Experiment 9

Simple Pendulum

Equipment List: Heavy string (or twine, or ribbon), quart size freezer bag, heavy paper clip (or safety pin), moderately heavy object that will fit inside of freezer bag (I used a coffee mug, but you could use a small stone, or a can of soup, etc.), marker, pencil (or short dowel rod, or similar), masking tape, a place to secure the pencil with the masking tape (I used the backs of two chairs), cell phone for stopwatch (or actual stopwatch).

Over

Start & Finish Position

and Back

Pivot Point

A simple pendulum is one that is free to swing, back and forth, with no assistance other than the force of gravity. The amount of time that the pendulum takes to swing from one position in the swing to the very same position (Start & Finish Position) is called the period of oscillation.

The equation that relates the Period of Oscillation to the Length of the pendulum is:

Where the length L is measured from the center of mass of the object at the end of the string to the pivot point of the pendulum.

By squaring both sides of the above equation and setting the constants of the equation inside of the square brackets we get the following:

We can now equate the above equation to the general linear form.

With T2 being the dependent variable and L being the independent variable of the equation.

In this experiment, you will measure the amount of time it takes for your pendulum to go through an oscillation for different lengths of your pendulum. Plotting the square of the Period (y-axis) versus the Length of the pendulum (x-axis) will result in a linear relation. From this a slope value will be determined. A comparison of the experimentally found slope will be done with the theoretical slope value. As you can see in the equation involving T2, the theoretical slope of the line should equal (4π2/g).

The Experiment

Set Up: Using two chairs (or a table and a chair) secure a pencil (or dowel rod) to the top of the chair backs as shown using the masking tape.

Place your object (coffee mug, stone, can of soup) into the quart size freezer bag and bundle up the top of the bag. Using the heavy paper clip (or large safety pin) make a hook out of the paper clip and poke the bottom of the hook through the layers of the freezer bag just under the bag seal. The other end of the paper clip hook will be attached to the string (twine, ribbon, etc.). Tie one end of the string to the paper clip hook. Approximate the center of mass (vertical) of your object in the freezer bag and mark this on the bag. Pull up on the string to stretch it out vertically and measure from the center of mass of your object to a point 20 cm from the center of mass and up along the string. Mark this point on the string with a marker. Continue to make more marks along the string at equal intervals. These intervals will be given by your lab instructor.

**Place a thin pillow, or a blanket on the floor between the two chairs (beneath where the pendulum will swing). This is done in case you accidentally drop the pendulum onto the floor, to protect both the floor and the object of your pendulum**.

I used a third chair to sit on next to the setup while taking data. Open the stopwatch function on your cell phone (or use a stopwatch). Place the cell phone on one of the chair seats. With one hand, hold the string of the pendulum such that your first mark of the string (L = 20 cm) is against the pencil (as in the above illustration). I pinched the string to the pencil with my thumb and forefinger to really secure the string. Alternatively, you could wrap the string about the pencil, but you would still need to hold the string from unwrapping and slipping off. With the other hand you will pull back the pendulum and let it go, allowing it to swing (no large amplitudes, keep it medium to small), and start and stop the stopwatch. The pendulum can swing for a couple of oscillations before you start timing, you don’t have to start timing at the onset of the first swing.

Because the amount of time for the Period is small, and there is a reaction time a person has in starting and stopping the stopwatch, you will minimize this effect by timing how long your pendulum takes to go through 10 complete oscillations. Then, you will divide this number by 10 to get the Period of Oscillation. Do this for each of the lengths.

Graphing

Plot the data on the Excel worksheet and Display the Equation to get the slope value of your trend line. No uncertainty analysis for the graph is required for this experiment.

Theoretical Slope Value

Determine the theoretical slope value and record this on the Excel worksheet. Use the percent error equation to compare your experimentally determined slope value with this theoretical slope value. Check with your lab instructor to make sure you have the correct value for the theoretical slope.

Results

Write a statement as to how well your experimentally determined slope value compares to the theoretical slope value.

Questions for Discussion

1. How well do the data points follow with the trend line? Do they all lie on the line, or do some not lie on the line? If they do not lie on the line, what could be some reasons for this?
2. Using the slope of the line from your graph determine the acceleration due to gravity and compare it with 9.801 m/s2.
3. Even though there was no uncertainty analysis values calculated in this experiment, make a list of what sources of uncertainty are associated with this experiment. State which are considered random sources of uncertainty, and which are considered systematic sources of uncertainty.
4. The value for the acceleration due to gravity in Dayton, Ohio is 9.80100 m/s2. Say you adjusted a grandfather’s clock perfectly here in Dayton. The Period of Oscillation being equal to 2 seconds. Then you moved to Denver, Colorado where the acceleration due to gravity is 9.79673 m/s2. However, you forgot to adjust the grandfather’s clock when you got there. After a whole year, how far off in time would the grandfather’s clock be?