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Course Name: Physics
Unit Title: Simple Pendulum

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Grade Level: HS Juniors and Seniors
Concept: Period of a Simple Pendulum

Goal: The goal of this learning sequence is to get students to use inquiry to learn how various factors affect the period of a simple pendulum.

Objectives: At the conclusion of this exercise the students will demonstrate the ability to:

1. state which factors influence the period of a simple pendulum (length and amplitude).
2. state that mass does not affect the period of a simple pendulum.
3. state the standard pendulum formula derived from theory or from dimensional analysis of an experimental constant.
4. state that the standard pendulum formula is typically constrained to angles of less than so many degrees if one expects a 1% precision, 5% precision, and so on.
5. state that the period of a pendulum is determined by the local value of the acceleration due to gravity.
6. use the standard pendulum formula to determine the local value of the acceleration due to gravity, *g*.

Content:

I. The typical simple pendulum consists of a string and a weight (bob):
   A. A simple pendulum has all its mass concentrated at one point
   B. A physical pendulum has its mass distributed over an area
   C. Samples and classification of different types of pendulums (e.g. torsion)

II. Simple pendulums have easily quantifiable parameters:
   A. length
   B. mass
   C. amplitude

III. Mathematical relationships exists between the period and pertinent factors:
   A. Period is proportional to the square-root of the length (L)
   B. Period is inversely proportional to the square-root of the acceleration due to gravity (*g*)
   C. Period and the square root of (L/g) are related by a proportionality constant, 2π.

Procedure: Because this is an inquiry-oriented lesson, questions will guide the discussion throughout. Students will direct the discussion and class activities by their responses to questions and suggestions for experiments. Here are the basic questions that will be followed throughout the activities.

Day 1 (Discovery Learning, Interactive Demonstration, Inquiry Lesson):

STATE LEARNING GOAL – The objective behind the next two class periods is to find the mathematical relationship between the period of a pendulum and the factors that affect it.

Discovery Learning:

Students develop an understanding of the concept of oscillatory motion. They characterize and conceptualize the motion and components by "playing" with varying configurations of simple pendulums without the use of time or distance measuring devices. Students characterize the system and identify variables and parameters of pendulums in general such as bob mass, string length, amplitude, magnitude of gravitational force constant, and the period. Terms are introduced after concepts are developed.

Interactive Demonstration:

In an effort to help students see that the period of a pendulum and its length are related in some meaningful fashion, the teacher sets up a pendulum with a length of 20cm and then determines the period with the use of an accurate timing device. The teacher then asks what will happen to the period if the length of the pendulum is halved (10cm) or doubled (40cm). Students make and record predictions and the demonstrations are carried out. Returning to the original 20cm, students are asked what would happen if the length was quartered (5cm) or quadrupled (80cm). Students are asked to state if they see some sort of relationship ship between quartering and quadrupling the length of a pendulum and the periods that result.

Inquiry Lesson:

Students observe to determine qualitatively which parameters besides length, if any, whose change will affect the period of a pendulum. Actions are undertaken to see if changing pertinent variables affect the period of the pendulum (bob mass and initial angle) and develop a conceptual relationship between variables (e.g., changing mass has no affect on the period, changing amplitude has a small but real effect). Make data tables or graphs of mass vs. period, length vs. period, and amplitude vs. period.

Inquiry Lab:

Using stopwatches, meter sticks, and protractors, students conduct a controlled experiment (under fixed amplitude) to collect data to determine the relationship between string length and period. That is, $P = k\sqrt{L}$.

Optional Inquiry Lab Extension:

Students use protractors and stopwatches to test different amplitudes to discover the accuracy of the small angle approximation in the relationship. Compare experimental values of period for various amplitudes with predicted values from constant angle formula and make a chart. They determine at what angle (amplitude) the predicted period diverge from the actual period by a certain percentage, say 5%.

Real-world Application:

Students solve a variety of problems using $P = 2\pi\sqrt{L/g}$ such as predicting the period of a long pendulum, how different lengths of pendulums will have different periods on different planets, and so forth. Students use the theoretically derived expression $P = 2\pi\sqrt{L/g}$ to determine the local value of the acceleration due to gravity, *g*.

Hypothetical Explanation:

More advanced students can reconcile experimental with theoretical relationships. The slope of the length vs. period graph can be related to standard constants using dimensional analysis (see the Illinois State University advanced *Student Laboratory Handbook** - for the PDF document "Reconciling Experimental with Theoretical Relationships". Using dimensional analysis, students can extract the values of *g* and 2π from the experimental proportionality constant to show experimentally that $P = 2\pi\sqrt{L/g}$.

* http://www.phy.ilstu.edu/pte/302content/student_lab_hdbk/slh.html