Name ____________________ Class _____________ Date ________

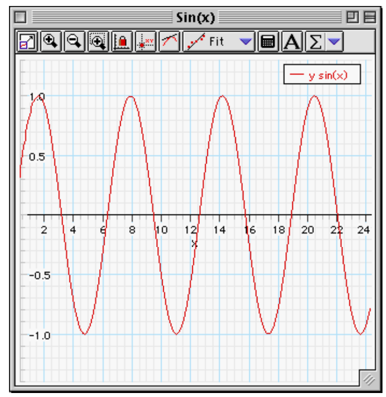
Simple Harmonic Motion

Experimental Objective

The objective of this experiment is to study two important examples of a linear restoring force, the simple pendulum and the vibrating spring. We will determine the period in each case.

Background

Simple harmonic motion results any time a linear restoring force exists. A linear restoring force is a force that is proportional to the displacement of the body on which the force acts from an equilibrium position, where the force is zero, and is always directed back toward that equilibrium position. A linear restoring force is given by, $\mathbf{F = -kx}$, *(1)* where **F** is the force, **x** is the displacement from the equilibium position and **k** is the proportionality constant. The negative sign indicates that the force points opposite to the direction of the displacement of the mass. The restoring force causes the mass to oscillate up and down and will bring the body back toward the equilibrium position. The period of oscillation depends on the mass and the spring constant.



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

As the mass oscillates, the energy continually interchanges between kinetic energy and some form of potential energy. If friction is ignored, the total energy of the system remains constant.

Equipment Needed

Photogate	Spring
Metal sphere on a long string	Motion Sensor
Vernier caliper	Mass and Hanger Set
Support Rod	2-Meter stick
Pendulum clamp	Various clamps

SAFETY REMINDER

- Follow the directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

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The Simple Pendulum

Use the photogate to determine the period as the pendulum swings thru it. The Data Studio program displays the period and its mean value.

PART A: Computer and Equipment Setup

1. Connect the *ScienceWorkshop* interface to the computer, turn on the interface, and turn on the computer.
2. Connect the Photogate's phone plug to Digital Channel 1.
3. Measure the diameter of the metal sphere with the vernier caliper. Record in the Data table.
4. Using the rod and the pendulum clamp, arrange and attach the string of the pendulum to the pendulum clamp.
5. Using rods and clamps setup the photogate below the path of the pendulum. The pendulum should swing freely through the photogate. The bob of the pendulum must block the beam as it swings.
6. Open the document titled as shown:

DataStudio
Simple Pendulum.ds

PART B: Data Recording: Dependence of the Period on Length

7. Adjust the length of the string so that the center of the sphere is about 0.6 m below the point of support. Measure the distance from this point to the upper surface of the sphere. Record this distance as the length of string used. The length of the pendulum will be this distance plus the radius of the metal sphere.
8. Displace the sphere to one side to an angle of no more than 5^o and let the pendulum oscillate. Press '*Start*' to begin data recording. After several cycles click on '*Stop*'. Record the mean value in the Data Table.
9. Repeat steps #7 and #8 making the length of the pendulum 0.8 m, 1.0 m and 1.2 m.

PART C: Data Recording: Dependence of the Period on Amplitude

10. Using a length of 0.5 m measure the period when the sphere is displaced 5^o let the pendulum oscillate. Press '*Start*' to begin data recording. After several cycles click on '*Stop*'. Record the mean value in the Data Table.
11. Repeat step #10 for a displacement of 30^o and 45^o.

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Vibrating Spring

PART I: Determining the Spring Constant

You will measure the amount of distance that the spring stretches. Calculate the force that stretches the spring as weight is added to one end of the spring. Plot a curve of the elongation of the spring vs. force, the slope of the best fit line of the graph is the spring constant "*k*".

PART A: Equipment Setup and Data Acquisition

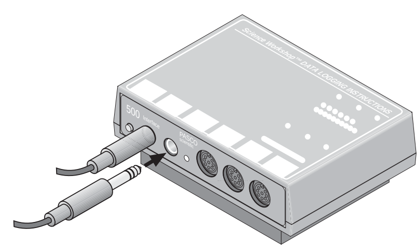
1. Weigh the spring and record its mass in the Data Table.
2. Remove the pendulum from the clamp and suspend the spring in its place. Using the 2 m stick and a caliper jaw, measure the position of the lower end of the spring (without any mass added to the spring). This is the equilibrium position of the spring, record this measurement in the Data Table.
3. Suspend 0.1 kg from the spring and record the new position of its lower end.
4. Repeat step #3 with loads of 0.2, 0.3, 0.4 and 0.5 kg suspended from the spring. Record the position of the spring's lower end in each case.

Part II: Oscillation

Use the Motion Sensor to record the motion of a mass that is suspended from the end of the spring. The Data Studio program records the motion and displays position and velocity of the oscillating mass. The period of oscillation is measured and compared to the theoretical value.

PART A: Computer Setup

1. Connect the Motion Sensor's stereo phone plugs into Digital Channels 1 and 2 of the interface. Plug the yellow-banded (pulse) plug into Digital Channel 1 and the second plug (echo) into Digital Channel 2.



2. Open the document titled as shown:

DataStudio
Oscillating Spring.ds

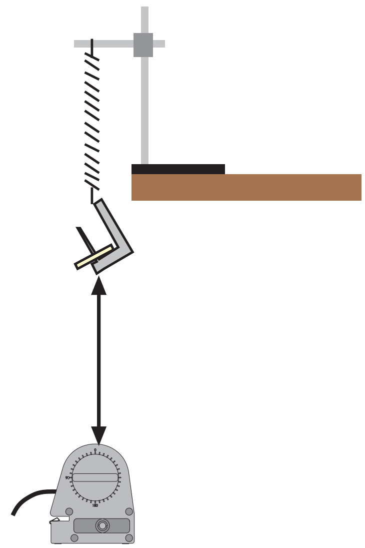
3. Using a support rod and clamp, suspend the spring so that it can move freely up-and-down. Put a mass hanger on the end of the spring.
4. Add a mass of 0.2 kg to the spring. Record the total mass in the Data section. Remember to include the mass of the hanger in your total.
5. Place the Motion Sensor on the floor directly beneath the spring and mass hanger. Adjust the Motion Sensor so that it is set to 90^o.

6. Adjust the position of the spring so that is positioned to a distance approximately 30 to 40 cm above the Motion Sensor.

PART B: Data Recording

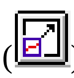
7. Pull the mass down to stretch the spring about 5 cm downward from its position of equilibrium. Release the mass. Let it oscillate a few times so the mass hanger will move up-and-down without much side-to-side motion.
8. Begin recording data.
9. The plots of the velocity and time of the oscillating mass will be displayed. Continue recording for several cycles.
10. End data recording.

- The data will appear as 'Run #1'.
- The curve should resemble the plot of a sine function. If it does not, check the alignment between the Motion Sensor and the bottom of the mass hanger at the end of the spring.
- To erase a run of data, select the run in the Data list and press the "Delete" key.



Analyzing the Data

a. Rescale the Graph axes to fit the data.

- In *DataStudio*, click on the 'Scale to Fit' button ().
- Observe the Sine Fit window, this shows the amplitude and frequency.

11. Record the amplitude and period in the Data Table. (Recall that the period, *T*, equals the reciprocal of the frequency, *f*, $T = \frac{1}{f}$).
12. Repeat steps #4 - #11 using a mass of 0.2 kg and stretch the spring about 10 cm downward from its equilibrium position.
13. Repeat steps #4 - #11 using a mass of 0.5 kg and stretching the spring about 5 cm downward from its equilibrium position.

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Lab Report

Simple Harmonic Motion: The Simple Pendulum

Diameter of sphere ____________

Radius of sphere ______________

Data Table: Dependence of Period on Length

Length of string used	Length of pendulum	Period	$(\text{Period})^2$

Value of g from the slope _____________________ Percent error ____________________

Dependence of Period on Amplitude

Length of string used ________________

Length of pendulum _________________

Data Table: Dependence of Period on Amplitude

Displacement	Period	$(\text{Period})^2$
5^o		
30^o		
45^o		

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Lab Report

Simple Harmonic Motion: The Vibrating Spring

Data Table: Part I – Spring Constant

Mass of the spring = ________________ kg

Mass Suspended from the Spring (kg)	Force Stretching the Spring	Position	Elongation
0			
0.1			
0.2			
0.3			
0.4			
0.5			

Force constant of the spring ___________________

Data Table: Part II - Oscillation

Mass of the spring = __________ kg

Mass Suspended from the Spring	Mass of the Vibrating System	Amplitude of Vibration	Experimental Value Period	Calculated Value Period	Percent Difference
0.2 kg					
0.2 kg					
0.5 kg					

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Calculations:

1. Calculate the square of the pendulum's period for each data run.
2. Plot a curve using the values of the square of the period as ordinates and the lengths of the pendulum as abscissas.
3. Determine your measured value of g from the slope of the curve and compare it with the known value, $g = 9.8\ m/s^2$, by finding the percent error.
4. Determine the elongation of the spring produced by each load by obtaining the difference between the new position and the equilibrium position.
5. Calculate the force stretching the spring in each case by multiplying each suspended mass load by $9.8\ m/s^2$.
6. Plot a curve using the values of the elongation as ordinates and the forces due to the corresponding load as abscissas.
7. Obtain the force constant of the spring from the slope of the curve.
8. Using Equation 2, calculate the value of the period for each of the 2 masses used. The effective mass of the oscillating system will be the mass suspended from the spring plus one third of the mass of the spring.
9. Calculate the percent difference between the experimental values of the period and the calculated values.

Questions:

1. Explain why the angle through which the pendulum swings must be no more than 10^o.

2. In the spring when the position of the mass is farthest from the equilibrium position, what is the velocity of the mass?

3. In the spring when the absolute value of the velocity of is greatest, where is the mass relative to the equilibrium position?