Experiment P19: Simple Harmonic Motion - Mass on a Spring (Force Sensor, Motion Sensor)

Concept	Time	SW Interface	Macintosh® file	Windows® file
harmonic motion	45 m	500 or 700	P19 SHM Mass on a Spring	P19_MASS.SWS

EQUIPMENT NEEDED	
• *Science Workshop™ Interface*	• clamp (for holding the spring)
• ±50 Newton force sensor	• masses and mass hanger
• motion sensor	• meter stick
• balance for measuring mass	• rod (for supporting the spring)
• base and support rod	• spring (k between 2 and 4 N/m)
• clamp, right angle	

PURPOSE

The purpose of this laboratory activity is to investigate the motion of a mass oscillating on a spring.

THEORY

Imagine a spring that is hanging vertically from a support. When no mass hangs at the end of the spring, it 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 $L + \Delta L$ 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, $\mathbf{F = -kx}$, where $\mathbf{x}$ is the distance the spring is pulled down and $\mathbf{k}$ 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. When the mass is at its highest point, the gravitational potential energy is at its maximum. When the mass is at its lowest point, the elastic potential energy is at its maximum.

INTRODUCTION

In the Pre-Lab for this activity, the force sensor measures the force that stretches the spring as weight is added to one end of the spring. You will measure the amount of distance that the spring stretches, and enter the distances into the computer. The *Science Workshop* program displays the force and the distance. The slope of the best fit line of a graph of force versus distance is the spring constant "k".

In the Procedure for this activity, the motion sensor measures the oscillation of the mass on the end of the spring. The *Science Workshop* program displays position and velocity versus time.

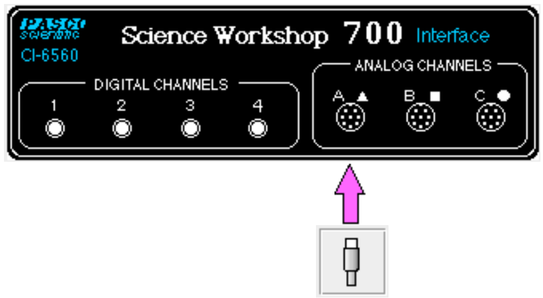
The program measures the period of oscillation, which is compared to the theoretical period of oscillation.

<u>PRE-LAB</u>: Determining the Spring Constant

Pre-Lab Part A: Computer Setup

1. Connect the *Science Workshop* interface to the computer, turn on the interface, and turn on the computer.

2. Connect the force sensor's DIN plug into Analog Channel A of the interface.

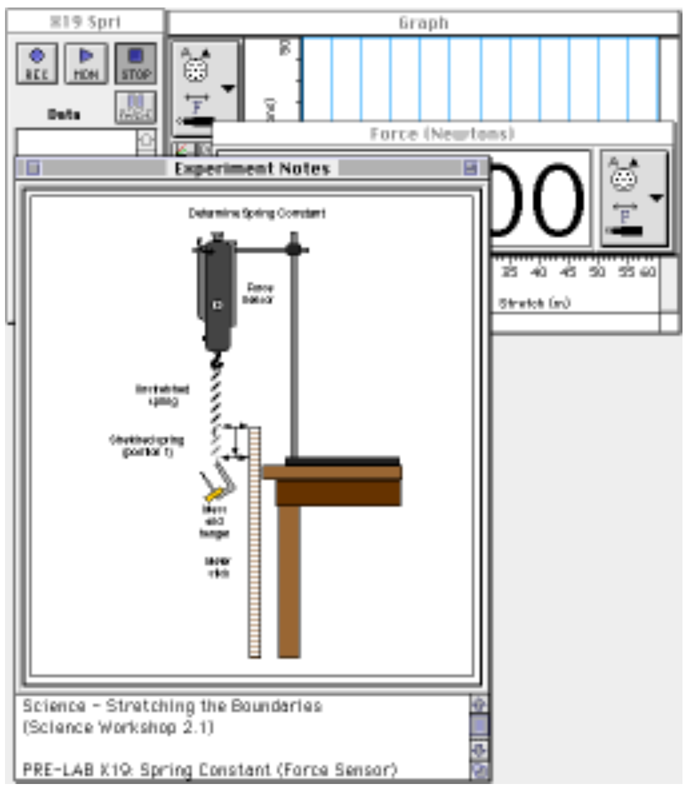


3. Open the *Science Workshop* document titled as shown:

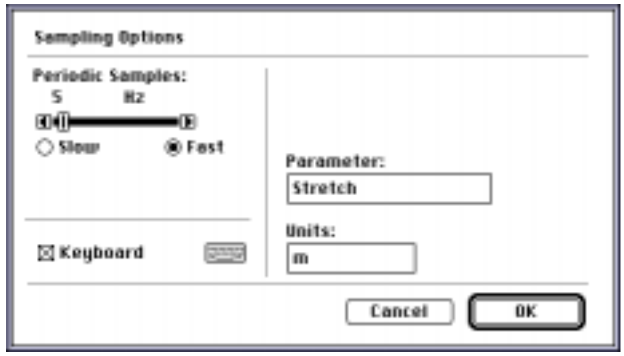
Macintosh	Windows
X19 Spring Constant	X19_SPNG.SWS

- The document will open with a Graph display of Force (Newtons) versus Stretch (m), and a Digits display of Force.

- Note: For quick reference, see the Experiment Notes window. To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. Change the Experiment Setup window by clicking on the **Zoom** box or the **Restore** or **Maximize** button in the upper right hand corner of that window.



4. The **Sampling Options…** are: **Periodic Samples = Fast at 5 Hz**, and **Keyboard** input with **Parameter = Stretch** and **Units = m (meters)**.

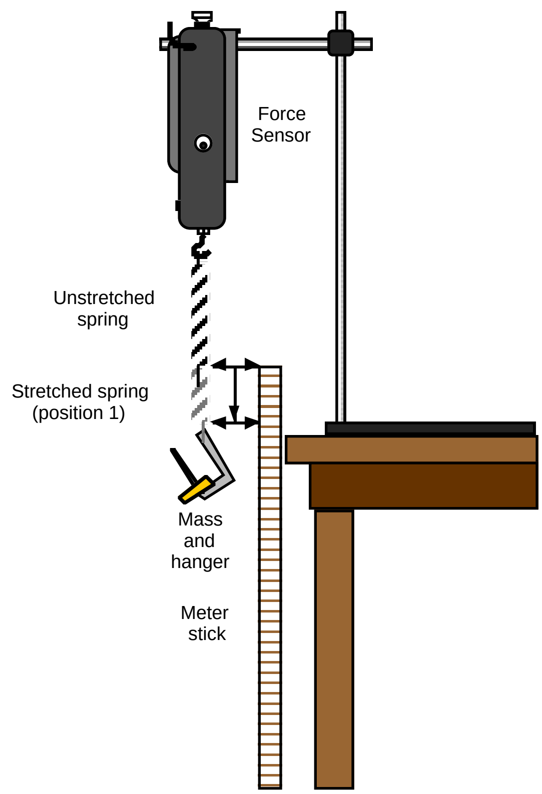


Pre-Lab Part B: Equipment Setup

1. Mount the force sensor vertically so its hook end is down.

2. Suspend the spring from the force sensor's hook so that it hangs vertically.

3. Use the meter stick to measure the position of the bottom end of the spring (without any mass added to the spring). Record this measurement as the spring's equilibrium position.

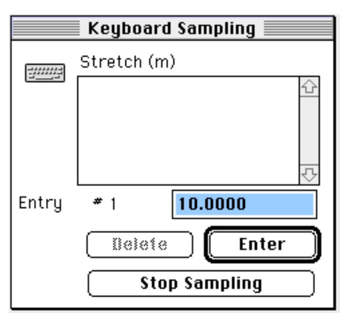


Pre-Lab Part C: Data Recording

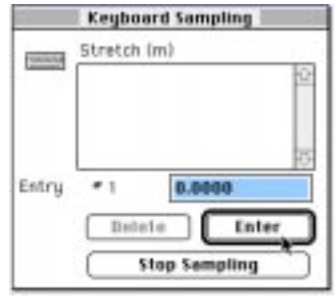
1. Click the **REC** button (

) to begin data recording. The **Keyboard Sampling** window will open. The default value is **10.0000**. Move the window so you can see it clearly during the activity.

2. Press the tare button on the side of the force sensor to zero the force sensor.



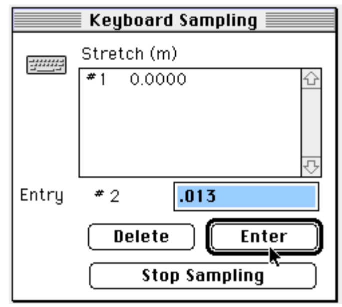
3. For **Entry #1**, type in “**0**” (since the spring is not stretched yet). Click **Enter** to record your value.



- The value you type in will appear in the Data list in the Keyboard Sampling window.

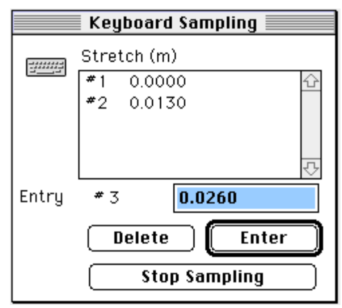
4. Add 20 grams of mass to the end of the spring (be sure to include the mass of the hanger).

5. Measure the new position of the end of the spring. Record the difference between the new position and the equilibrium position as **Δx** or “Stretch” (in meters).



6. For **Entry #2**, type in the value of **Δx** (in meters). Click **Enter** to record your typed in value.

- The value you type in for Entry #2 will appear in the Data list, and the default value for Entry #3 will reflect the pattern of your first two entries.



7. Add 10 grams to the spring and repeat the measurement of the new position of the end of the spring.

8. Type in the new **Δx** as **Entry #3**, and click **Enter** to record your typed in value.

9. Continue to add mass in 10 gram increments until you have added 70 grams. Measure the new stretched position of the end of the spring each time you add mass. Type in each new Δx in the Keyboard Sampling window. Click **Enter** each time to record your value.

10. Click the **Stop Sampling** button to end data recording.

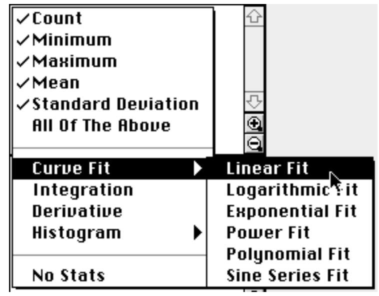
- The Keyboard Sampling window will close, and **Run #1** will appear in the Data list in the Experiment Setup window.

Table 1: Determining the spring constant

Equilibrium Position = _______ m

Mass (g)	20	30	40	50	60	70
Δx, “Stretch” (m)						

Pre-Lab Part D: Analyzing the Data



1. Click on the Graph to make it active. Click the **Statistics** button ( ) to open the Statistics area. Click the **Autoscale** button ( ) to rescale the Graph.

2. Click the **Statistics Menu** button ( ) in the Statistics area. Select **Curve Fit, Linear Fit** from the Statistics Menu.

- The slope of the best fit line of Force versus Stretch (coefficient **a2**) is the spring constant "k".

3. Record the value of "k"

Spring Constant, k = _________ N/m

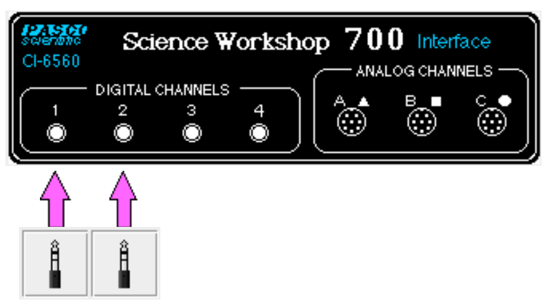
PROCEDURE

In this part of the activity, a motion sensor measures the motion of a mass that is suspended from the end of the spring. The *Science Workshop* 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 I: Computer Setup

1. Unplug the force sensor's DIN plug from the *Science Workshop* interface.

2. 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.

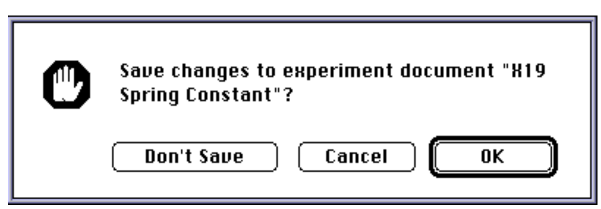


3. Open the *Science Workshop* document titled as shown:

Macintosh	Windows
P19 SHM Mass on a Spring	P19_MASS.SWS

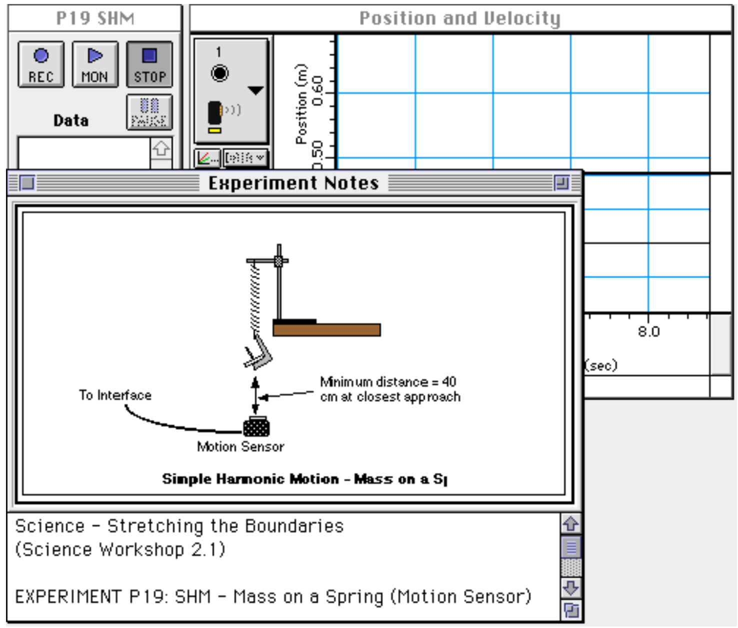
- An alert window appears when you select **Open** from the File menu.

- Click **Don't Save** or **OK**, and then find the *Science Workshop* document.



- The *Science Workshop* document will open with a Graph display with plots for Position (m) and Velocity (m/sec) versus Time (sec).

- Note: For quick reference, see the Experiment Notes window. To bring a display to the top, click on its window or select the name of the display from the list at the end of the Display menu. Change the Experiment Setup window by clicking on the **Zoom** box or the **Restore** or **Maximize** button in the upper right hand corner of that window.



PART II: Sensor Calibration and Equipment Setup

- You do not need to calibrate the motion sensor.

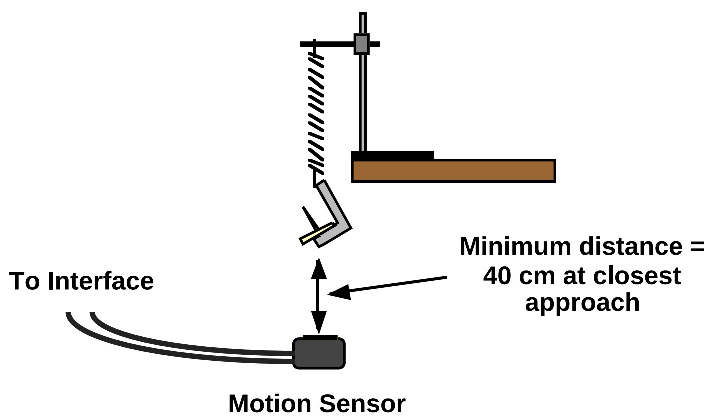
1. Using a support rod and clamp, suspend the spring so that it can move freely up-and-down. Put a mass hanger on the end of the spring.

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 mass (in kilograms) 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 40 cm at the bottom of the mass hanger's movement.

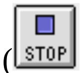


PART III: Data Recording

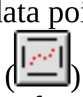
1. Pull the mass down to stretch the spring about 20 cm. Release the mass. Let it oscillate a few times so the mass hanger will move up-and-down without much side-to-side motion.

2. Click the **REC** button () to begin recording data.

3. The plots of the position and velocity of the oscillating mass will appear in the Graph display. Continue recording for about 10 seconds.

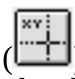
4. Click **STOP** button () to end data recording.

- **Run #1** will appear in the Data list in the Experiment Setup window..

Troubleshooting Note: If the data points do not appear on the plots for position and velocity, click on the “Autoscale” button () to automatically rescale the graph. The position curve should resemble the plot of a sine function. If it does not, check the alignment of 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. Click the **Autoscale** button  to rescale the Graph display.

2. Click the **Smart Cursor** button (). The cursor changes to a cross-hair when you move it into the display area of the graph. The X- and Y-coordinates of the cursor’s position are shown next to the horizontal and vertical axes.

3. Use the Smart Cursor to find the average period of oscillation of the mass. Move the cursor/cross-hair to the first peak in the plot of position versus time and read the value of <u>time</u> (shown below the horizontal axis). Record the value of time in the Data section.

4. Move the Smart Cursor to each consecutive peak in the plot and record the value of time shown below the horizontal axis for each peak..

5. 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.

DATA TABLE

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

Average period of oscillation = ________ sec

4. 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. (Use mass in kilograms for this calculation).

Mass = _________ kg

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

Calculated period of oscillation = ________ sec

QUESTIONS

1. How does your calculated value for the period of oscillation compare to the measured value for the period of oscillation? Find the percent difference between your calculated value and the measured value.

- Reminder: percent difference = $\left|\frac{\text{calculated} - \text{measured}}{\text{calculated}}\right| \times 100\%$

2. When the position of the mass is farthest from the equilibrium position, what is the velocity of the mass? (Hint: Move the Smart Cursor to a peak on the position plot, hold down the Shift key, and move the Smart Cursor onto the velocity plot. The velocity will be given next to the vertical axis.)

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