HOOKE'S LAW

Objective

To measure the effect of amplitude, mass, and spring constant on the period of a spring-mass oscillator.

Equipment

Two lab posts and a clamp, spring, meter stick or metric tape measure, weight hanger, weights.

Introduction

The force which restores a spring to its equilibrium shape is equal to the one that deformed it, but in the opposite direction. Frequently we find that the deviation from equilibrium position is proportional to the applied force. For one dimensional motion, we can express this behavior mathematically as:

$$\vec{F} = -k\vec{x} \tag{1}$$

Where $\vec{F}$ is the restoring force, $\vec{x}$ is the displacement away from equilibrium, and k is a constant that depends on the material and its shape.

The negative sign reminds us that the restoring force acts in the opposite direction from the displacement, so as to bring the body back to its original shape. Equation 1 is called Hooke's Law and describes a surprisingly large number of physical situations.

Systems such as a mass on the end of a spring can be described with Hooke's law. The oscillate as simple harmonic oscillators with a displacement x given by

$$x = x_0\, cos(2\pi \frac{t}{T}) \tag{2}$$

and a period of vibration T given by

$$T = 2\pi\sqrt{\frac{m}{k}} \tag{3}$$

Thus, if we know that a system consisting of a mass on a spring obeys Hooke's law, and if we can determine the spring constant k, then we know a great deal about how the system will behave.

In this lab, we will determine the spring constant for a spring by two different methods and compare the results.

Activity 1.

1) Place a lab post on your lab table in the lab post holder. Attach a horizontal crossbar to the post using a clamp. Suspend a spring from the crossbar with the smaller end at the top. Add a weight hanger to the bottom of the spring.

2) Record the initial position of the bottom of the weight hanger in Table 1 on your data sheet.

Activity 2.

3) Adding 50 grams,(g), at a time, record the positions and total mass on your data sheet until you have added 250g. Don't forget to include the mass of the weight hanger when recording the masses.

NOTE: You must add 50g each time, not make 150g by taking off two 50g masses and putting a 100g and a 50g mass back on. Place the masses gently so that the spring will not start oscillating.

4) Now remove the masses, 50g at a time, and record the position and mass on your data sheet. You should find that the positions as you remove mass are very close to the positions as you added mass.

Activity 3.

5) Calculate the gravitational force due to the masses. Record these values in Table 1 on your data sheet.

6) Using a spreadsheet, preferably Microsoft Excel, or other graphing software, prepare a graph of force versus displacement. The displacement is the final position at a given mass minus the initial position at the first mass (50g).

7) Using the trend line function, add linear trend lines to your plot. Make sure you turn on the trend line values to see the equation of the line. *If the resulting line (or a portion of it) is straight, we say that Hooke's Law is obeyed in that region.*

8) Determine k, in N/m, from your graph. Show any needed calulations.

Activity 4.

9) Place 50g on the weight hanger for a total mass of 100g. Stretch the spring a short distance and release it. Measure the period of the oscillation, T, by timing a number of oscillations with a stopwatch. Repeat for a total of 5 trials. Find the average period, T from the 5 trials and calculate T^2. Record all values in Table 2 on the data sheet and show any calculations used.

10) Repeat step 9 with a total of 150g.

11) Repeat step 9 with a total of 200g.

12) Repeat step 9 with a total of 250g.

Activity 5.

13) Using a spreadsheet, preferably Microsoft Excel, or other graphing software, prepare a graph of T^2 versus m using the data from steps 9-12.

NOTE: If we square both sides of Eq. (3), we can set it up into the equation of a line, $y = mx + b$. The result is:

$$T^2 = \frac{4\pi^2}{k}(m) \tag{4}$$

where $y = T^2$, x=mass, and m (slope) $= 4\pi^2/k$.

14) Using the trend line function, add linear trend lines to your plot. Make sure you turn on the trend line values to see the equation of the line.

15) Using Eq. 4, determine the spring constant, k, and record on your data sheet. Include any needed calculations.

Activity 6.

16) Compare your experimental values for the spring constant, k, by computing the percent difference. The percent difference is given by:

$$\text{percent difference} = \frac{\left|1^{st} measurement - 2^{nd} measurement\right|}{\left(\frac{1^{st} measurement + 2^{nd} measurement}{2}\right)} * 100 \tag{5}$$

Summary.

Answer the following questions and include with your data sheet:

How well do your experimental values for the spring constant compare?

Based on your observations of the oscillating spring, does the spring and mass behave like a harmonic oscillator? Explain your answer.

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DATA SHEET

Activity 1, 2, and 3.

Table 1: Record the positions of the bottom of the weight hanger for different masses.

	Increasing Mass		Decreasing Mass	
Mass (g)	Height (cm)	Force (N)	Height (cm)	Force (N)

Graph force .vs. displacement and determine the spring constant, k.

Spring Constant, k (in N/m): ____________________

Activity 4.

Table 2: Measure the period for different masses. Compute T^2.

Mass (g)	Trial 1 (s)	Trial 2 (s)	Trial 3 (s)	Trial 4 (s)	Trial 5 (s)	Average T(s)	T^2 (s^2)

Activity 5.

Graph T^2 .vs. m and determine the spring constant, k.

Spring Constant, k (in N/m): ____________________

Activity 6.

Compare your experimental values for the spring constants above by computing the percent difference.

Percent Difference: ______________________________

Answer the questions from the summary.