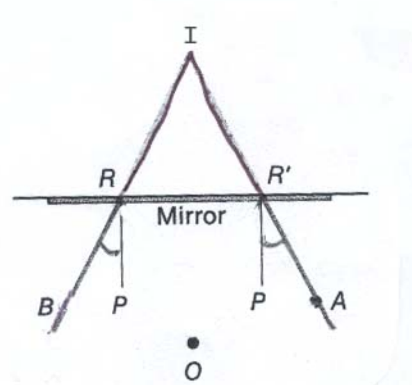
Place a mirror (the largest available) on a desk in the front of the room. Ask students to predict where the light will fall when a student shines the flashlight at the image of a student in the mirror. Then have a student to do so. The light will fall on the target student. Have three students take a long piece of string and use it to trace the path of the flashlight beam to and from the mirror, and measure the angles formed on the face of the mirror. Have students attempt the process by shining the light directly perpendicular to the mirror face and at different angles. Students should sketch and label their findings in their science *learning logs* (view literacy strategy descriptions). This is a good introduction to the unit since it demonstrates the law of mirrors that states the angle of incidence equals the angle of reflection.

Activity 3: Plane Mirror Lab (SI GLE: 7; PS GLE: 27)

Materials List: plane mirror attached to support block, ruler, push pin, plain unlined paper, protractor, safety glasses

In this activity, students first practice using sight lines to locate a virtual image in a plane mirror. Once they have mastered this, they use sight lines to locate the three vertices of a scalene triangle and then construct the triangle and compare it to the mirror image. (The scalene triangle makes it possible to see the left-to-right reversal.) Using the same idea introduced in Activity 2, explain to students that if they sight along an imaginary line from an object to its image in the mirror, they can locate the image. However, to quantitatively locate an image or a point, they need the intersection of two lines. Students will need a plane mirror supported so that it stands perpendicular to the countertop.





Student directions: Position the paper with one half behind the mirror and draw a line to locate the placement of the mirror. On the front half, draw a dot roughly in the center of the exposed paper and place the pushpin over the dot to increase its visibility. Put on your safety glasses. To find a sight line, place your eyes level with the countertop. Move your head slightly to the right of the pin and observe the image of the pin. If you have difficulty, close one eye. Use the ruler to mark the line of vision between your eye and image in the mirror; draw along this line. Now move your head slightly to the left of the pin and repeat the process. Remove the mirror and extend the two lines until they cross; this represents the location of the image. Draw a line from the location of the object to the point where the two lines cross. Measure the distance of the object from the mirror and the distance of the image from the mirror; these should be equal. Now measure the angle between the mirror face and the image-object line; this should be 90^o. Calculate the percent error by using the distance of the object in front of the mirror as the accepted value and the line distance of the image behind the mirror as the experimental value. If your error is 5 % or less, you are ready to proceed. If your error is greater than 5 %, ask your teacher for assistance and attempt a second trial. Once your error is acceptable, repeat the process with a clean sheet of paper and instead of a single dot, draw three dots that will form the vertices of a scalene triangle (do not draw the triangle yet). Label your dots, draw two sight lines for each dot and label them to match your dots. When the sight lines are in place, remove the mirror, extend the lines, and use their intersection points to construct a triangle. Use your dots in front of the mirror to form a second triangle. Observe the two triangles and record your observations. Measure and compare the angles and sides; with the front triangle as the accepted, calculate error using either angles or sides. In your conclusion, formulate a statement that describes all aspects of the images formed by plane mirrors. Include a statement of the law of reflection.

Activity 4: Concave/Convex Mirror and Lens Lab (SI GLEs: 2, 5, 14; PS GLE: 27)

Materials List: access to Internet, library resources, trade books, optical bench, concave and convex mirrors and lenses, candle, safety glasses

As an introduction to the activity, ask students to conduct a brief search of the literature to learn about the development of the science of optics. Instruct them to include the role that the advancements in optics technology have affected society. Also, point out to students that scientists conduct investigations by using many methods such as they will be doing in this activity. These include literature survey, observation, and experimentation. They should include their findings in the introduction portion of their lab reports.

This activity is a traditional mirror/lens lab found in most physics lab manuals. It should include sample data tables that will guide students in collecting a suitable amount of data. First, students need to know the parts of a mirror and lens (focal length, focal point, center of curvature, vertex, principal axis). Students should use an optical bench with a lit candle as the object to determine the relationship between the focal length, size and location of the object to the size and location of the image produced. Data should be recorded in table form. When students examine the data, they will realize that concave mirrors behave in a very similar manner to convex lenses and that convex mirrors form the same kinds of images as concave lenses. As a follow-up, the teacher should model suitable problem solving techniques, and students should be presented with problems that require them to locate position of images and their sizes by constructing ray diagrams and by mathematical calculations.

Activity 5: Refraction Lab (SI GLEs: 3, 4, 9; PS GLEs: 26, 27)

Materials List: Lab Report Rubric: Refraction Plan a Lab BLM

Given the general research question, "Does the medium affect the refraction of light?" ask students to develop a hypothesis and then design and carry out an experiment that will answer the research question. Students should research the question and include this in the introduction. The procedure should allow for comparison of at least two different media and include sketches of experimental design. Quantitative data in the form of angle measurements should be collected. Ask students to use the grading rubric and the Science as Inquiry GLEs 3, 4, and 9 to develop a specific research question and then plan and carry out the activity, recording the investigation in their *science learning log* (view literacy strategy descriptions). This report will include background information, formulation of a research question, a hypothesis, materials list, safety concerns, clear steps for the experimental design, data processing and analysis, and a conclusion that focuses on whether or not the data supports the hypothesis. The analysis should consist of calculations including experimental error and ways to reduce error. The conclusion portion should clearly state the evidence that supports the conclusion drawn. Follow this with an assignment of refraction problems using Snell's Law.

Activity 6: Total Internal Reflection Demonstration (SI GLE: 7; PS GLE: 27)

Materials List: aquarium or other clear square or rectangular container, flashlight or laser pointer, powdered milk

Fill an aquarium or other clear square or rectangular container with water and add some solid such as powdered milk that will produce a suspension. At this point, students have gained knowledge about refraction and reflection of light but may not be aware of the interesting phenomena of critical angle and total internal reflection. Ask students to predict what they think the possible paths of the light will be when the lighted pointer is directed to the suspension. Then, using a flashlight or a laser pointer (which works better), locate the critical angle and the angle of total internal reflection. As each of these is demonstrated, challenge students to explain what is occurring in terms of what they have learned about the behavior of light. Have them sketch and label each of the three phenomena in their *science learning logs* (view literacy strategy descriptions). Ask whether or not anyone has observed examples of these in the real world. Students who are swimmers may have observed these phenomena while swimming underwater but may not be aware of the mechanism.

Activity 7: Interference, Diffraction and Polarization Demonstration (SI GLEs: 5, 7, 6; PS GLEs: 28)

Materials List: clear flat plastic tray for holding water, dropper pipettes, small wood or plastic blocks, plane-polarized film, science learning logs

Question students about observations they have made that are related to behavior of the surface of water when it undergoes a disturbance. They will probably recall throwing stones that cause concentric circles, observing ducks swimming through still water, forming compressed semicircles in front of them and leaving a V shaped wake behind them. They may have observed the semicircles formed by water moving through a narrow opening between two bodies of water or running through openings in river locks. Ask them how sunglasses work; they will say the lenses filter light, but probe to try to get them to speculate about the filtering process.

Instruct students to record observations and draw sketches of the following demonstrations in their science *learning logs* (view literacy strategy descriptions) for future reference. Use dropper pipettes and a clear plastic tray filled with about an inch of water and place on the overhead projector to demonstrate interference. Release single drops of water and observe the concentric circles with light and dark crests and troughs. Dark areas are clearly areas of destructive interference while bright areas are those of constructive interference.

Place blocks in the center of the tray, leaving small gaps between them. Use a ruler or some such device to generate a wave front. Students will observe that the wave front becomes semicircles as it passes through the narrow openings and that these semicircles exhibit constructive and destructive interference as they interact on the other side of the barrier.

Place two pieces of plane-polarized film on the overhead and rotate one to show that the amount of filtering changes as the orientation of the two changes.

Once students have observed these wave behaviors, they should be receptive to exploring the mechanisms by which they occur and the role they played in the development of light theory. This is a good introduction to the Activity 8 research activity that explores how observations of these and other behaviors spurred scientists to explore the nature of light.

As a follow-up, have students construct the resultant pulse produced when two wave pulses undergo constructive and destructive interference. If a calculator or computer interfaced light probe is available, students may use this to complete an activity to test the effectiveness of polarized sunglasses as compared to regular sunglass lenses.

Activity 8: Research the History of Light (SI GLEs: 6, 8, 11, 14; PS GLE: 32, 34)

Materials List: research tools such as Internet, textbooks, library resources

In this activity, students will have an opportunity to research the history of the development of light theory and the impact this has had on society. They will trace the evolution of our understanding of the differences and similarities between mechanical and electromagnetic waves. Divide the research into time periods and allow students to work in groups. For example, groups might be divided into pre-15th, 16th, 17th, 18th, 19th, 20th, and 21st centuries; additional groups might work on the impact related discoveries have had on the scientific world and our daily lives. Students should prepare a presentation of their findings, using technology, if available. A possible format to be used is *RAFT* writing (view literacy strategy descriptions). *RAFT* writings give students the freedom to approach learning from a new perspective, to assume the role of writer, and to approach a concept from this new perspective. The topic (T) would be the history of light theory and its impact on our modern culture. The product could be in the form (F) of press releases to the local news media. Some groups could take the role (R) of on-the-spot news reporters while others could become time travelers (R) following the scientific breakthroughs into the future to assess their impact on the world. The audience (A) would be the readers of the news items, in this case their classmates. At the conclusion, the class should bring the research findings together and make a time line that can be displayed in the classroom. This time line can be referred to throughout a class discussion of light theory based on student *RAFT* products that extend from Newton and his particle theory through early wave theory and on to the modern wave/particle duality concept.

Activity 9: Resonance Demonstration (SI GLEs: 6, 15; PS GLEs: 25, 33)

Materials List: large graduated cylinder, hollow glass or plastic tube, tuning fork, hot and ice water, thermometer or CBL with temperature probe (for air temperature)

After an introduction of the properties of sound, demonstrate how to use the principle of resonance to determine the speed of sound in air and also demonstrate how the speed of sound changes with temperature. Fill a graduated cylinder with hot water and insert a hollow glass or plastic tube into the cylinder. Strike a tuning fork with a rubber mallet and hold it over the open end of the tube. Raise and lower the tube into the water until the point of loudest sound is located. Have students record the length of the tube above the water; this length is one fourth of a wavelength or four times the length above the water, which is equal to one wavelength ($4L = \lambda$). Also have them record the air temperature in the middle of the glass tube and the frequency of the tuning fork. Repeat the process with ice water in the graduated cylinder. Using the equation $v = f\lambda$, ask students to calculate the experimental speed of sound in air. Discuss the findings and ask students to write and defend a conclusion based on their data and calculations. Then give them the conversion factor for temperature adjustment of the theoretical speed of sound in air and have them compare their experimental speeds with the accepted values and calculate experimental error. If electronic temperature and sound probes are available, these may be used to collect temperature and sound data. Follow this activity with teacher modeling of problems involving production of sound by musical instruments and the travel of sound in different media. Students should then complete practice problems.

Activity 10: Doppler Effect Demonstrations (SI GLE: 7, 14; PS GLE: 35)

Materials List: ripple tank or shallow transparent tray, loud battery powered buzzer inside a foam ball and/or a fog horn held with insulated mitts, practice problem list

Begin the activity with a discussion of the Doppler shift, the shortening of sound waves and the resultant increase in frequency due to compression of the waves by the source of the sound as it moves toward a stationary observer. Students may be familiar with Doppler radar and sonic booms and they have observed the apparent shift in pitch of vehicles with sirens as they move along the street. Challenge them to come up with other examples which may include bats who send out radar signals to locate flying insects, the use of the Doppler effect in medicine to detect fetal heartbeat and arterial obstructions to blood flow. Astronomers also use it to determine whether or not stars are moving toward or away from our galaxy.

A simple method of demonstrating the Doppler shift is by moving a point source across a ripple tank or a transparent tray of water on an overhead projector. This may remind students of observing water birds swimming across still water. Other methods are to obtain a loud battery powered buzzer and put it inside a foam ball so it does not break if accidentally dropped. Ask two students to toss the ball while observers try standing at various points between the two. Another very effective method, if available, is to have students stand in a group out-of-doors and select the fastest runner to run past them sounding a fog horn. (Be sure the fog horn holder has insulated mitts, since the can containing the propellant will get very cold – a good illustration of the Joule-Thompson effect.) Follow this with a mathematical model of the Doppler shift and provide guided and individual practice in problem solving.

Activity 11: Solve Problems Involving Different Types of Waves and Different Media (SI GLE: 5; PS GLEs: 4, 25, 27, 28, 33, 35)

Materials List: set of problems with answers, calculator

Students should refer to their *vocabulary self-awareness chart* (view literacy strategy descriptions) and their *RAFT*-generated time line (view literacy strategy descriptions) throughout the unit review. Begin by reviewing with students the different types of problems in the unit that represent concepts requiring a mathematical analysis. For example, there are problems involving wavelength, frequency, and speed of sound and light, resonance in hollow and open tubes, harmonics, beat frequencies, refraction, reflection, law of mirrors and lenses, and magnification. Once the problem types have been identified, ask students to form groups of five. Each group should identify a problem from previous assignments, their textbook or a teacher generated set of problems with answers. They will then solve this set of problems using a *story chain* (view literacy strategy descriptions). Ask each student to identify and select a problem and pass it along to a second student who will identify the known variables and the unknown variable to be solved. The third person will select the proper equation and isolate the unknown. The fourth person will plug in the numbers, cancel units, and do the math calculation. The fifth and final person will check the use of dimensional analysis, making sure all units are correct and properly canceled, round to the correct numbers of significant digits, and check the answer for correctness. They may stop and discuss difficulties as they arise. Remind students that they are also expected to know how to draw and label wave phenomena including reflection, refraction, and constructive and destructive interference. These practice exercises should be added to their study lists.

Sample Assessments

General Guidelines

Assessment techniques should include the use of scale drawings, models, sketches of lab set-ups, laboratory investigations with reports for which students have been given the grading rubric in advance, performance-based assessments including projects and oral and written research reports, reflective assessment including group discussion and analysis of laboratory work, and traditional summative assessments including paper-and-pencil quizzes and tests. Assessments could include the following:

- Students should be monitored during activities and the teacher should make note of pertinent observations. This may be done in the form of journaling or an observation rubric.
- All student-generated work should be evaluated.
- Use a rubric to assess student proficiency in all laboratory techniques and skills, including social/group skills.
- A format for writing laboratory reports should be provided by the teacher. Students should write reports including analysis of the significance of the activity as it relates to the concept being studied.
- When appropriate, students should be given the opportunity to help develop grading rubrics.
- For multiple-choice items on written tests, allow students to justify their responses. This may identify poorly written test items as well as student misconceptions.
- Students should be given opportunities to evaluate their own work and progress through journaling and/or as part of their laboratory reports.

General Assessments

- The student will describe the nature of waves and differentiate among wave types
- The student will label parts of transverse and compressional waves.
- The student will diagram and identify by type interactions wave interactions with other waves and with matter. Explain significance of the capability of waves to transfer energy.
- The student will solve problems involving reflection, refraction, and movement of sound and electromagnetic waves through different media.

Activity-Specific Assessments

- <u>Activity 1</u>: The emphasis for this activity should be on whether or not the students can resolve the differences between their observations and the wave behavior predicted in the literature. Use the Activity 1 Observation of Wave Interactions in a Snakey Spring BLM to assess the students understanding.

- <u>Activity 4</u>: Since students are provided with a procedure that includes data tables, blanks to fill in, questions to answer, and applications, the teacher should make a key from the handout and use it to score the lab results.

- <u>Activity 5</u>: See the Lab Report Rubric: Refraction Plan a Lab BLM as a possible rubric for the activity requiring students to plan a lab to answer a research question. This may be modified to meet your individual classroom needs.

- <u>Activity 8</u>: This activity may be assessed using the research rubric from Unit 2 Activity 6, titled The History of Gravitational Theory BLM, which is suitable for a research project. It will require some modification, but that is easily done since the basic rubric is in place.

Resources

Videos

- www.lpb.org/cyberchannel
  Elements of Physics: Light: Optics and Electricity - discussion of reflection, refraction, and speed of light appropriate for this unit.

  A World of Motion: The Photon Model of Light - topics are blackbody radiation, photoelectric effect, Maxwell's model, new modern model for light.

  Special Theory of Relativity
  Light, Optics and Electricity - reflection, refraction, electromagnetism, speed of light, and electricity in telecommunications.

  Sound and Electromagnetism - energy propagated as waves; wave/particle duality.

Lesson Plans

- www.scilinks.org
  Electromagnetic Spectrum: Electromagnetic Waves - a dialogue between a scientist and a non-scientist and includes games and demonstrations that teach the student about electromagnetic radiation.
- www.physicsclassroom.com - refraction tutorial with graphics.
- www.physicsclassroom.com/Class/waves/U10L1a.html - waves and wave behavior
- www.physicsclassroom.com - sound waves and light
- http://phet.colorado.edu/web-pages/simulations-base.html - waves on a string

Physics
Unit 6: Interactions of Energy and Matter/Electricity and Magnetism

Time Frame: Approximately six weeks

Unit Description

The focus of this unit is on electrostatics, circuit electricity, and magnetism. Electrostatics includes test charges, electric fields and magnetic fields along with Coulomb's law that quantifies electric charges. Electricity involves constructing circuits and calculating current, voltage, resistance, energy, and power. Electromagnetic induction is used to link the nature of electricity and magnetism.

Student Understandings

A charged object produces an electric field around itself that exerts an electric force. Electric force, like gravitational force, varies inversely to the distance between charged objects. When electric charges move through a wire, they become current electricity which can be transformed into power and used to do work. Electricity is closely linked to magnetism since an electric current moving through a wire sets up a magnetic field around itself. A magnetic field can likewise cause a current to flow through a wire that moves through its force field, thus inducing a current. Electromagnetism is an interaction between electric and magnetic fields. Students explore and describe the relationship between electrical force and magnetism. Student measurements of current, resistance, and electrical potential energy are used to solve problems.

Guiding Questions

1. Can students solve problems involving point charges?
2. Can students draw diagrams representing lines of force around point charges, magnets, and current-bearing wires?
3. Can students describe applications of electrostatics?
4. Can students construct and label circuits?
5. Can students solve problems involving amperage, voltage, resistance, energy, and power?
6. Can students relate motors and generators to electromagnetic induction?
7. Can students explain how current is transported?
8. Can students discuss the significance of electrical energy in their lives?

Unit 6 - Grade-Level Expectations

GLE #	GLE Text and Benchmarks
Science as Inquiry	
5.	Utilize mathematics, organizational tools, and graphing skills to solve problems (SI-H-A3)
7.	Choose appropriate models to explain scientific knowledge or experimental results (e.g., objects, mathematical relationships, plans, schemes, examples, role-playing, computer simulations) (SI-H-A4)
9.	Write and defend a conclusion based on logical analysis of experimental data (SI-H-A6) (SI-H-A2)
10.	Given a description of an experiment, identify appropriate safety measures (SI-H-A7)
14.	Cite examples of scientific advances and emerging technologies and how they affect society (e.g., MRI, DNA in forensics) (SI-H-B3)
15.	Analyze the conclusion from an investigation by using data to determine its validity (SI-H-B4)
Physical Science	
8.	Compare and calculate electrostatic forces acting within and between atoms to the gravitational forces acting between atoms (PS-H-E1)
29.	Describe observed electrostatic phenomena, calculate Coulomb's law, and test charge pole, electric field, and magnetic field (PS-H-G2)
30.	Construct basic electric circuits and solve problems involving voltage, current, resistance, power, and energy (PS-H-G2)
31.	Describe the relationship of electricity, magnetism, and inductance as aspects of a single electromagnetic force (PS-H-G2)

Sample Activities

Remind students at the beginning of the unit that they are to continue to utilize their *vocabulary self-awareness chart* (view literacy strategy descriptions).

Activity 1: Safety (SI GLE: 10)

Materials List: art supplies or drawing software, poster paper or card stock, lab manuals or access to the Internet for researching safety precautions

Instruct students to form groups and research the dangers of electricity; allow them to share their results with the class. Ask students to devise safety precautions for each activity in the unit. This could be done in the form of a poster, a comic strip, a cartoon, or a safety bulletin such as those issued by science supply houses. Purchased science materials and equipment usually include safety concerns. Laboratory manuals also include appropriate safety precautions. *RAFT writing* (view literacy strategy descriptions) provides a model for this kind of activity. Students assume the **R**ole of safety experts. The **A**udience is other physics students. **F**orm can be a safety bulletin, poster, etc. The **T**opic is how to work with electricity safely. Confirm safety procedures for each activity to assure that proper safety concerns are addressed.

Activity 2: Demonstration of Force Lines (SI GLE: 7; PS GLE: 29)

Materials List: transparency film, a pair of bar magnets, overhead projector, iron filings**,** safety goggles, copy of Laboratory Report Grading Rubric BLM, science learning logs

Safety Note: Since iron filings contain fine particles, it is essential that students use their safety goggles throughout the activity.

As an introduction to magnetic and electric force fields, remind students that when one body exerts a force on another over a distance, this is explained by the concept of force fields. An example studied earlier is gravitational force that exists between two bodies that have mass; this can occur over very great distances between objects such as planets and the sun. These gravitational force fields are difficult to observe but magnetic force fields are relatively easy to observe.

Using iron filings and a piece of transparency film to separate the iron filings from the magnet, review with students that attractive force lines are visible between unlike poles and that repulsive force lines are visible between like poles. Identify the magnetic north and south poles and explain that not only do the forces exist, they also have direction; the force of the magnetic field is exerted outward from the magnetic north pole and inward toward the magnetic south pole. Discuss the concept of electric fields and the fact that forces are exerted inward toward negative charges and outward from positive charges. Remind students that electric force cannot be separated from magnetic force since they are two components of natural magnetic force. They may remember this from their earlier study of the nature of light in Unit Five. Ask students to sketch and label the forces for a pair of like and unlike magnets and a pair of like and unlike charges.

This is a good opportunity to discuss the use of models; although the force fields do exist, the lines themselves are imaginary but serve as a very useful model to demonstrate that the force fields are real. Follow the activity with an introduction of the work of Millikan and Coulomb that led to the discovery of the elementary unit of charge. Include a comparison of gravitational potential energy to electric potential difference. Students are to record their observations in their science *learning logs* (view literacy strategy descriptions).

The Laboratory Report Rubric BLM may be used for student assessment.

Activity 3: Electrostatics Lab (SI GLEs: 5, 7, 9, 14GLEs: 8, 29)

Materials List for Part 1: rolls of sticky tape, research vehicle, Electrostatics Research Grading Rubric, science learning logs, Coulomb's Law Apparatus and/or other materials (may vary with the activity chosen and materials available**)**

Part One*:*
As an introduction to electrostatics, present the following demonstration. Tear off two 20 cm strips of sticky tape. (Some brands work better than others. Try it ahead of time on the day you plan to use it because if humidity is too high, it will not work.) Hold the strips by the ends and bring them together side by side and note that they repel each other. Students will probably know this indicates they have a static charge. They need an opportunity to discuss what they know about static electricity and how it is produced; usually they will say that friction causes static electricity. Make tabs on the ends of the strips to make them easier to grip. Stick the two strips together, sticky side of one to the smooth side of the other, without rubbing them and quickly pull them apart. Now when they are brought together, they should attract.

Question students about how the charge was produced. Have a student pull off two strips of tape and stick them together, sticky sides facing in; when the student pulls them apart, they will not be charged. Again ask students to explain how this can be. (It is unlikely that they noticed that the sticky and smooth sides were put together by the teacher.) The discussion will probably not result in a conclusion, so ask students to form groups of two and challenge them to find different combinations of tape pairs that might help them figure out how and why the strips have attractive, repulsive, or no charges. Suggest that they try pairs of tape with one pair stuck sticky sides together and another with one sticky side exposed. Provide a rubber balloon that students can hair-charge since this type of balloon will always have a negative charge. Students should record in their science *learning logs* (view literacy strategy descriptions) data from all trials and outcomes along with any ideas that may come to them as they experiment.

When their trials are complete, continue the class discussion. Guide them toward the idea that the tape is made up of two different materials whose electrons rearrange themselves when they are in close contact. This is the property of adhesion that is the result of two unlike materials being attracted because one of the materials attracts some electrons from the other and produces an "opposites attract" situation. When the unlike sides of the tape are ripped apart, outer electrons are forcibly pulled from their protons so the strips become charged. Thus, static electricity is not about rubbing or friction but about contact that results in uneven charge distribution followed by physical separation of electrons and protons.

Question students as to where the concept of friction comes into play. (Rubbing is used to increase contact area, thus increasing the amount of separated charge.)

Have students research some everyday applications of electrostatics using the Electrostatics Research Grading Rubric BLM as a guide. This report should become part of their report of the tape activity to be included in their science *learning logs.* As stated in the grading rubric, the conclusion should consist of a summary of the concept of electrostatics and what was learned during this activity.

Part Two: Use this part of the activity to provide students with some additional laboratory experience with electrostatics. This is a good opportunity to ask students to plan and carry out an activity involving electrostatics. They may use the Internet or other sources to come up with an experiment. Most high school physics lab manuals have the procedure for testing Coulomb's Law. Commercial Coulomb's Law apparatus is available at a low cost. This will allow students not only to observe that like charges repel and opposites attract but also to confirm quantitatively Coulomb's inverse square equation. The data will permit students to plot a $y = k/x$ graph where $x = \text{radius}^2$ and a $y = kx$ graph where $x = 1/\text{radius}^2$. If graphing software is available, this may be used. Otherwise, students may plot the graphs manually. Students should do at least two trials and work quickly because of charge leakage; humidity will also hamper success. Follow this activity with a formal presentation of Coulomb's Law and accompanying problems.

Activity 4: Series and Parallel Circuits (SI GLEs: 9, 10; PS GLE: 30)

Materials List: voltmeters and ammeters, cells, lights or other resistors, wires, switches, Laboratory Self-Assessment Grading Rubric BLM, Series and Parallel Circuits Graphic Organizer BLM, set of problems for guided practice

Ask students to look at the features listed in the safety bulletin generated in Activity 1 and include them in their laboratory procedures. Provide students with cells, lights, or some other type of resistors, wires, switches, voltmeters, and ammeters. Students who are not familiar with the use of voltmeters and ammeters must be instructed to wire the voltmeter in parallel across the resistor to be measured while the ammeter must be wired in series. Distribute copies of the Series and Parallel Circuits Graphic Organizer BLM which is a *graphic organizer* (view literacy strategy descriptions). Instruct students to copy or cut and paste it into their science *learning logs* (view literacy strategy descriptions) and then construct a series circuit using one resistor, measure voltage and amperage, sketch using schematic symbols, and label their set-up. They should predict in writing in their science *learning logs* what will happen when a second and third resistor are added.

After completion of this part of the activity, students are now ready to build the additional series circuits, take amperage and voltage readings, draw and label their circuits in their science *learning logs* and record all their voltage and amperage changes in the *graphic organizer.* Now they have a schematic drawing in their science *learning log* and numerical values in their *graphic organizer* so that they can easily analyze and defend their experimental data and note differences between the two types of circuits. A summary of the changes in voltage and amperage relative to resistance changes in series and parallel circuits should be written in their science *learning logs*.

When the activity is complete, students may evaluate their laboratory work using the Laboratory Self-Assessment Grading Rubric BLM.

Continue the exploration of electric circuits with model problems that include voltage, amperage, resistance, power and energy. Provide guided practice in problem solving.

Activity 5: Magnetic Fields around Magnets and Current Bearing Wires and Magnetic Induction (SI GLE: 15; PS GLE: 31)

Materials List: for each student group - safety goggles, 2 bar magnets, string, several small compasses, transparency paper or plastic wrap, large iron nail, steel paper clips, a cardboard square, a long wire, DC power source or three 1.5 volt cells, galvanometer, ring stand, 2 clamps, 2 horseshoe magnets, enameled wire (22-28 gauge) to form a coil, sandpaper, science learning logs

Note: Students should use safety goggles when working with iron filings. Remind students to review their safety notations from Activity 1. Remind students that the wiring may heat up due to resistance of current flow; wires should be disconnected from the cells or DC power source as soon as each observation has been made.

Students have observed that magnetic fields exist around magnets and it has been proposed to them that electric fields and magnetic fields are closely related. This activity will enable students to establish a clear link between the two. Remind students to make labeled sketches of all observations including the positive and negative terminals of the cells or power source used in their science *learning logs* (view literacy strategy descriptions).

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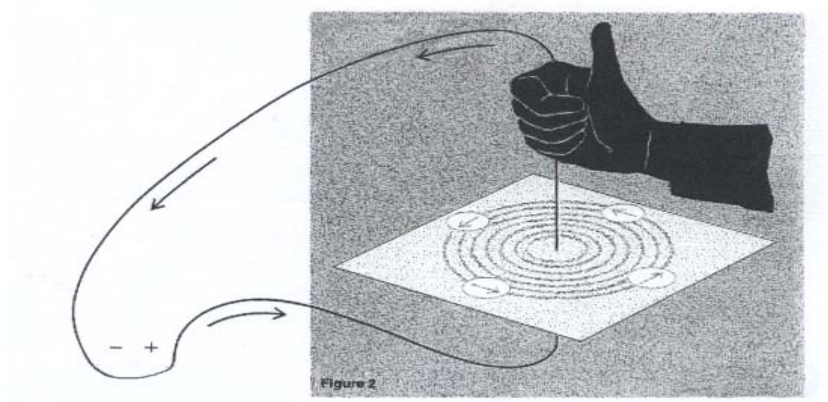
1. Provide students with a bar magnet and a string from which to suspend it horizontally. They will observe that the end labeled north points toward the direction of North; this will provide an opportunity to discuss whether the North Pole is really north.

2. Ask students to look at their sketches from Activity 2 and predict what will happen if they line up two magnets and place a small piece of iron metal between the unlike poles close to but not touching them and what would happen if they used a small iron washer instead. Using transparency paper or plastic wrap to keep the iron filings off the magnets, have students sprinkle iron filings over the ends of the magnets and the block of iron and then the iron ring and sketch their observations.

3. Give students a large iron nail and some steel paper clips to test whether the nail is magnetic. Then touch the nail against one end of the magnet and test again using the paper clips. To determine the polarity of the nail, once again suspend the other magnet from the string and observe which end is attracted to the free end of the nail. Record observations. Give each group of students a number of small

compasses and have them try and locate the direction of the force field around a magnet by observing the direction of the deflection of the compass needles.

4. Students will now try to locate a magnetic field around a current-bearing wire. Have students make a hole in the center of a piece of stiff paper or cardboard and insert the end of a 1-2 m long insulated wire through the hole, then attach the wire ends to a DC power source or three 1.5 volt cells. The wire needs to be held perpendicular to the cardboard as the magnets are placed around the wire. The direction of the compass needles should be noted and recorded. Results should be confirmed by applying the right hand rule.



5. Students disconnect the wire and wrap it around the iron nail to build a simple solenoid. Have students connect the wire to one 1.5 volt cell and use the paper clips to test whether or not the nail is now magnetic. If so, students should determine the polarity by testing the ends with a bar magnet. Ask them to use the right hand rule to verify their findings.

6. Before starting this next investigation, discuss with students that the principle of a motor is the conversion of electrical energy to mechanical energy in an electric field and the generator converts mechanical energy to electrical energy in an electric field. Provide students with a galvanometer with zero in the center, magnet wire for making loops, sandpaper to strip the ends of the wires where they are connected to the galvanometer, and 2 bar magnets. You may want to assign different groups different numbers of coils to wrap but each group should make three coils with different numbers of loops. Students are to move first one magnet and then two magnets in and out of the coils and observe the deflection of the galvanometer.

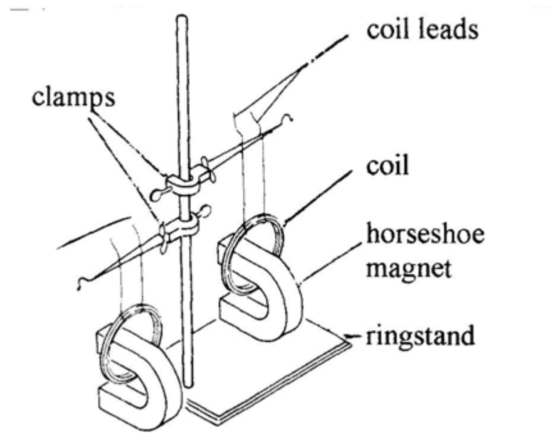
   This activity further explores electromagnetic induction and the functioning of motors and generators. Discuss Lenzs' Law at the beginning of this part of the activity. In addition to the galvanometer and wire, student groups need two strong horseshoe magnets, a ring stand with two clamps, tape to hold the loops in each coil together, and two pairs of wire leads. Assemble the magnets and coils so that the coils can swing back and forth around the top pole of the magnet. Make the following observations:

One: Attach one set of leads to the galvanometer and swing this coil on the magnet. Try swinging at different speeds and adding an additional magnet with like poles together. Use the right-hand rule to determine the direction of current flow and label the positive lead; repeat for the second coil.

Two: Disconnect the galvanometer. Swing one coil and observe its motion. Connect your two positive leads, and then connect the other two to complete the circuit.

Three: Swing one coil and observe the system.

Four: Unhook one of the lead wires and connect the galvanometer in series. Swing one coil and observe the galvanometer. In your conclusions, discuss the following: (a) factors affecting the strength of the current, (b) how swinging one coil causes the other to swing in the opposite direction, (c) why the unattached coil swings faster, and (d) at what point one coil is acting as a generator and the other as a motor.



Students will see that both the number of turns and the speed at which the magnet is moved increase the current flow. Also, the direction of the current changes with the motion of the coil as it moves back and forth around the magnet.

Students should conclude that when the coils are connected, the current flowing through the first interacts with the magnetic field of the second, causing it to move. When the second coil swings back, it generates a current in the opposite direction that flows back to the first coil. When the coils are not connected, the unattached coil swings faster in keeping with Lenzs' Law; when the second coil is attached, the first coil acts as a generator and a load exists on it, creating an opposite force that slows it down. This means that the second coil is acting as a motor.

Complete the activity with a mathematical analysis of forces on currents single charged particles in magnetic fields, electromotive force, alternating current generators, and inductance between coils. The teacher should model problem solving and assign appropriate problems.

Sample Assessments

General Guidelines

Assessment techniques should include the use of scale drawings, models, sketches of lab set-ups, laboratory investigations with reports for which students have been given the grading rubric in advance, performance-based assessments including projects and oral and written research reports, reflective assessment including group discussion and analysis of laboratory work, and traditional summative assessments including paper-and-pencil quizzes and tests. Assessments could include the following:

- Students should be monitored during activities and the teacher should make note of pertinent observations. This may be done in the form of journaling or an observation rubric.
- All student-generated work should be evaluated.
- Use a rubric to assess student proficiency in all laboratory techniques and skills, including social/group skills.
- A format for writing laboratory reports should be provided by the teacher. Students should write reports, including analysis of the significance of the activity as it relates to the concept being studied.
- When appropriate, students should be given the opportunity to help develop grading rubrics.
- For multiple-choice items on written tests, allow students to justify their responses. This may identify poorly written test items as well as student misconceptions.
- Students should be given opportunities to evaluate their own work and progress through journaling and/or as part of their laboratory reports.

General Assessments

- The student will draw diagrams representing lines of force around point charges, magnets, and current-bearing wires.
- The student will describe applications of electrostatics.
- The student will solve problems involving point charges, amperage, voltage, resistance, electrical energy, and power.
- The student will construct and label series and parallel circuits.
- The student will relate motors and generators to electromagnetic induction.
- The student will discuss the impact of electricity on daily life.

Activity-Sample Assessments

- <u>Activity 2</u>: The Laboratory Report Grading Rubric BLM is an appropriate assessment for this activity.

- Activity 3: Part One of this activity is a narrative report so it may be assessed using a writing rubric such as the Electrostatics Research Grading Rubric BLM.

- Activity 4: Give students an opportunity to completely evaluate their own performance of this laboratory activity using the Laboratory Self-Assessment Grading Rubric BLM.

Resources

http://www.colorado.edu/physics/phet/web-pages/simulations-base.html - This site provides balloons and static simulations and a circuit construction kit

Videos
http://www.lpb.org/cyberchannel

Physics: World of Motion: Electric Potential - compares electric and gravitational effects; includes a mathematical model.

Physics: A World in Motion: Coulomb Forces in Nature - explores Coulomb's Law using vectors and vector components.

*Physics: A World in Motion: Charged particles in Magnetic Fields - d*escribes the interaction between a charge and a magnetic field.

Electric Circuits - www.scilinks.org
Electric Circuits: How Light Bulbs Work - explains and gives a visual diagram of a light bulb.