PHYS 2425
Engineering Physics I
EXPERIMENT 9

SIMPLE HARMONIC MOTION

I. INTRODUCTION

The objective of this experiment is the study of oscillatory motion. In particular the spring-mass system and the simple pendulum will be studied. For the spring, the student will measure the spring constant k by measuring the spring stretch as various weights are hung from the spring. Then the period of oscillation of the spring-mass system will be measured and compared to theoretical predictions. For the pendulum, the period of oscillation will be measured and its dependence on several parameters such as length of pendulum string, the mass and the angle will be investigated.

II. APPARATUS

Spring, weights, strings, protracter, meter stick, photogate and a computer.

III. EXPERIMENTAL PROCEDURE

Procedure 1

1. Hang the spring from a support and attach a $50\,\mathrm{g}$ hanger. Place a meter stick next to the spring so you can measure the spring stretch. It is better to have the big numbers on the meter stick toward the bottom. Tape the meter stick so it does not move. Record the position of the bottom of the hanger. Call it x_0.

2. Place a $20\,\mathrm{g}$ mass on the hanger. The spring will stretch a certain amount. Record the new position of the bottom of the hanger. The difference between this reading and the previous reading, x_0, is the spring stretch.

3. Repeat for masses of $40\,\mathrm{g}$, $60\,\mathrm{g}$, $80\,\mathrm{g}$ and $100\,\mathrm{g}$. Each time subtract x_0 from the new position of the bottom of the hanger to get the spring stretch. Enter the positions and the corresponding spring strectches in the data table.

Procedure 2

1. The computer and LabPro should already be on. If they are not, turn them on. Plug the photogate into the LabPro Dig/Sonic 1.

2. Double click on **Logger Pro** and then double click on **Pendulum Timing**.

3. Remove the masses from the spring but leave the hanger. Hang a single $100\,\mathrm{g}$ ($= 0.10\,\mathrm{kg}$) mass on the hanger making the total mass $150\,\mathrm{g}$.

4. Attach (tape) a flag to the mass and set up the photogate such that it is blocked and unblocked by the flag as the mass oscillates up and down. This will allow the computer to measure the period of oscillation of the spring-mass system.

5. Set the spring into oscillation by pulling the mass down $3.0\,\mathrm{cm}$ and releasing. As much as possible the motion of the mass needs to be up and down and not sideways.

6. The computer will display the measured periods of oscillation on the screen. Calculate the average of the first five displayed periods. Call this the measured period of oscillation of the spring-mass system and record it in the appropriate place in the data table.

7. Measure the mass of the spring and record it in the data table.

THE PENDULUM

We would like to establish here that if the pendulum angle is kept small (compared to 1 radian), then the period of the pendulum depends only on the length of the string. Other parameters such as the angle and the mass of the pendulum bob do not affect the period.

Procedure 3

1. Fix the length of the pendulum string from the point of support to the center of the mass to be $l = 1.00\,\mathrm{m}$. Also fix the mass by using the brass pendulum bob. Place the photogate such that the pendulum bob blocks and unblocks it as it swings back and forth.

2. Pull the pendulum aside until the vertex angle is 5° and release. The computer will display the measured periods of oscillation on the screen. Calculate the average of the first five displayed periods. Call this the measured period of oscillation of the pendulum and record it in the appropriate place in the data table.

3. Repeat above step for vertex angles of 10°, 15° and 20°.

Procedure 4

1. Fix the length of the pendulum string to be $1.00\,\mathrm{m}$ and the angle at 10.0°.

2. Using the brass pendulum bob, measure the period of oscillation the same way as you have done in the previous procedure and record it in the data table.

3. Repeat the above step for the two other available pendulum bobs which have different masses.

Procedure 5

1. Fix the mass of the pendulum by using the brass pendulum bob and also fix the vertex angle at 10°.

2. With the string length at $l = 1.00\,\mathrm{m}$, measure the period of oscillation just like you have done in the previous procedures and record it in the data table.

3. Repeat the above step for string lengths of $l = 0.500\,\mathrm{m}$, $l = 0.750\,\mathrm{m}$, $l = 1.250\,\mathrm{m}$ and $l = 1.50\,\mathrm{m}$. Each time record the measured period of oscillation.

IV. ANALYSIS

1. Using the data of procedure 1, plot the force, $F = mg$, (in Newtons) on the vertical axis and the spring stretch (in meters) on the horizontal axis. This should be a straight line graph which goes through the origin $(0, 0)$. The slope of this graph is the spring constant, k. Calculate k in SI units (N/m). Recall that Hooke's law states that $F = -kx$ where k is the spring constant, x is the spring stretch and F is the force exerted by the spring on the mass hanging on it. In this case the spring force is equal to the weight of the hanging mass, mg.

2. Theoretically, the period of the spring-mass system is given by

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{m}{k}}. \tag{1}$$

   This equation holds for situations where the entire oscillating mass is concentrated at the end of the spring. It is a good aproximation for problems and experiments where the mass of the spring is very small compared with the hanging mass. If this is not the case for your experiment, then the mass of the spring must be taken into account and the correct expression for the period of the spring-mass system is

$$T = \frac{2\pi}{\omega} = 2\pi\sqrt{\frac{(m + (m_s/3))}{k}} \tag{2}$$

   where m_s is the mass of the spring. Use this expression to calculate the period of the spring-mass system using the value of k claculated in step (1).

3. Calculate the relative uncertainty in the calculated period, $\frac{\delta T}{T}$, and compare it to the relative uncertainty in the measured period as given by the computer.

4. Calculate the percent difference between the theoretical value calculated above and the experimental value measured in precedure (2)

$$\%\,\text{diff.} = \frac{|T_\text{th} - T_\text{exp}|}{\left(\frac{T_\text{th} + T_\text{exp}}{2}\right)} \times 100. \tag{3}$$

5. From the data of procedure (3), what is the dependence of the period of the pendulum on the vertex angle? If the answer is not clear from the data, plot the period on the vertical axis and angle on the horizontal axis to show the dependence more clearly. Remember that there is uncertainty in this measurement. So if the variation in the period is small (under 5 percent), then this variation can be attributed to experimental uncertainty and you must reach the conclusion that the period of the pendulum does not depend on the vertex angle.

6. From the data of procedure (4), what is the dependence of the period of the pendulum on the mass? If the answer is not clear from the data, plot the period on the vertical axis and the mass on the horizontal axis to show the dependence more clearly. Use the same reasoning here you used in the above step to decide whether the period is dependent on the mass.

7. Using the data of procedure (5), plot the square of the measured period of the pendulum on the vertical axis and the length of the string on the horizontal axis. This graph should be a straight line going through the origin. Calculate the slope of this line and compare with that predicted by theory by calculating the percent difference. Theoretically, the small-angle approximation for the motion of the pendulum gives the period of the pendulum as

$$T = 2\pi\sqrt{\frac{l}{g}}.$$

This expression will allow you to calculate the slope of the line as predicted by theory.

8. Write a conclusion summarizing your results. Comment on the accuracy of this experiment. procedures and how well do the theoretical expressions predict the period of simple harmonic oscillation for the spring and the pendulum.

Experiment (12) Data Table: Procedure (1)			
Hanging Mass m (kg)	$F = W = mg$ (N)	Position (m)	Spring Stretch x (m)
Hanger (0.00)	0.00	$x_0 =$	0.00
0.020			
0.040			
0.060			
0.080			
0.100			
Measured Spring Constant $k =$			

Procedure (2)
Oscillating Mass $M = 0.150\,\text{kg}$
Spring Mass $M_\text{s} =$
Measured Period of Oscillation $T_\text{exp} =$
Theoretical Period of Oscillation $T_\text{theory} =$
Percent Difference $=$

Procedure (3)	
Pendulum Length $l = 1.0\,\mathrm{m}$	
Mass $m =$	
Vertex Angle θ (deg)	T_{exp} (s)
$5.00°$	
$10.0°$	
$15.0°$	
$20.0°$	
How does the pendulum	