# Simple Pendulum

## Objective

To investigate the fundamental physical properties of a simple pendulum.

## Equipment Needed

- Simple Pendulum Apparatus with Meter Scale and Protractor
- Bobs – 3 (Aluminum, Steel, and Wood)
- Table Clamp
- Stop Watch

## Introduction

An ideal simple pendulum consists of a particle of mass *m* suspended by an un-stretchable, weightless string of length *L*, as shown in Figure 1. The particle is known as the bob of the pendulum, and is free to swing back and forth to the left and right of the vertical line through the pendulum's pivot point. The time taken for one complete oscillation is called period *T*. One oscillation is the motion taken for the bob to go from position A (initial position) through C (center position) to B (the other extreme position) and back to A.

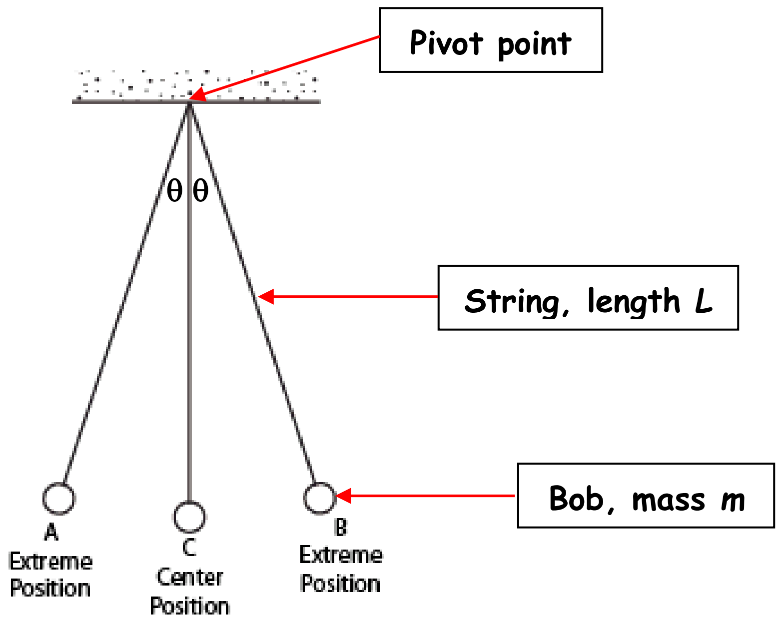



**Figure 1**

For small oscillations (θ less than 10°), the period *T* of a simple pendulum is given by

$$T = 2\pi \, (L/g)^{1/2}$$

where, g is the free-fall acceleration and is equal to 9.80 m/s$^2$. Notice that the period of a simple pendulum is (a) independent of the mass *m* of the particle and (b) proportional to the square root of the length of the pendulum. (c) the formula $T = 2\pi\ (L/g)^{1/2}$ is accurate only for small oscillations

In this lab you will be making measurements on a real-world pendulum, in which the string is light, but not weightless, and the mass is not a point, but has some dimensions. Nevertheless, if you measure the length $L$ from the pivot point to the center of mass of the bob, it will turn out that the measured periods for small oscillations will agree very well with the equation given above. The experimental set up is shown in Figure 2.

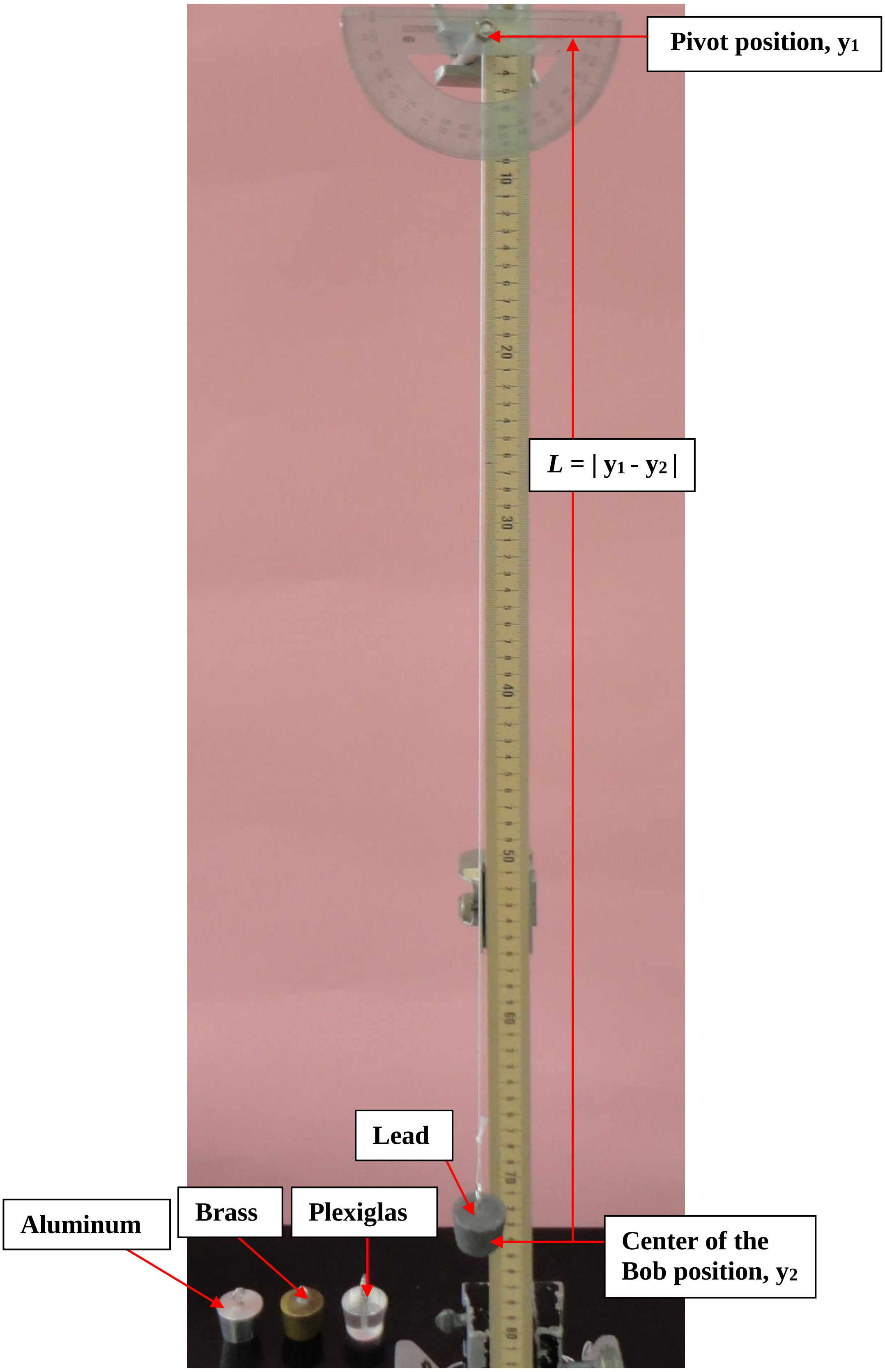

Pivot position, $y_1$
$L = | y_1 - y_2 |$
Lead
Aluminum
Brass
Plexiglas
Center of the Bob position, $y_2$

**Figure 2**

**Exercise 1 – Fixed Length, Variable Mass**

In this exercise, you will check whether the period *T* is independent of the mass *m* for a fixed value of length *L*. You will be able to vary the mass *m* by attaching various objects made of aluminum, Wood, and Steel to the string.

1. Measure the masses of the objects using a triple beam balance.

2. Attach one of the objects to the string, and fix the length *L* from the pivot point to the center of mass of the object to 70.0 cm.

3. Displace the object from the vertical line by θ = 10° and let it go.

4. Using a stop watch, measure the time $t_1$ for 10 oscillations.

5. Repeat Steps 3 and 4 twice more, and measure the times $t_2$ and $t_3$ for 10 oscillations. This step is required to reduce the error caused by your reaction time in starting and stopping the timer.

6. Record your data in a new Excel sheet as shown in Figure 6. To write $t_1$ in cell C1, first type t1 then double click on the cell, select 1, right click, choose ***Format cells***, and then select ***subscript*** in the Format cells window. Do the same in cells D1, E1 and F1 as well.

| Object | m(Kg) | $t_1$(s) | $t_2$(s) | $t_3$(s) | $t_{avr}$(s) | T(s) |
|---|---|---|---|---|---|---|
| Aluminum | | | | | | |
| Wood | | | | | | |
| Steel | | | | | | |

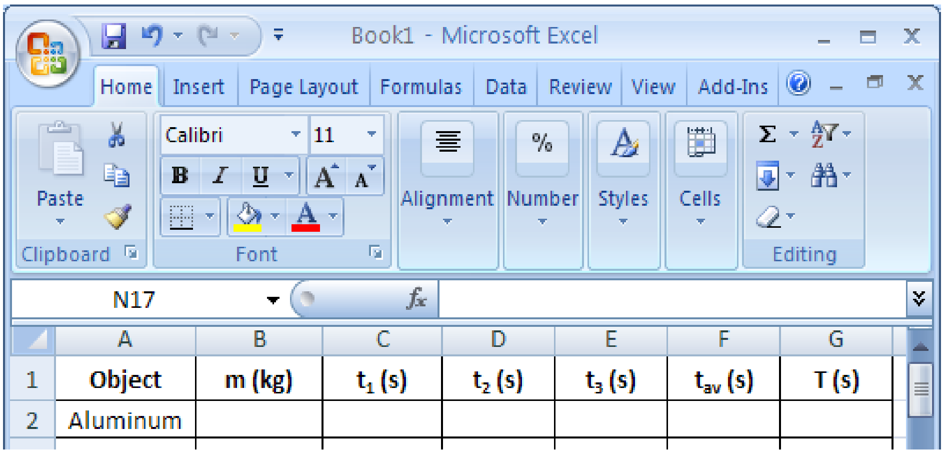



**Figure 6**

7. Repeat Steps 2 to 5 for the other two objects as well, and record the data in the Excel sheet.

8. To calculate the average value $t_{av}$ for aluminum, type in cell F2 *=average(C2:E2)* and press ***Enter*** key.

9. To calculate *T* for aluminum, type in cell G2 = *F2* /10 and press ***Enter*** key.

10. To calculate $t_{av}$ and *T* for the other three objects, select cells F2, G2 and use the left mouse button to press on the small square at the lower right corner of cell G2 and drag it down.

11. Copy the table from the Excel sheet to the lab report

12. What can you conclude from your results?

**Exercise 2 – Fixed Mass, Variable Length**

In this exercise, you will verify that the period of a simple pendulum is proportional to the square root of the length of the pendulum. You will also determine experimentally the free-fall acceleration *g*.

1. Choose any one of the Three objects used in Exercise 2 as the bob of the pendulum.

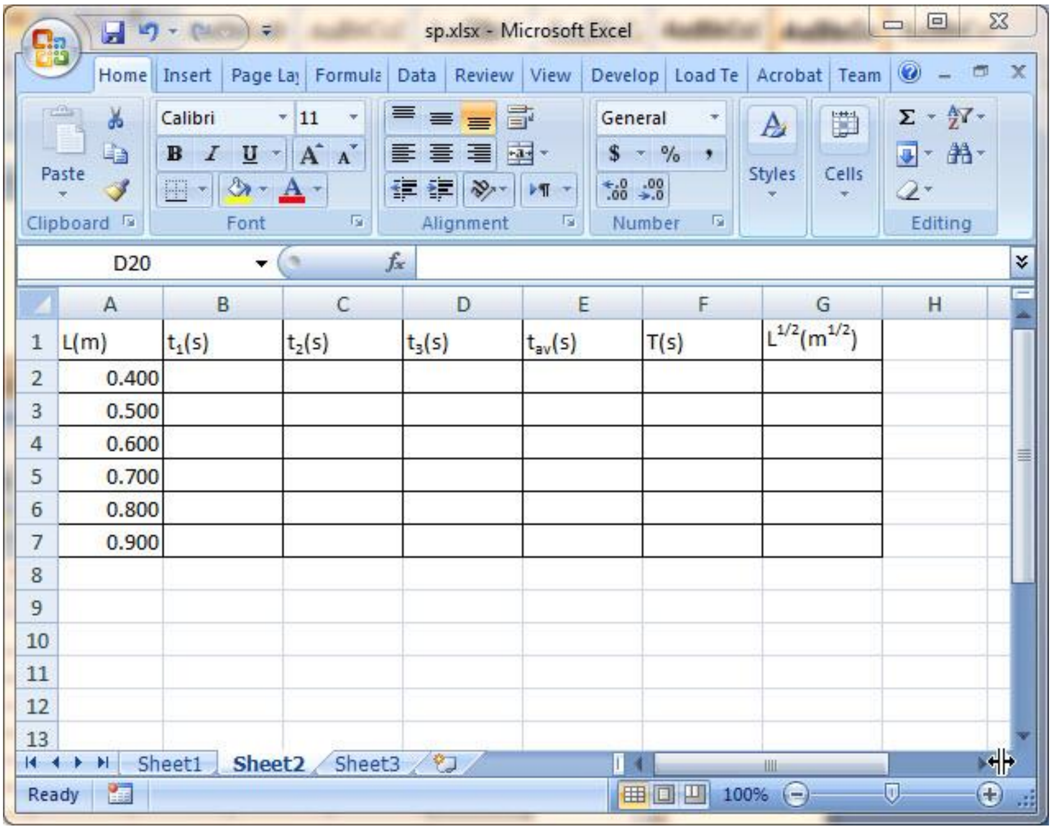
2. Change the length *L* from the pivot point to the center of mass of the object to 40.0 cm.

3. Displace the object from the vertical line by θ = 10° and let it go.

4. Using a stop watch, measure the time $t_1$ for 10 oscillations.

5. Repeat Steps 3 and 4 twice more, and measure the times $t_2$ and $t_3$ for 10 oscillations.

6. Record your data in a new Excel sheet as shown in Figure 7.



| L(m) | $t_1$(s) | $t_2$(s) | $t_3$(s) | $t_{av}$(s) | T(s) | $L^{1/2}(m^{1/2})$ |
|---|---|---|---|---|---|---|
| 0.400 | | | | | | |
| 0.500 | | | | | | |
| 0.600 | | | | | | |
| 0.700 | | | | | | |
| 0.800 | | | | | | |
| 0.900 | | | | | | |

**Figure 7**

7. Repeat Steps 3 to 5 for *L* = 50.0 cm, 60.0 cm, 70.0 cm, 80.0 cm and 90.0 cm as well, and record the data in the Excel sheet.

8. Calculate $t_{av}$ and *T* as you did in Exercise 2.

9. To calculate $L^{1/2}$, type in cell G2 =*sqrt(A2)* and press ***Enter*** key. Then select cell G2 and use the left mouse button to press on the small square at the lower right corner of cell G2 and drag it down.

10. Copy the table from the Excel sheet to the lab report

11. Plot *T* versus $L^{1/2}$ and add trendline as you did in the previous labs. Make sure you have plotted *T* on the y-axis and $L^{1/2}$ on the x-axis.

12. Copy the graph into your lab report.

13. Recalling the formula $T = 2\pi\,(L/g)^{1/2}$, determine $g_{exp}$ from the slope and calculate the percent difference between $g_{exp}$ and the accepted value, $g_{acc}$ = 9.80 m/s$^2$.

14. Comment on the sources of error in this experiment.