Experiment 5. Simple Pendulum

A pendulum isn't just for keeping time. One can also study gravity with it.

Objective:

(a) To verify that the time period of a simple pendulum is proportional to the square root of its length, if the amplitude is small, and to determine the value of g, the acceleration due to gravity.

(b) To show that the period oscillation is independent of its amplitude for small amplitudes only.

Apparatus:

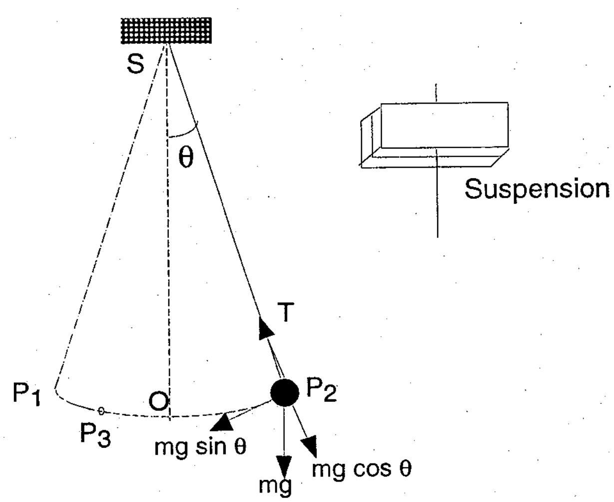
A simple pendulum, a meter stick, photogate, CHAMP interface and a personal computer.

Theory:

A simple pendulum consists of a small spherical metal bob suspended from a fixed support by means of a light inextensible string. The length of the pendulum ℓ is defined as the distance between the point of suspension S and point of oscillation O.

Thus ℓ = length of the string (including the hook) + radius of the bob.

When the pendulum is oscillating, one round trip is defined as one oscillation. In the figure below, one oscillation is from O to P_2 to P_1 and back to O. The round trip from P_3 to P_1 to P_2 and back to P_3 is also one oscillation.



The period or time period T of a pendulum is defined as the time for one complete oscillation.

The amplitude of oscillation is defined as the maximum displacement of the center of the bob from the equilibrium position O.

Thus amplitude is $OP_1 = OP_2$.

The amplitude can also be measured in terms of the maximum value of angle θ.

If the amplitude of oscillation is small (maximum value of $\theta \leq 0.05$ radian, that is, $OP_1 = OP_2 \leq 5$ cm for about 100 cm long pendulum), the time period of a simple pendulum is almost independent of the amplitude of oscillation. Further, in such a case, the motion of the pendulum is simple harmonic, and the time period is given by

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad (1)$$

where g is the acceleration due to gravity (which is the acceleration of an object falling freely under gravity).

Squaring equation (1), we get

$$T^2 = 4\pi^2\frac{\ell}{g} = \left(\frac{4\pi^2}{g}\right)\ell \qquad (2)$$

The acceleration due gravity g is constant at a given place. Thus T^2 is directly proportional to ℓ. Therefore, a plot of T^2 vs. ℓ gives a straight line.

By choosing two points with coordinates $(T_1{}^2, \ell_1)$ and $(T_2{}^2, \ell_2)$ on the straight line graph, we get

$$T_1^2 = \left(\frac{4\pi^2}{g}\right)\ell_1 \quad \text{and} \quad T_2^2 = \left(\frac{4\pi^2}{g}\right)\ell_2$$

By subtracting and some mathematical manipulation, we get

$$g = 4\pi^2\left(\frac{\ell_2 - \ell_1}{T_2^2 - T_1^2}\right) \qquad (3)$$

Eq. (2) gives $g = 4\pi^2\left(\frac{\ell}{T^2}\right)$.

Hence the average value of g can also be calculated by using the average value of $\frac{\ell}{T^2}$.

Procedure:

1. Set up the pendulum and measure the diameter of the bob.
2. Turn on the CHAMP and then the computer.

   At the prompt

   C:TPACK>

enter TP
Follow the directions on the screen.
Use PASS as the password.
Select "M" to test the photogate.
The CHAMP determines the period by measuring the time between every other interruption of the photogate.

3. Measure the length of the string.
   Press any key to return to the main menu. To study the period of oscillation of the pendulum, select "D: Pendulum Timer."
   At the pendulum timer screen, start the oscillations. Keep the amplitude small. When the pendulum is at one extreme, press 'ENTER'.
   Accumulate data for about 10 full swings of the pendulum.
   Press any key to terminate the data collection.
   You will see a table of time periods.
   To edit the time periods that are not consistent, press any key to get the data analysis menu.
   Select E to edit the timing data.
   The screen will give directions to edit the data. Move the cursor to the line which contains the data to be deleted and press enter. An asterisk (*) will appear next to the data to be omitted. Press ESC and follow the directions on the screen to return to the data analysis menu.
   Now select A to display the data again. Record average T.
   Select C to analyze the timing data.
   While entering the length of the pendulum, remember to add the radius of the bob to the length of the string. Enter the length in meters.
   Record the value of 'g' calculated by the computer.
4. By selecting H, repeat step 3 with 5 different lengths of the string by changing the length by about 8 cm each time.
5. Tabulate the data, plot a graph between length and T^2 and determine 'g' from the slope of the graph.
6. Keeping the length of the string fixed at about 70 cm, determine the periods of oscillations for 3 different amplitudes (about 5 cm, 10 cm and 40 cm).

Use mks units in this experiment.

York College of The City University of New York

Physics I

Name:

Experiment No. 5: Pre-Lab Questionnaire

1. What is a simple pendulum? Define time period and amplitude of a simple pendulum.

2. A student obtained $\ell_1 = 0.564$ m, $T_1^2 = 2.26$ s^2; $\ell_2 = 0.823$ m, $T_2^2 = 3.30$ s^2 from the graph between ℓ and T^2. Calculate 'g'.

Experiment No. 5

Name:

Marks:

Partner:

Remarks:

Section:

Date Submitted:

Title:

Objective:

Theory/Formulas:

Data Sheet

Diameter of the bob: Reading 1 = Reading 2 =

Average diameter = Radius =

No.	Length of string	Length of pendulum	T	g (CHAMP)	T^2	$\frac{\ell}{T^2}$

Average $\frac{\ell}{T^2}$ =

From the average $\frac{\ell}{T^2}$, g = Percent error =

Average 'g' (CHAMP) = Percent error =

From the graph, $T_1{}^2$= ; ℓ_1 = ; $T_2{}^2$= ; ℓ_2 =

'g' (graph) = Percent error =

Dependence of T on amplitude

No.	Amplitude	T
1		
2		
3		

54

Remarks and conclusions about study of dependence of T on amplitude:

Experiment No. 5: Questions

1. Why should the amplitude of oscillation of the pendulum should be kept small?

2. What will happen if a rubber string is used instead of an inextensible string to suspend the bob?

3. Will the time period of a pendulum increase or decrease if it is taken from the earth to the moon? Explain.

4. The time period of a simple pendulum is 0.8 second. If its length is made four times the original length, what will be its new period?