Lab M20 – Hooke's Law and Simple Harmonic Motion
PH305 4/28/03

Goals: To determine the spring constant for a spring that is stretched by a hanging mass, and to study the motion of the system when it is displaced from equilibrium and then released.

Equipment and Experiment Setup:

1. Plug motion detector into **DIG/SONIC 2,** ***NOT*** DIG/SONIC 1.

2. Plug force sensor into Port 1 and make sure the switch on the sensor, if there is one, is on 10 Newtons.

3. In the Logger Pro software, select the File menu, Open, and choose the Experiments directory, then Probes & Sensors, Motion Detector, MOT&DFS. Press Open.

4. Close the graphs window and maximize the Data Table window.

Part I. Measuring spring constant and period

Be sure to use the same spring throughout this entire experiment.

If you change springs, you will have to remeasure the spring constant.

1. Write the color code of the spring you are using.

[*Spring colors* =]

2. Hang the weight hanger from the spring. Tape a piece of cardstock to the bottom of the weight hanger to increase the reflection area. Position the sonic ranger on the floor directly below the weight hanger. With the motion sensor below the weight hanger, press Collect. The position should read constant. Record this value. Position the rod that supports the spring so that the bottom of the weight hanger is 0.65 to 0.70 m above the ranger. Be sure that the ranger is not reading the bottom edge of the table. When the weight hanger is motionless, record the position reading.

[*Equilibrium position for 0.050 kg* =]

3. Now add additional masses of .050kg, one at a time, to the weight hanger (for a total of 0.250 kg). For each added mass, measure the equilibrium position of the system. Report all your results in the data table below.

Total Hanging Mass (kg)	Weight of Hanging Mass (N)	x_{eq} = Equilibrium Position of Hanging Mass (m)	Distance Spring has been Stretched = $\Delta x = x_{eq}$ (.050 kg) - x_{eq}
.050			
.100			
.150			
.200			
.250			

4. Do a net force problem (including a force diagram) to prove why the force that the spring makes on the hanging mass must be equal to the weight of the hanging mass.

5. Use your calculator to create a graph of Spring Force vs. Distance Spring has been Stretched. Then do an appropriate regression to fit your graph. Below, make a large sketch of your graph (with appropriate scales, labels and units of course). Use the usual matching procedure to report your math equation, physics equation and matching table for the fit you did.

6. Leave a total of 0.150 kg hanging from the spring. Set the spring into oscillation by lifting it up--but not so much as to completely relax the spring--and releasing it; i.e., the amplitude of the motion that results should be small. Measure the period of oscillation to 3 significant figures using a stopwatch. Describe the method that you used to get 3 significant figures.

[*Number of cycles* =]

[*Total time measured* =]

[*Measured period of 0.150 kg =*]

[*Description of how 3 significant figures were obtained*]

7. Assuming that the period, P, of an oscillating mass on a spring spring depends only the spring constant, k, and the mass, m, determine the mathematical combination of k and m that gives the right units for period. This result should be correct to within a constant numerical factor, to be determined in step #8 by experiment.

8. Using your measured spring constant, mass and period, and your formula from #7, calculate the numerical constant in the formula for period. What familiar number is it close to? What does the text say it should be? Percent error?

[*Calculated constant =*]

[*Expected constant =*]

Part II. Position vs. time graph

1. A total of 0.250 kg should be placed on the spring. Use masking tape to hold the weights securely to the weight hanger. This is done **SO THAT THE WEIGHTS WILL NOT FALL ONTO THE SONIC RANGER.**

   Measure the position of the bottom of the weight hanger as you have done previously.

   [*Equilibrium position for 0.250 kg mass* =]

2. Go to Setup Menu, Data Collection, Sampling tab, and change the sampling speed to 30 samples/sec.

3. Go to Window Menu, New Tall Window, Graph, and click on the label of the y-axis of the graph that appears. Select Distance Only. Click OK. Repeat this process three more times, creating graphs with Velocity, Acceleration and Force only. On the position vs. time graph, click on the y-axis, and press manual scaling. Enter 0.4 m as the min. value, and 0.8m as the max. Go to Setup Menu, Data Collection, Sampling tab, and set experiment length to 5 sec. Click OK.

4. Set the spring into oscillation. Click Collect to start data collection. You should obtain smooth, sinusoidal graphs. There may be stray points toward the end of the time interval if the spring starts to sway from side to side. Make a half-page sketch of the position vs. time graph, labeling the axes and placing numbers on them. Draw a horizontal dotted line to show the equilibrium position of the spring.

5. Now remove 0.100 kg mass from the weight hanger so that a total of 0.150 kg hangs from the spring. Set the weight into oscillation as before. Make a half-page sketch of the new position vs. time graph. Describe several ways in which this graph is different from the one sketched in step 4.

   [*Total Mass = 0.150 kg*]

6. Read the coordinates of three consecutive extremum points. (An extremum point is a peak or a valley.) These points span one complete cycle of the motion. Record the results *with units.*

   [(t,y) *coordinates of consecutive extremum points* =]

7. Use the data to calculate the period of the motion. Show your work. As a check, this value should be within 5% of the value calculated in Part I.

   [*Period calculated from graph* =]

   [*Measured period from Part I* =]

   [*Percent difference* =]

8. Use the data you collected in step 6 above to calculate the equilibrium position. Show your work. Measure the equilibrium position as you did in Part I, #2.

[*Total mass* =]

[*Calculated equilibrium position* =]

[*Measured equilibrium position* =]

[*Percent difference* =]

9. Use the step 6 data to calculate the amplitude of the motion. Show your work.

[*Calculated amplitude* =]

10. Determine the equation for the position, y, of the spring as a function of time, t. First decide whether you want to call the curve a sine curve or a cosine curve. (Why is the choice arbitrary?) Then decide how the constants of the motion calculated in 7,8, and 9 will be incorporated into the equation. Give the equation of fit in symbols first, and then substitute constants with units.

Part III. **Position, velocity, acceleration and force relationships**

In this part of the lab, you'll measure the displacement, velocity, and acceleration of the spring with the sonic ranger at the same time that you measure force with the force probe.

1) Record the letter of your computer. Open the software in the same way as Parts I and II:

In the Logger Pro software, select the File menu, Open, and choose the Experiments directory, then Probes & Sensors, Motion Detector, MOT&DFS. Press Open.

[*Computer:*]

2) Go to Setup, Data Collection, Sampling tab, and set the experiment length to 2 seconds and the sampling speed to 30 samples/sec. Press OK.

3) Calibration: You first need to calibrate the probe to measure force in newtons. What force does the force probe measure ? Does it measure weight (and, if so, whose weight?), spring force ?, or net force (and, if so, net force on who ?)? Once you have answered that question, use the following procedure:

- Remove all weights, except the spring;
- Go to Experiment Menu, Calibrate;
- If the software presents an error reading, "The default calibrations folder could not be found," or "The folder does not contain the correct calibrations," then press OK to these errors. Click Cancel on the calibrations screen, and select File Menu → Preferences. On the "Folder Locations" tab, press the Browse/Modify button next to the "Calibrations" blank. Select the C:\Program Files\Vernier Software\Logger Pro 2.0\Calibrations\ folder, and press OK. Then, press the Browse/Modify button next to the "Experiment" blank, and select the C:\Program Files\Vernier Software\Logger Pro 2.0\Experiments\ folder. Press OK. This will remedy the error message. Select Experiment → Calibrate again.
- Select the icon for channel 1, which should be a big "F," and press Perform Now;
- Wait for the reading by "Channel 1" to stabilize, and type "0" (zero) into the Value 1 box, and press Keep;
- Add a known mass (0.200 kg total recommended), on the force probe hook;

  [*Total Mass* =]
- When the reading stabilizes again, enter the force in Newtons to 3 significant figures in the Value 2 box and press Keep.

  [*Force* =]

4) The software probably opened with a block of distance, acceleration, and force-vs-time graphs. You will need to close these. Do not close the data table; do not minimize the data table.

Go to Window menu, New Wide Window, Graph, and select it. Then go to View, Graph Layout, and then click 2 panes (one vertically over the other). Repeat this procedure so that you have two windows, each window containing two graphs. Configure the graphs in the top window to be position vs time and velocity vs time; configure the graphs in the bottom window to be acceleration vs time and force vs. time. Each of the graphs should have the same time range (2.0 sec should be fine).. If you want to print two of the graphs, minimize one of the two-graph windows, and make the remaining two-graph window fit the screen

5) Place 0.200 kg total mass on the spring. Set the mass into oscillation and collect data.

[*Total Mass* =]

6) You should get a smooth curve for the position and force graphs, but the velocity and acceleration graphs may show some scatter in the points. (This has to do with the method used to calculate velocity and acceleration from the position data.) Select View, then Autoscale if the curves are not showing on any of the graphs. Then collect data as before.

7) Print out your final graphs. In order to conserve paper, print two graphs per page: the position and velocity graphs on one page; the force and acceleration graphs on the next. Be sure to print them all with the same time scale. Data tables are not necessary.

8) Use your graphs to answer the following questions:

A) Where (in position) is the mass when the velocity is a maximum? What is this velocity? What is the acceleration at this point? Where, relative to its equilibrium position, is the mass at this point (at equilibrium, above equilibrium, below equilibrium ?) [To find curve or slope values, select Analyze, then Examine or Tangent Line.]

[*position of mass at maximum velocity* =]

[*maximum velocity* =]

[*acceleration at maximum velocity* =]

[*position of mass relative to equilibrium (above, below, at)* =]

B) Where is the mass when the acceleration is a maximum? What is the value of the maximum acceleration? What is the velocity at this point? Where, relative to its equilibrium position, is the mass at this point (at equilibrium, above equilibrium, below equilibrium ?)

[*position of mass at maximum acceleration* =]

[*maximum acceleration* =]

[*velocity at maximum acceleration* =]

[*position of mass relative to equilibrium (above, below, at)* =]

C) Does the maximum acceleration magnitude occur at the same time as the maximum force magnitude? What physics predicts that it should? (remember what force is being graphed !)

D) Does the maximum displacement magnitude occur at the same time as the maximum acceleration magnitude? What physics predicts that it should?

One way to summarize some of the results above is to say that the position and velocity are 90° (1/4 cycle) out of phase, and position and acceleration are 180° (1/2 cycle) out of phase. Net force and acceleration, though are 0° out of phase - that is, they are *in phase*.