Simple Harmonic Motion
Investigating a Mass Oscillating on a Spring

A spring that is hanging vertically from a support with no mass at the end of the spring has a length L (called its rest length). When a mass is added to the spring, its length increases by x. The equilibrium position of the mass is now a distance $L + x$ from the spring's support. The spring exerts a restoring force, $F = -kx$, where x is the distance the spring is displaced from equilibrium and k is the force constant of the spring (also called the *spring constant*). The negative sign indicates that the force exerted by the spring on the mass is directed opposite to the direction of the displacement of the mass. The restoring force causes the mass to oscillate up and down, and is always directed toward the equilibrium position. The period of oscillation depends on the mass and the spring constant.

PURPOSE

In this lab you will determine the spring constant for a spring, predict the period of oscillation for several different masses using the measured spring constant, and find their relative error. A graph of position vs. time and velocity vs. time for a mass in simple harmonic motion will be constructed and analyzed for the energy aspects of the motion.

MATERIALS

- spring
- pendulum clamp
- meter stick
- LabPro® or other computer interface
- graphing software
- ring stand or table clamp with rods
- mass set
- motion detector
- Logger *Pro*® or other appropriate data collection software

PROCEDURE

PART I: FINDING THE SPRING CONSTANT *k*

1. Attach a clamp to a ring stand so that your spring will hang over the edge of the table.

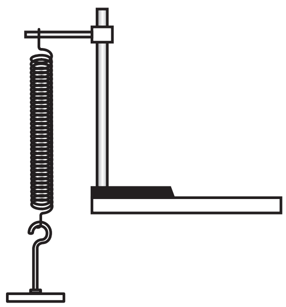

Figure 1

2. Hang a mass hanger on the spring so that it will slightly stretch your spring and hang at rest. With your meter stick, measure the distance from the bottom of the hanger to the floor where the motion detector will eventually be positioned. Make all successive measurements from this same position, which will serve as the equilibrium position. This will be considered your unstretched length.

3. Measure the amount of stretch for 5 different masses added to the spring. The amount of stretch is the difference between the unstretched length and the stretched length. Record your measurements in Data Table 1 on your student answer page.

PART II: ADDITIONAL METHOD FOR FINDING THE SPRING CONSTANT *k*

1. Attach a motion detector to your computer and start the appropriate software.

2. Place the motion detector on the floor directly beneath the spring. Make sure that the mass does not come closer than the measurement limit for your motion detector, usually 40 cm for Vernier motion detectors, or 15 cm for PASCO Motion Detector II's. When Logger *Pro* is opened, if it does not automatically identify your motion detector, drag the motion detector icon to Digital Channel 1. A graph of position vs. time and a second graph of velocity vs. time should open.

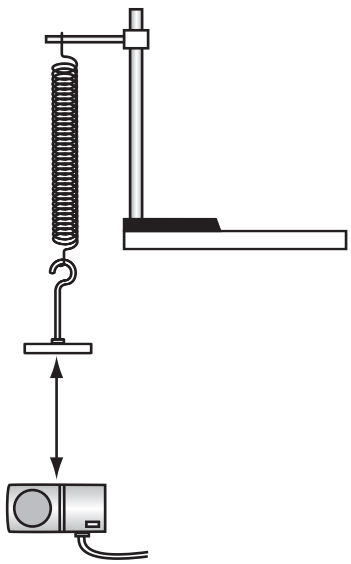

Figure 2

3. Using each of the 5 masses from Part I, set the mass into smooth oscillations, with amplitudes of about 10 cm (depending on the original length of your spring). Start the motion detector data collection. Gather data for about 3 seconds or until you have more than 10 complete oscillations with each of the 5 masses.

4. Using the analysis tool on Logger *Pro* or your software, find the time for ten complete oscillations of your spring. Record this, as well as the mass on the spring, in Table 2 on your student answer page.

PART III: ENERGY IN SIMPLE HARMONIC MOTION

1. With the motion detector placed on the floor as in Part II, zero the motion detector when the mass is motionless. To zero the motion detector, click on the LabPro icon on the tool bar. Double click on the motion sensor icon, and then select "zero". This is your equilibrium position. This will have to be repeated with each mass.

2. Set the mass into smooth oscillations with amplitude of about 10 cm (depending on the original length of your spring). Collect data for about three seconds.

3. Using the analysis tool, determine both the position and velocity for the mass at its maximum amplitude and for the next position of zero amplitude. Record these values in Table 3 on your student answer page.

Name ___________________________________

Period __________________________________

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DATA AND OBSERVATIONS

PART I: DETERMINING THE SPRING CONSTANT *k*

Data Table 1					
Run #	**Mass on Spring (kg)**	**Force (N)**	**Position 1 with Only Hanger (m)**	**Position 2 with Added Mass (m)**	**Amount of Stretch (m)**
1					
2					
3					
4					
5					

ANALYSIS

PART I: DETERMINING THE SPRING CONSTANT *k*

1. On the mass below, draw and label the forces acting on the mass when it is hanging at rest on the end of the spring.

2. Using either graph paper or graphing software, construct a graph of Force (N) vs. Amount of Stretch (m). Determine the slope of this graph.
   a. What are the units for the slope?

   b. The equation relating the magnitude of the force and the stretch is $F = kx$. How does this equation relate to the slope of your graph?

PART II: ADDITIONAL METHOD FOR FINDING THE SPRING CONSTANT *k*

1. The period of oscillation for your mass spring system can be calculated using the following equation. Rearrange this equation to solve for the spring constant *k*, and show your work below. For each of your five runs, calculate a value for the spring constant and then find the average of these values. Place your calculations in Table 2.

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

Table 2				
Run #	**Mass on Spring (kg)**	**Time for 10 Oscillations (s)**	**Measured Period (s)**	**Calculated Value for *k* (N/m)**
1				
2				
3				
4				
5				
AVERAGE				

2. Compare the average value for *k* that you calculated in Part II to the value you found for *k* in Part I. Calculate a relative error for the two values.

PART III: ENERGY IN SIMPLE HARMONIC MOTION

1. For this oscillating system, the energy of the system should remain constant for short periods of time involving one or two oscillations. Over time friction will convert some of the energy to heat, but for a single oscillation, the elastic potential energy U_s of the system at maximum amplitude should be relatively close to the kinetic energy KE when the system returns to the equilibrium position. Calculate these values and compare them by finding a relative error.

$$U_s = \frac{1}{2}kx^2$$

$$KE = \frac{1}{2}mv^2$$

$$\text{Relative Error} = \frac{|U_s - KE|}{U_s} \times 100$$

Table 3						
Run #	**Mass on Spring (kg)**	**Amplitude of Stretch (m)**	**Velocity at Equilibrium Position (m/s)**	**Calculated U (J)**	**Calculated KE (J)**	**Relative Error (%)**
1						
2						
3						
4						
5						

2. The errors in this part of the lab may be relatively large. Write a statement analyzing the errors in this lab and suggest ways that the errors might be reduced.

CONCLUSION QUESTIONS

1. A person who weighs 670 N steps onto a spring scale in the bathroom, and the spring compresses by 0.79 cm.
   a. What is the spring constant? Be sure to specify your units.

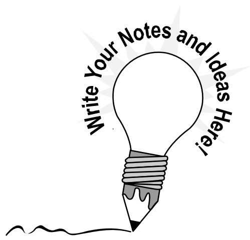
   b. What is the weight of another person who compresses the spring by 0.34 cm?

2. What is the shape of the plot of data for the oscillating spring-mass system on your graph? Describe the shape physically.

3. In terms of the changes in force, displacement, acceleration, and energy, describe one full oscillation of a mass on a spring.

4. When a 2.8-kg object is suspended from a spring, the length increases by 0.018 m. If the frequency of vibration is $f = 3.0$ Hz, how much mass is attached to this spring?

5. What is the maximum speed of the mass in question 4?


Write Your Notes and Ideas Here!