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Activity P14: Simple Harmonic Motion - Mass on a Spring (Force Sensor, Motion Sensor)

Equipment Needed	Qty	Equipment Needed	Qty
Economy Force Sensor (CI-6746)	1	**Mass and Hanger Set (ME-9348)**	1
Motion Sensor (CI-6742)	1	Meter stick	1
Balance (SE-8723)	1	**Support rod (ME-8736)**	1
Base and Support Rod (ME-9355)	1	**Spring, k ~ 2 to 4 N/m (632-04978)**	1
Clamp, right-angle (SE-9444)	1		

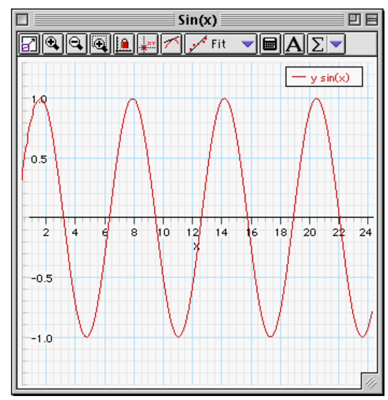
What Do You Think?

What is the motion of a mass oscillating on a spring? What other motions can you think of that are similar?

Take time to answer the 'What Do You Think?' question(s) in the Lab Report section.

Background

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 ΔL. The equilibrium position of the mass is now a distance L + ΔL from the spring's support. What happens when the mass is pulled down a small distance from the equilibrium position? 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 points opposite to the direction of the displacement of the mass. The restoring force causes the mass to oscillate up and down. The period of oscillation depends on the mass and the spring constant.



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

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.

SAFETY REMINDER

- Follow the directions for using the equipment.

THINK SAFETY
ACT SAFELY
BE SAFE!

Pre-Lab For You To Do

In the Pre-lab use the Force Sensor to measure the weight of a hanging mass. Use ‘Keyboard Sampling’ to enter the displacement of the spring from equilibrium. Use *DataStudio or ScienceWorkshop* to determine the spring constant k for the spring.

Pre-Lab PART I: Sensor Calibration and Equipment Setup

1. Use the meter stick to measure the position of the bottom end of the spring **(without any mass added to the spring)**. For your reference, record this measurement as the spring’s equilibrium position in the Data Table in the Lab Report section.

Pre-Lab PART II: Data Recording

1. Press the tare button on Force Sensor to zero the Force Sensor.
2. Start data recording. The program will begin Keyboard Sampling. Enter **0.000** in units of meters (m) because the spring is unstretched.

In *DataStudio*, move the Table display so you can see it clearly.

- Click on the ‘Start’ button to start recording data. The ‘Start’ button changes to a ‘Keep’ and a ‘Stop’ button (

). The Force will appear in the first cell in the Table display. Click the ‘Keep’ button to record the force value.

3. Add 20 grams of mass to the end of the spring (be sure to include the mass of the hanger).
4. Measure the new position of the end of the spring. Enter the difference between the new position and the equilibrium position as the **Δx**, ‘Stretch’ (in meters), and record a Force value for this Stretch value by clicking on ‘Keep’ in *DataStudio*, or ‘Enter’ in *ScienceWorkshop*.
5. Add 10 grams to the spring (for a total of 30 g additional mass). Measure the new position of the end of the spring, enter the stretch value and click ‘Keep’ or ‘Enter’ to record the force value.
6. Continue to add mass in 10 gram increments until you have added 70 grams. Each time you add mass, measure and enter the new displacement value from equilibrium. Click ‘Keep’ in *DataStudio*, or ‘Enter’ in *ScienceWorkshop* to record the force value.
7. End data recording.

- In *DataStudio*, stop data recording by clicking on the ‘Stop’ button.

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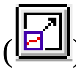
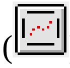
Pre-Lab Analyzing the Data

1. Determine the slope of the Force vs. Stretch Graph.

- In *DataStudio*, click the 'Scale to fit' button () to rescale the Graph axes to fit the data. Next, click the 'Fit' menu button (). Select 'Linear'.

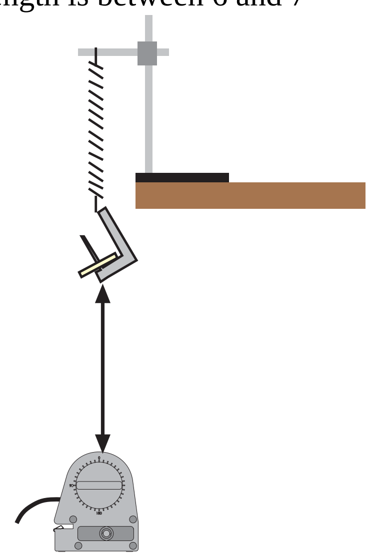
- In *ScienceWorkshop*, click the 'Autoscale' button () to rescale the Graph axes to fit the data. Click the 'Statistics' button to open the Statistics area on the right side of the Graph. In the Statistics area, click the Statistics Menu button (). Select 'Curve Fit, Linear Fit' from the Statistics Menu.

2. Record the slope of the linear fit in the Data Table in the Lab Report section.

LAB PART I: Sensor Calibration and Equipment Setup

- You do not need to calibrate the Motion Sensor.

1. 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.
2. Add enough mass to the hanger so that the spring's stretched length is between 6 and 7 times its unloaded length (about 70 grams if you are using the harmonic spring from the PASCO Introductory Dynamics System.)
3. Remove the hanger and masses temporarily. Measure and record their total in the Data section. Return the hanger and masses to the end of the spring.
4. Place the Motion Sensor on the floor directly beneath the mass hanger.
5. Adjust the position of the spring so that the minimum distance from the mass hanger to the Motion Sensor is greater than the Motion Sensor's minimum distance at the maximum stretch of the spring.



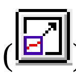
PART II: Data Recording

1. Pull the mass down to stretch the spring about 20 cm. Release the mass. Let it oscillate a few times so the mass hanger will move up-and-down without much side-to-side motion.
2. Begin recording data.
3. The plots of the position and velocity of the oscillating mass will be displayed. Continue recording for about 10 seconds.
4. End data recording.

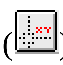
- The data will appear as ‘Run #1’.
- The position curve should resemble the plot of a sine function. If it does not, check the alignment between the Motion Sensor and the bottom of the mass hanger at the end of the spring. You may need to increase the reflecting area of the mass hanger by attaching a circular paper disk (about 2” diameter) to the bottom of the mass hanger.
- To erase a run of data, select the run in the Data list and press the “Delete” key.

Analyzing the Data

1. Rescale the Graph axes to fit the data.

- In *DataStudio*, click on the ‘Scale to Fit’ button ().

2. Find the average period of oscillation of the mass.

In *DataStudio*, click the ‘Smart Tool’ button ().

- Move the Smart Tool to the first peak in the plot of position versus time and read the value of time. Record the value of time in the Data Table in the Lab Report section.
- Move the Smart Tool to each consecutive peak in the plot and record the value of time shown for each peak.

3. Find the period of each oscillation by calculating the difference between the time for each successive peak. Find the average of the periods. Record your result in the Data Table.

Record your results in the Lab Report section.

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Lab Report - Activity P14: Simple Harmonic Motion - Mass on a Spring

What Do You Think?

What is the motion of a mass oscillating on a spring? What other motions can you think of that are similar?

Pre-Lab Data Table

Item	Value
Equilibrium Position	
Spring Constant (slope)	

Data Table

Mass = __________ kg

Peak	1	2	3	4	5	6	7
Time (s)							
Period (s)							

Average period of oscillation = _________ sec

Questions

1. Calculate the theoretical value for the period of oscillation based on the measured value of the spring constant of the spring and the mass on the end of the spring.

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

2. How does your calculated value for oscillation compare to the measured value of the period of oscillation? What is the percent difference?

3. When the position of the mass is farthest from the equilibrium position, what is the velocity of the mass?

4. When the absolute value of the velocity of is greatest, where is the mass relative to the equilibrium position?

