Lab 4. Simple Pendulum

Goals

- To design and perform experiments that show what factors, or parameters, affect the time required for one oscillation of a compact mass attached to a light string (a simple pendulum).
- To use a simple pendulum in an appropriate manner to determine the local acceleration of gravity.

Introduction

A simple pendulum consists of a relatively small (in dimension) mass on the end of a string, so the motion may be analyzed as if the mass were a point mass. (For masses with larger dimensions the rotational motion of the mass must also be included in the analysis for good agreement with experiment.) The parameters that potentially affect the period of a simple pendulum are relatively easy to study. Therefore the simple pendulum provides a good "test case" for the application of the scientific method. Although you may ask your TA for help, each lab group is responsible to decide how to measure the relevant quantities on their own. It is especially important in this lab for you to record how you make these measurements. If you are asked to repeat some portion of this laboratory on the lab exam, your lab notes will be your only source of information. Your choice of method also affects how you interpret your results.

Preliminary observations

Although theory is helpful, it is unwise to design an experiment on the basis of theory alone. A few preliminary observations can dramatically improve your experiment. First, set up Capstone to measure the elapsed time for one complete oscillation, or period, of the pendulum. Be sure that it is measuring what you think it is. Then let the pendulum oscillate 40–50 times and display your data in a table. Use care in releasing the pendulum at large amplitudes so that the photogate is not damaged. Practice releasing the pendulum so that it swings in a single plane. The mean value and the standard deviation of the period can then be determined. Do this for at least two initial amplitudes (initial angles). One amplitude should be about as large as you can reasonably manage. The other should be as small as you can reasonably manage, where the mass swings through a distance of only three or four mass-diameters.

Consider carefully whether the period **varies randomly** from swing to swing, or whether the period changes in a **systematic fashion**. When you examine the data on screen or on a printout, the scales may hide the information. If all period values are identical, maybe the number of displayed significant digits are too small. Make appropriate adjustments. If in trouble, ask your TA for assistance. If the period varies randomly, the standard deviation of the mean for the data in your table reflects random variations and is a good measure of uncertainty. In this case, averaging the period over ten or more back-and-forth swings can improve the precision of your period measurement. If the period varies systematically, the standard deviation is more related to (possibly unknown) changing conditions than it is to random variations. If at all possible, your experiment should be designed so that any systematic variations are smaller than the random variations.

One way to reduce the systematic error in this case is to make five separate measurements of the period for single back and forth swings; then calculate the average and standard deviation of the mean of these measurements. It is important to have a reliable value for the uncertainty in your measurements, as they are needed to determine which parameters affect the period in this experiment. Real differences must be larger than these uncertainties.

What makes a pendulum tick?

For the simple pendulum determine which parameters affect the period (defined as the time for one complete back and forth swing) of the oscillation. Consider such things as the amplitude (the angle of the swing) of the oscillation, the mass of the bob, and the string length. Vary each parameter over as wide a range as is feasible with the equipment at hand. You will need to support your findings with adequate data in order to be convincing. Explain the effect of each parameter on the period.

Determine the acceleration of gravity

When a pendulum is displaced from the vertical position, it is the gravitational force that is ultimately responsible for bringing it back to the vertical position. Thus it is not surprising that there is a relationship between the oscillation period and the acceleration of gravity. We can imagine that on the Moon, where the acceleration due to gravity is less than here on Earth, the force bringing the pendulum back to vertical would be smaller; thus the acceleration would be smaller, and the time for an oscillation would be larger. It appears then that the period of the pendulum and the acceleration of gravity are related by an inverse relation; that is, when one parameter gets larger the other gets smaller.

You may need to look in a textbook to find an expression for the relationship between the acceleration of gravity and the period of oscillation. (A shortcut to a PDF copy of the open source *OpenStax College Physics* is on the desktop of your lab computers.) Be sure to note under what conditions the relationship is valid and plan your experiment accordingly. Then take data to determine the acceleration of gravity. Some of the data from the previous exercise may be useful, but you will need to supplement it in order to make a good determination of g.

Use a graphical technique to find g. (Hint: Find a way to graph the measured parameters in such a

fashion that g may be calculated from the slope of a straight-line graph. Use the uncertainty of the slope (the standard error) to determine whether your measurement is consistent with the accepted value of g for Pullman, Washington. Your TA will have some suggestions here, if necessary.)

General reminders

Carefully describe your measurement procedures in your notes. Be sure that any conclusions you make are justified by your data. When can differences in measured values be attributed to random variations, and when do they represent real differences? How do you decide? Show representative calculations for each step in your analysis.

Before you leave the lab please:
- Straighten up your lab station.
- Report any problems or suggest improvements to your TA.