Physics 110 Lab 3: Hooke's Law & Oscillations

Name ____________________ Section__________ Date __________

Objectives

- To investigate Hooke's law and measure the force constant of a spring.
- To investigate the relationship between the period of the motion and the mass of an object oscillating on a spring.

Introduction

According to Hooke's law the force that a spring exerts when it is stretched or compressed is proportional to the distance over which it is compressed or stretched and in a direction opposite to the compression or stretch. This can be expressed as

$$F = -kx \tag{1}$$

where k is the force constant and x is the distance over which the spring is stretched or compressed.

When a mass hanging from a spring is displaced vertically from the equilibrium position and released, it will undergo simple harmonic motion about the equilibrium position. If the spring is ideal and massless, the relationship between the period of the motion T and the hanging mass m is given by

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{2}$$

where k is the force constant of the spring.

Apparatus

- Large spring
- Two-meter stick
- Motion sensor
- Variety of masses
- *Science Workshop 750 Interface*
- *DataStudio* software

Procedure

Part 1: Hooke's Law and the Force Constant

(a) Hang the spring from the clamp with the large diameter coils down and hang a 50-g mass from the spring. Draw a free-body diagram in the space below and apply Newton's second law to derive an expression for the magnitude of the force exerted by the spring in terms of the weight of the mass.

(b) Measure the distance that the spring stretches when the 50-g mass is hung from it and record the value in the table below. Repeat the measurement for the other values of mass listed in the table.

m (kg)	x (m)
0.050	
0.100	
0.150	
0.200	
0.250	
0.300	
0.350	
0.400	

(c) Enter your data into an Excel spreadsheet and calculate the magnitude of the force F exerted by the spring for each mass. Create a graph of F along the vertical axis versus x along the horizontal axis. Is the graph linear? Does the spring appear to obey Hooke's law? (Answer these questions using complete sentences in the space below.)

(d) Fit the data to determine an equation that describes the relationship between F and x and display the equation on the graph. Title the graph and label the axes appropriately. Also, change y in the equation to F. Print a copy of the graph and attach it to the lab when you hand it in.

(e) Determine the spring constant k from the fit to the graph. Use the linear regression tool in Excel to determine the uncertainty in k. (Your instructor will show you how to do this.) Record the value for k with uncertainty in the space below. Be sure to use the appropriate number of significant figures.

Part 2: Period of Oscillations

(a) Hang a 200-g mass from the spring and place the motion sensor facing up directly below the spring. Open the DataStudio software and create an experiment to use the motion sensor to record the position of the mass as it oscillates on the spring. Push the mass straight upward about 15 cm, and let go. Adjust the height of the support so that the mass comes no closer than 0.15 m to the detector. Record data for four or five cycles of the motion. Does the motion appear to be periodic? Is it sinusoidal? (Answer these questions using complete sentences in the space below.)

(b) Fit the data with a sine curve to determine the period of the motion and record it in the table below. Repeat this procedure for the other masses listed in the table. You may have to adjust the height of the support to get good oscillations and to make sure that the mass comes no closer than 0.15 m to the detector.

m (kg)	T (s)
0.050	
0.100	
0.150	
0.200	
0.250	
0.300	
0.350	
0.400	

(c) Enter the data into an Excel spreadsheet and create a graph of T along the vertical axis versus m along the horizontal axis. Does the graph appear to be linear? Should it be? (Answer these questions using complete sentences in the space below.)

(d) Fit the data with a power function to determine an equation that describes the data and display the equation on the graph. Title and label the axes of the graph appropriately. Also, change y to T and x to m in the equation. Print a copy of the graph and attach it to the lab.

(e) How does the value for the power of m determined from the fit to the data compare with the value from the theoretical expression? Can you think of a possible reason for the discrepancy?

(f) The reason for this discrepancy is that the spring is not massless and some fraction of the mass of the spring must be taken into account. To determine this fraction, we square both sides of Equation 2 and replace m with $m + m_s$ to get

$$\begin{aligned} T^2 &= \frac{4\pi^2}{k}(m + m_s) \\ &= \frac{4\pi^2}{k}m + \frac{4\pi^2}{k}m_s \end{aligned} \tag{3}$$

where m is the hanging mass and m_s is the fraction of the spring mass. Create a graph of T^2 versus m. Does the graph appear to be linear?

(g) Fit the data to determine an equation that describes the data and display the equation on the graph. Title and label the axes of the graph appropriately. Also, change y to T^2 and x to m in the equation. Print a copy of the graph and attach it to the lab.

(h) Determine the force constant k from the fit to the data and use the linear regression tool to determine the uncertainty. Does this result agree with the result from Part 1 within experimental uncertainties? Show your work in the space below.

(i) Determine the value for m_s from the fit to the data and use the linear regression tool to determine the uncertainty. Show your work in the space below.

(j) Measure and record the mass of the spring M along with an estimated uncertainty in the space below. Also, calculate the fraction m_s/M along with the appropriate uncertainty.