

Experiment #: 11

Experiment Title: Mathematical pendulum

Objectives:

1. To determine the
2. To verify the

Theory:

Simple Harmonic Motion

An object that experiences a linear restoring force about its equilibrium position exhibits a periodic motion called Simple Harmonic Motion (SHM). This behavior is observed in both the mass-spring system and the rubber band that obey Hooke's Law.

In this lab we will study two systems that exhibit SHM, the simple pendulum and the mass-spring system. From the equation of motion of a simple harmonic oscillator the angular frequency, ω , of the motion can be determined. Since $\omega = 2\pi/T$ this same equation of motion gives a relationship for the period of the motion.

The purpose of this lab is to test the dependency of the period relationships on the system parameters for the pendulum and the mass-spring systems.

Theory - Pendulum

Figure 1

A motion that repeats itself is called periodic. The period is the time it takes for an object exhibiting periodic motion to return to its starting point. If the period of that motion is exactly the same for each recurrence of the motion then that object has the basis of a time keeping device. The period of a pendulum was used for centuries as an accurate timekeeper.

Simple pendulum motion can be demonstrated by a point-like mass (called a bob) on the end of a string. The length is measured from the pivot point to the center of mass of the bob. For small displacement angles, i.e. less than 15° , the period of a pendulum depends only on the length of the pendulum and on no other physical characteristic of the pendulum.

The period of oscillation for a pendulum, this is given by

$$T = 2\pi\sqrt{\frac{L}{g}} \quad \text{or} \quad T^2 = 4\pi^2 \frac{L}{g}$$

where “L” is the length of the pendulum and “g” is the acceleration due to gravity.

List of Equipment:

Apparatus

1. Light barrier with Counter
2. Power supply 5 V DC/0,3 A
3. Steel ball with eyelet, d 24.4 mm
4. Meter scale
5. Cursors
6. Fish line
7. Right angle clamp
8. Clamping pads on stem
9. Support rod
10. Tripod base

Circuit Diagram:

Procedure:



1. Assemble the pendulum by attaching the top end of the string to the pendulum clamp and attaching the pendulum bob to the lower end.
2. Orient the photogate so that the center of mass of the pendulum bob passes through the photogate beam, at the lowest point of its swing.
3. Open the Pendulum file. (Click on the File menu and then on the Open menu item. Under the Probes and Sensors folder, double click on the Photogate folder. In the Photogate folder, double click on the Pendulum Timer file.)
4. The nature of the Pendulum Program: The Pendulum file is a program that uses the photogate to implement an event timer specific to pendulum motion. The specific nature of

pendulum motion, and simple harmonic motion in general, is that in the course of moving through one cycle of its motion it will pass through the equilibrium point of its motion two times. The first pass initiates the event timer, the second pass is ignored, and the third pass will terminate the timer when the photogate beam is broken the third time. The time recorded is the time interval from the 1st breaking of the beam to the third breaking of the beam (the beginning of the next cycle). This will produce an experimental estimate for the period of the simple pendulum.

Experimental Procedure - Pendulum

5. Measure the length of the pendulum string and record it in the Pendulum Data Table. The length of the pendulum is measured from the top end of the string where it emerges from the bottom of the pendulum clamp to the center of mass of the pendulum bob.
6. To begin an experimental run, move the pendulum bob about 15 degrees from the vertical and release it. The pendulum bob should travel in a plane and not trace out an elliptical path. If the bob moves in an elliptical path, start it again.
7. Click on the Collect button to start the measurement process.
8. Measure at least 20 complete cycles and then click the Stop button.
9. Measure the Average Period using the graph on the computer screen and the Logger Pro

Statistics functions. Select a region of the graph that encompasses at least 20 period measurements. Click on the Statistics button and pick the Mean or Average option. Record this Average Period in the Pendulum Data Table.

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10. Repeat the experimental procedure for 7 different string lengths ranging from 10 to 70 cm, releasing the pendulum bob each time from an angle of 15 degrees.
11. Plot a graph of T^2 vs. L .
12. Perform a best fit to the data with a Linear Trendline. (Don't force the trendline through the origin). Display the equation of the trendline and the correlation coefficient.
13. Using the Excel worksheet function LINEST calculate the uncertainty (Std Error) in the value of the slope of the trendline.
14. Calculate the value of "g" from the slope. The slope is equal to $4\pi^2/g$ and therefore $g = 4\pi^2/\text{slope}$.
15. The uncertainty in $g = (\text{Slope Uncertainty}/\text{Slope}) * g$ (explained below "Uncertainty Analysis")
16. Compare to the accepted $g = 9.81 \text{ m/s}^2$ and calculate the % error.

Data Collection:

Pendulum Data Table

Length L (m)	Average Period T (s)	T²(s²)

Slope = _____ +/- Uncertainty _____ s²/m

“g” from slope; $g = 4\pi^2/\text{slope}$ _____ +/- Uncertainty _____ m/s²

% error: _____

Uncertainty Analysis:

The uncertainties (std errors) computed by the Excel worksheet function LINEST are the uncertainties in the slope. In this lab we are interested in quantities calculated from these slope values. The questions arises: How do these slope uncertainties propagate into the final calculated quantities? The quick answer is to express the uncertainties as a fraction of their respective slopes and then apply these fractions to the respective calculated quantities to determine their uncertainties. With uncertainties in the low single digit percentage range the errors in this approximation are negligible.

Calculation:

Result: