22

The Simple Pendulum

Grandfather's Clock

Purpose

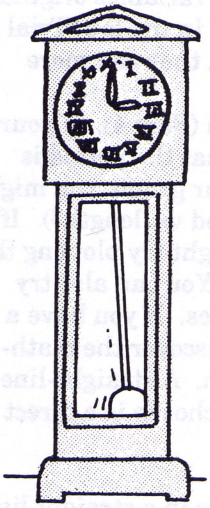
To investigate how the period of a pendulum varies with its length.

Required Equipment and Supplies

ring stand
pendulum clamp
pendulum bob
string
stopwatch *or*
- Apple II Series computer
- interface box with photogate (light probe)
- *LabTools* software
- ring stands with clamps
- light source (flashlight preferred)

Data Plotter graphing program

Discussion



What characteristics of a pendulum affect its period—the time taken for one oscillation? Galileo timed the swinging of the chandelier in the cathedral at Pisa using his pulse as a clock. He observed that the time it took to oscillate back and forth was approximately the same regardless of its amplitude, or the size of its swing. Its mass also does not affect the period of a pendulum.

The period of a pendulum depends on its *length*. In this experiment you will try to determine exactly how the length and period of a pendulum are related. Instead of Galileo's pulse, you will use a stopwatch or a computer.

Procedure

Step 1. Set up a pendulum using the listed equipment. Make its length 65 cm. Measure its period five times by timing the oscillations with a stopwatch or computer photogate system. If you are using the computer to measure the period of your pendulum, connect a photogate to the interface box and boot *LabTools*. Select the "Period of a Pendulum" program. Use clamps and ring stands to position a light source (such as a flashlight) so that the pendulum bob eclipses the photogate somewhere in its path. Record the *average* period in Data Table 22.1.

Data Table 22.1

LENGTH (cm)	PERIOD (s)
65	
60	
55	
50	
45	
40	
35	
30	
25	
20	
15	
10	

Step 2. Shorten the pendulum length by 5 cm. Measure its period as in Step 1, and record the average period in Data Table 22.1.

Step 3. Complete Data Table 22.1 for the remaining pendulum lengths indicated there. Measure periods as you did in Step 1.

Step 4. Inspect your data. What happens to the period as the length decreases? Although a pendulum of zero length is physically impossible, what would be its period if you extrapolated your data to such a limit? Make a graph of period vs. length for the pendulum. Use *Data Plotter*, if available. To make the shape of your graph more apparent, add the limiting point, (0,0) to your data table.

1. Describe your graph from Step 4. Is it a straight line that shows that the period is directly proportional to the length? Or is it a curve that shows that the relationship between period and length is *not* a direct proportion?

Step 5. Often data points appear to lie on a curve that is not a straight line. It is very difficult to determine the relationship between two variables from such a curve. It is virtually impossible to extrapolate accurately from a curve. Experimentalists instead try to produce a straight-line graph, by plotting appropriate powers (squares, cubes, etc.) of the variables originally used on the horizontal and vertical axes, just as you did in the lab "Trial and Error." When they succeed in producing a straight line, they can more easily determine the relationship between variables.

For example, consider your graph of period vs. length (Step 4). If your graph has an increasing slope (Figure 22.1), it means that the period is increasing *faster* than the length. To straighten out your graph, you might try plotting the period vs. the *square of the length* (period vs. length^2). If your graph has a decreasing slope (Figure 22.2), you might try plotting the *square of the period* vs. the length (period^2 vs. length). You can also try plotting the cubes of the variables or exchanging the axes. If you have a computer with the *Data Plotter* program, use them to discover the mathematical relationship between the period and the length. A straight-line plot shows that the relationship between the variables chosen is a direct proportion.

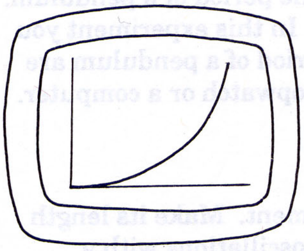


Figure 22.1

2. What plot of powers of period and/or length results in a straight line?

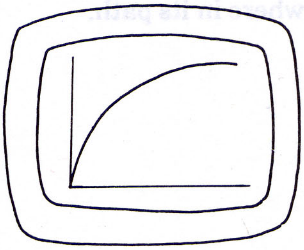
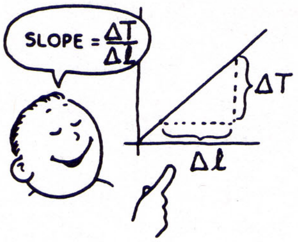


Figure 22.2

Step 6. From your graph, predict what length of pendulum has a period of exactly two seconds.

predicted length = ________



Step 7. Measure the length of the pendulum that gives a period of two seconds.

measured length = ________

3. Compute the percentage error for the measured length compared to the predicted length.

percentage error = ________

Going Further

Use *Data Plotter* to plot the *natural* logarithm (ln) of the period vs. the natural logarithm of the length. Make a printout of the graph and label the origin (0,0). Choose another point, P, along the graph, and draw a right triangle from the origin to the point P. Use the legs of the right triangle to find the slope of the graph. How is the slope of the graph related to the functional relationship between period and length of a pendulum?

Repeat these steps, plotting the *common* logarithm ($\log_{10}$) of the period vs. the common logarithm of the length. How does the slope of the graph using $\log_{10}$ compare to the graph of $\log_e$?