Simple Harmonic Motion

Name:

Group Members:

Date:

TA's Name:

Learning Objectives:

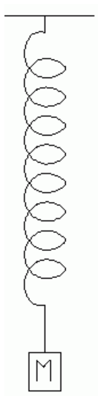
1. Use Hooke's law to find a spring constant
2. Understand position-time and velocity-time graphs for a simple harmonic motion
3. Calculate and measure the period for an oscillating mass and spring system

Apparatus: Spring, metal stand and fixing bracket, mass hanger, set of weights, PASCO computer interface, motion sensor, meter stick

Overview: In this experiment you will investigate simple harmonic motion for a spring and mass system. You will design an experiment to determine the spring constant of given spring and use that to predict the frequency of oscillations. You will then measure the oscillation behavior of the spring and mass system to measure the frequency and to investigate the nature of position vs. time and velocity vs. time graphs.

Part A: Finding the spring constant k

1. We want to design an experiment to determine the spring constant k. A starting point may be to hang a mass from the spring as shown in the figure and to investigate the equilibrium of spring and mass system for this case. To develop your procedure, begin by drawing the free body diagram for the mass M. Then use the forces on your diagram to write down Newton's Second Law in the vertical direction. Also write down's Hooke's Law for the force from a spring.



Free body diagram for suspended mass M in equilibrium

Newton's Second Law
$\sum F_y = ma_y$

Hooke's Law

2. Now use Newton's Second Law and Hooke's Law to come up with an experiment that will allow you to determine the unknown spring constant from quantities you can measure. Describe your experimental design by answering the three questions below.

   What will you do?

   What data will you collect?

   How you will analyze the data?

3. Now label the axes of the graph you plan to construct and sketch your prediction of the data you will get. Also show how you will get your result from the data.

4. Now you are ready to do the experiment to determine the spring constant. Think about how you will establish a point of reference to measure any required lengths. Use masses no larger than *400 g*. Record at least 5 data points. Make a table in Excel to enter your data. Graph your data in Excel and use it to determine $\boldsymbol{k}$. Remember units. ***Copy and Paste your table and your graph into your Word document.***

   Calculated Spring Constant: $\boldsymbol{k}$ = ________________________________

Part B: Simple harmonic motion

5. For an ideal spring-mass system the time period $\boldsymbol{T}$ of oscillations is given as $\boldsymbol{T = 2\pi\sqrt{\frac{m}{k}}}$, where $\boldsymbol{T}$ is the period of the oscillation, that is, it is the time for one complete oscillation. $\boldsymbol{m}$ is the mass suspended from the spring. For a real spring (not an idealized massless spring), the period equation still can be used but we have to account for the fact that the spring is also oscillating. The bottom is oscillating a lot while the top is oscillating very little, so we need to use only a portion of the spring's mass. When we calculate the amount of the spring's mass we end up with a total mass to use in the period equation of $m = m_{suspended} + \frac{1}{3}m_{spring}$. Measure the mass of the spring.

   m_{spring} = ________________________________

6. Predict the period of the oscillation you will get if you attach a mass of *250 g* to the spring. Use the value of $\boldsymbol{k}$ you found in Question 4 to make the prediction. Show your calculations.

   Period: $\boldsymbol{T}$ = ________________________________

   Remember to include units!

7. Now select *200 g* mass and hang it from the spring using the *50 g* mass hanger. Note the equilibrium level. Make the mass stable and then slowly pull the mass vertically down about *5 cm* and then release. Observe the oscillations of the mass. Is the period of the oscillation approximately the same as your prediction in Question 6?

   If not, you should check your calculations for the predictions again.

8. Now pull the mass down by *10 cm* and release, observe the oscillations of the mass again. In your observations, how does the period of oscillation compare between the *5 cm* and the *10 cm* amplitudes?

9. Now set the motion sensor up directly under the mass. Keep enough distance between the mass and the sensor for oscillations. The motion sensor should be arranged so that it captures the motion of the mass. Setup the PASCO interface to show the position vs. time graph and ***change the Sample Rate to 50 Hz***. ***Set the number of decimal places to 3*** by choosing Data Summary on the left side menu bar and selecting the Properties for your position measurement then selecting Numerical Format. After changing Number of Decimal Places to 3, click OK.

   Let the mass oscillate after starting the motion *5 cm* below the equilibrium point and obtain a position vs. time graph. You may need to make several trials to get a good graph. ***Copy and Paste your labeled graph into your Word document.***

10. Determine the amplitude and period of the oscillation from your graph. Remember units.

    Amplitude: $\boldsymbol{A}$ = ________________________________

    Period: $\boldsymbol{T}$ = ________________________________

11. How does the value for period compare with your prediction in Question 6?

12. Now collect position vs. time data for oscillations starting *10 cm* below the equilibrium point. Determine the amplitude and period of the oscillation from your graph.

    Amplitude: $\boldsymbol{A}$ = ________________________________

    Period: $\boldsymbol{T}$ = ________________________________

13. How does the period of the oscillation compare between the *5 cm* and the *10 cm* data?

14. What can you conclude about the dependence of the period of oscillation on amplitude?

Part C: Position, velocity, acceleration for simple harmonic motion

15. Start a new experiment in Capstone where you have 3 graphs: position vs. time, velocity vs. time, and acceleration vs. time. ***Change the Sample Rate to 25 Hz.*** Just as you did earlier, ***set the number of decimal places to 3 for each variable*** by choosing Data Summary on the left side menu bar and selecting the Properties for each measurement then selecting Numerical Format. After changing Number of Decimal Places to 3, click OK and proceed to the Properties for the next variable.

    Collect data for about 3 cycles of an oscillation starting *5 cm* below the equilibrium point. ***Copy and paste the 3 graphs into your Word document.***

16. From your graphs, find a time where the position is at a maximum. t = ______________________

17. What is the state of the spring at that time, that is, is it more or less compressed or extended than it is at equilibrium?

18. At the time when the position is at a maximum, is the acceleration near a maximum, minimum (most negative), or zero value? ______________________________________

    Explain why the acceleration is what it is when the position is at a maximum.

19. At the time when the position is at a maximum, is the velocity near a maximum, minimum (most negative), or zero value? ______________________________________

    Explain why the velocity is what it is when the position is at a maximum.

Part D: Conclusions

20. What evidence do you have in this experiment that Hooke's Law is reliable?

21. State your conclusion about the relationship between amplitude and period for simple harmonic motion. Defend your conclusion based on your experimental results.

22. State your conclusion about the relationship between position, velocity, and acceleration for an object in simple harmonic oscillation.

Instructions on how to submit the graphs:

1. Open a Word document and type the names of all present group members.
2. Paste into the Word document your Excel table and graph you used to determine the spring constant in Part A.
3. Paste position vs. time graph from *5 cm* oscillations with 250 g suspended mass in Part B.
4. Paste position, velocity, and acceleration vs. time graphs from Part C.
5. Print the Word document and attach it to this lab write-up.