

## *Lab #2*

### *Period of a mass-spring system*

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## Part A: Using the Science Workshop Interface

### 1. Objectives

- To learn the use of the computerized Science Workshop interface for data acquisition.
- To calculate the spring constant of a spring from a graphical analysis.

### 2. Equipment

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| <ul style="list-style-type: none"> <li>• Stand with ruler</li> <li>• Universal clamp</li> <li>• Pulley rod</li> <li>• Masking tape</li> <li>• Large spring</li> </ul> | <ul style="list-style-type: none"> <li>• Hooked weights</li> <li>• Science Workshop interface</li> <li>• Force sensor</li> <li>• Motion sensor</li> <li>• Stopwatch</li> </ul> |
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### 3. Setup

1. Turn on the Science Workshop interface (black box next to the computer screen)
2. Login to your account on the computer. Use the login and password written on your schedule. Start the Science Workshop (SW) program.

START:PROGRAMS:SCIENCE WORKSHOP: SCIENCE WORKSHOP

3. Build the setup illustrated in figure 1.
4. Connect the force sensor to *Analog channel A*.

In the SW window, click and drag the analog plug (on the right) to *Analog channel A*.

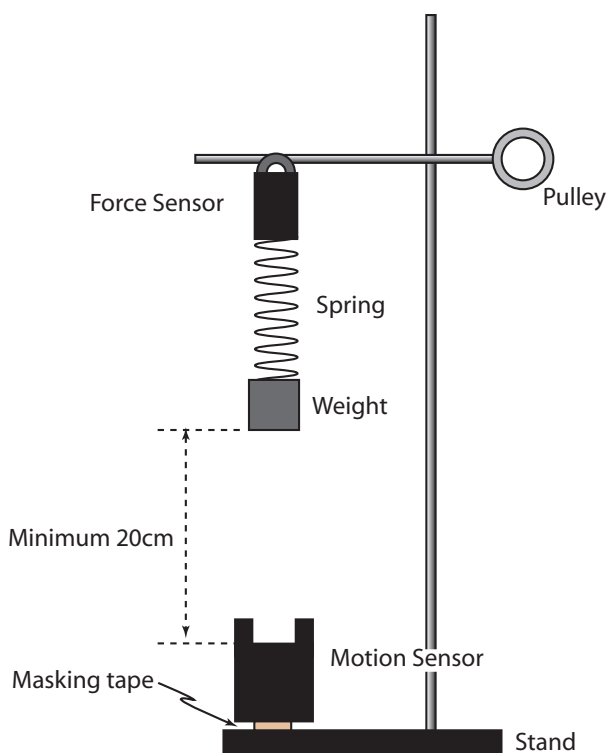
Choose analog *Force Sensor*.

5. Connect the yellow digital connector of the motion sensor to the digital channel 1 and the black connector to channel 2.

In the SW window, click and drag the digital plug (on the left) to digital channel 1.

Choose motion sensor.

6. You must now *calibrate the speed of sound* for the sensor to work properly. With the motion sensor measure a known distance of at least 20 cm, and preferably closer to 1 m, using a fixed object such as the wall or your logbook



held at one end of the table. Write the measured distance in the correct box and click OK. The motion sensor is now calibrated and you should have a speed of sound close to 343 m/s. Record the speed of sound in your logbook. If the speed of sound is far from the expected value, verify the distance, the positioning of the motion sensor and the calibration procedure. If you are still far off, ask the professor.

7. **Calibration of the force sensor.**

Click and drag the digits icon on the Analog A, to display the value of the measured force in newton. Click on the icon MON (play).

Remove the hooked weights and push the TARE button on the force sensor. This should zero the value measured by the force sensor.

8. Set sampling options for the motion sensor.

Click on the button **Sampling options...**

Periodic Sample: choose 10 Hz

Click: FAST

Stop/Start condition: NONE

9. GRAPH

Click and drag the graph icon onto the Analog Channel A to display a graph of the measured force. The y-axis should be FORCE (N) and the x-axis TIME (S). Click on the clock to change the x-axis to: digital1, position (m).

Double-click on the axis to change the scale. Choose an appropriate scale to display all your data points.

#### 4. Data acquisition

1. Stretch your spring-mass system and release it, it will start to oscillate up and down.

**WARNING:** make sure the mass doesn't bounce off the spring and fall on the motion sensor, you could damage the device.

2. To monitor your data points without recording them, push the MON button. When you click STOP, the points are not kept into memory. Use this to make sure all is setup correctly.

3. To record a set of data points push REC. Keep recording until you have enough points to see a straight line (~ 10s), then push STOP.

4. On the graph window in the lower left you have several display options buttons. Click on the tiny graph with connected dots.

A graph setup window opens. Change the name of the window to: **your name**, and uncheck: **connected points**.

5. Maximize the window and click on the autoscale button.

6. Click on the  $\Sigma$  button and choose curve fit: linear fit. All your data points may not follow a straight line, but if you select (by click and drag) only the area in your graph which follows a linear behaviour, the computer will recalculate the best fit ONLY on the selected points. The slope of this graph should represent the spring constant of the system.

7. To print your graph go to FILE: Print active display. **Paste this graph into your logbook.**

8. Redo the experiment with 3 other masses. Make a table of all your results. find the average spring constant from these results. *You do not need to print a graph each time.*

## Part B: Period of a mass-spring system

### 1. Objective

To verify the period equation of a mass-spring system.

### 2. 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, the spring's equilibrium length increases by  $\Delta L$ . The new equilibrium position of the mass-spring system is  $L + \Delta L$  from the spring's support. If the mass is pulled down a small distance  $x$  from the equilibrium position, the spring's exerts a restoring force  $\vec{F} = -k\vec{x}$  (where  $\vec{x}$  is the displacement of the mass and  $k$  is 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. If the *position of the mass with respect to the equilibrium is graphed as a function of time*, a sinusoidal graph is obtained. For a real-life massive spring, the period of oscillation depends on the spring constant, and both the hanging mass and the mass of the spring as follows:

$$T = 2\pi\sqrt{\frac{m_{eff}}{k}}, \quad \text{where } m_{eff} = m + \frac{m_s}{3}$$

$m$  is the hanging mass and  $m_s$  the spring mass.

### 3. Procedure

1. In part A, you have measured the spring constant of your system.
2. Using the Science Workshop Interface, measure the period of the system for a hanging mass of 100 g. What are the uncertainties on this value? *It is not necessary to print a graph*, but you must record the relevant information in your logbook. Calculate the theoretical period and record it next to your measured value in a table.
3. Add 25 g to the hanging mass and measure the period again. Continue to add mass in 25 g increments until you have reached a total mass of 250 g.
4. Using the data recorded in your logbook, plot a graph of  $T$  vs  $m_{eff}$ . Include error bars in your graph. *Paste this graph into your logbook.*
5. Using Excel, transform the data, so you can plot it as a straight line. Use the rules of propagation of uncertainties to find the new error bars. *Paste this graph into your logbook.* Find the slope and intercept and their uncertainties using the function LINEST. From these values, obtain a value for the spring constant and compare it to the one obtained in part A.
6. Make a list of errors that can influence your results.