

Experiment 1

To determine the acceleration due to gravity
applying linear least square regression method
by using a simple pendulum.

Physics Lab 1

Summer 2020-21

Department of Physics

American International University-Bangladesh

Objectives:

- To determine the acceleration due to gravity in the lab with a simple pendulum.
- Also to learn how the linear least square regression method can be used to find the regression line for a set of data.

Outcomes:

After completing this experiment student should be able to answer the following questions:

- What is acceleration due to gravity?
- How a simple pendulum can be constructed and what are its criteria?
- How linear least square regression method (LLSRM) can be used to find the regression line? Why we need to learn it?
- How LLSRM method can be used to find slope and intersection for any number of data?
- How acceleration due to gravity can be calculated from the slope of the regression line?

Timing and Length of Investigation (Total 3 Hours):

- **Lecture on Theory (30 minutes):**
 - Theory of the experiment will be discussed.
- **Lecture on Procedure (10 minutes):**
 - Students will learn about the procedure of the experiment through a video lecture.
- **Experimental Work (90 to 100 minutes):**
 - A sample data table will be provided to students and teacher will clarify every part of it.
 - Students will do all the calculations, draw graphs in excel and complete the result part.
- **Post Lab Discussion (15 to 20 minutes):**

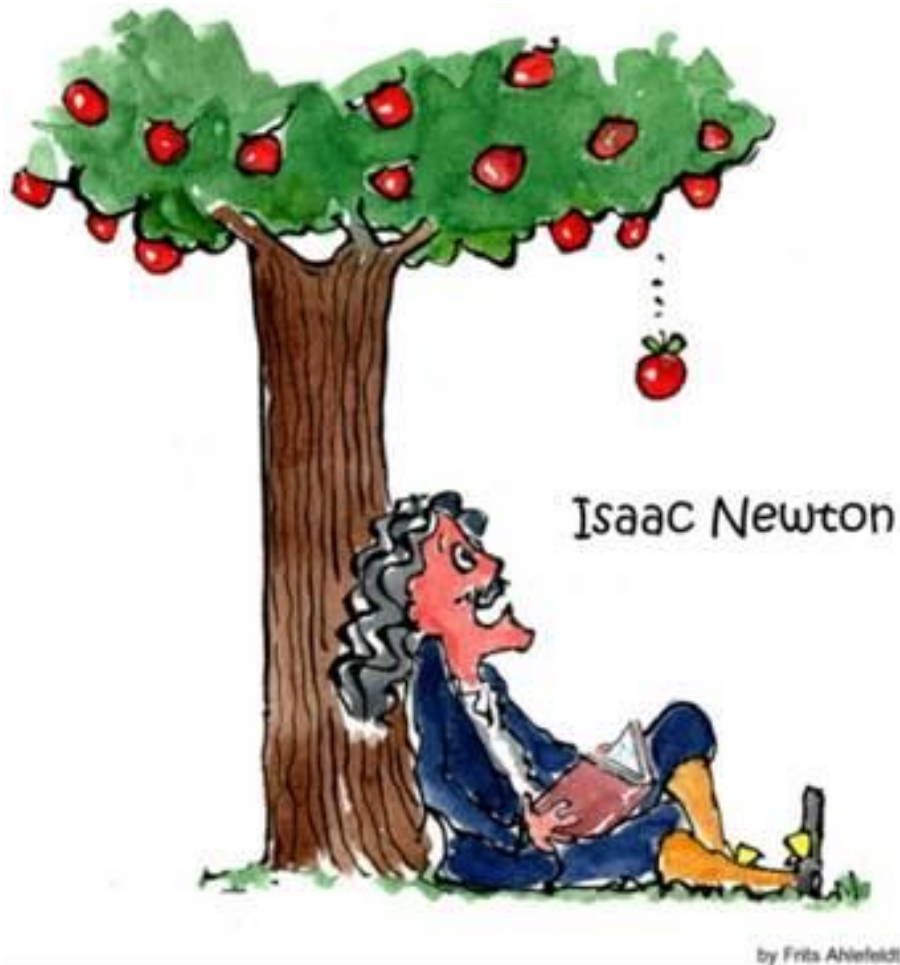
Teacher will summarize the total lab work and have a discussion with the students related with the questions given in the outcomes part.

Report Submission:

Students will upload their lab reports as groups in teams **lab day by 11:59 pm.**

Theory: acceleration due to gravity

Acceleration of a free-falling object near the earth due to gravity.



Newton's Famous Story

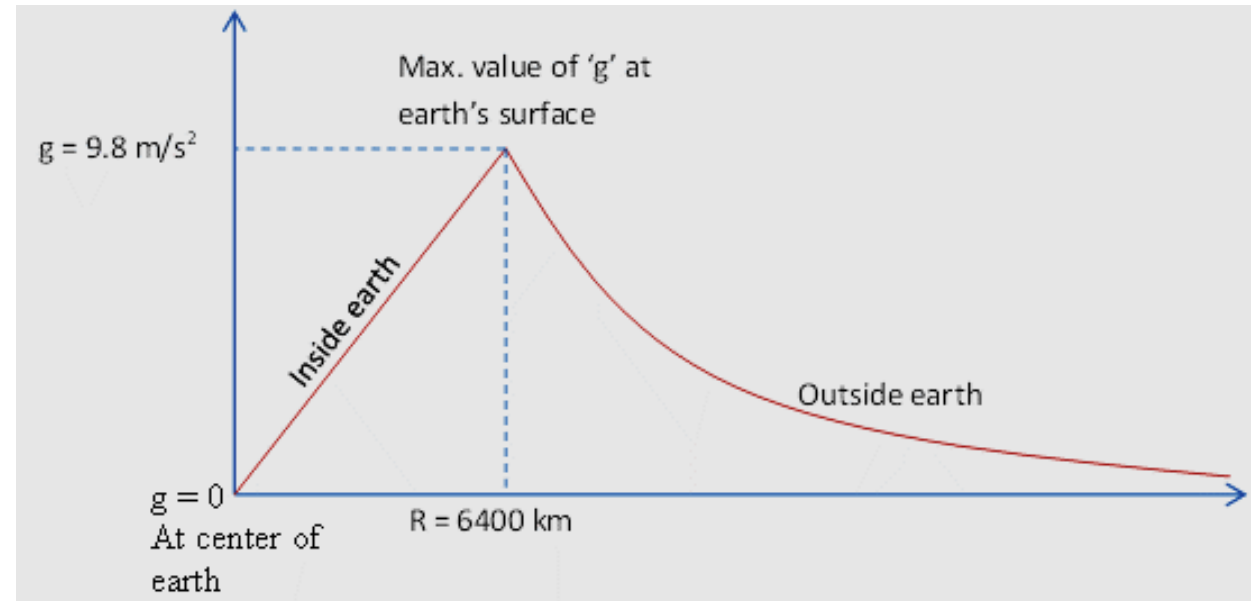
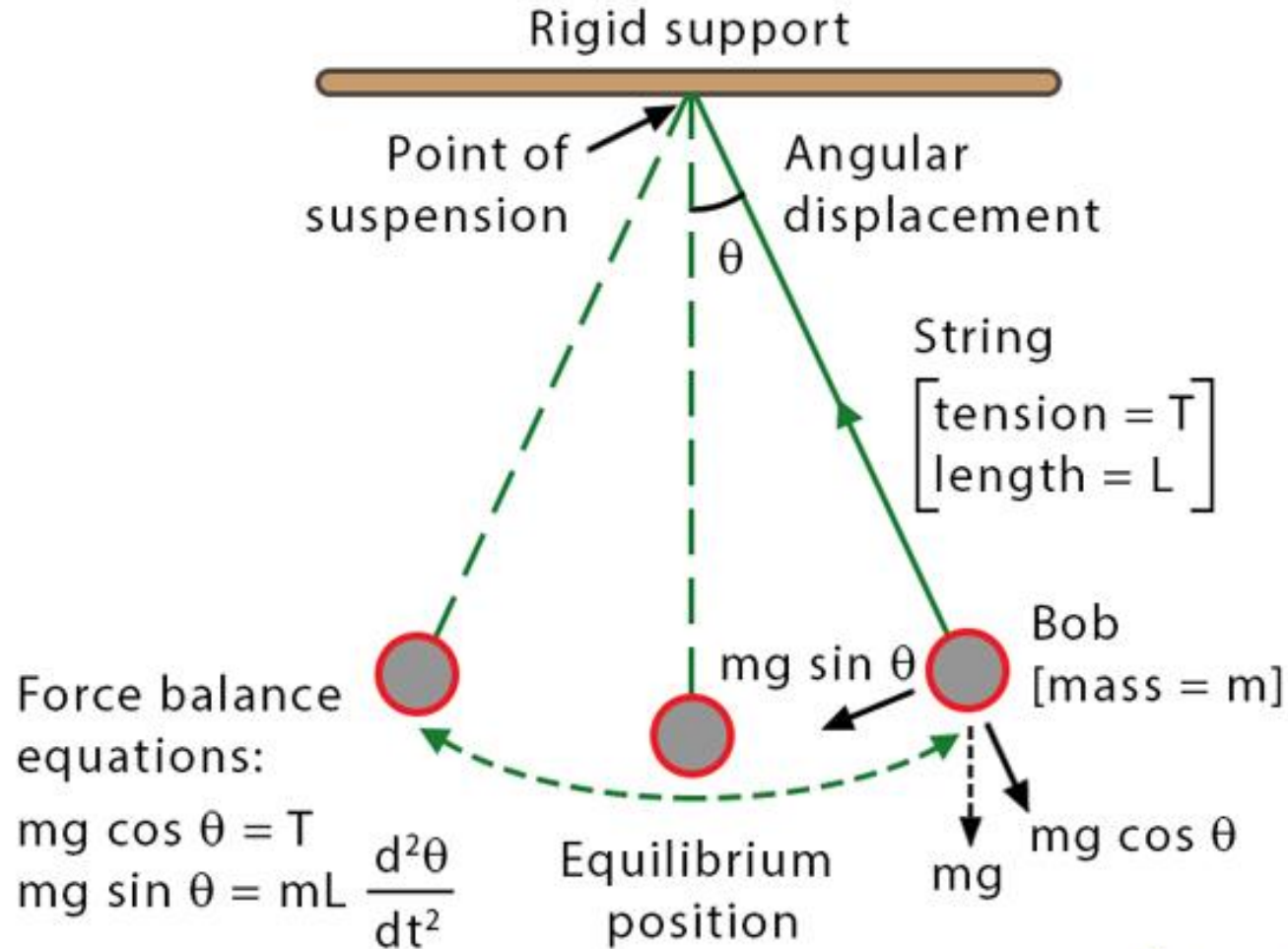


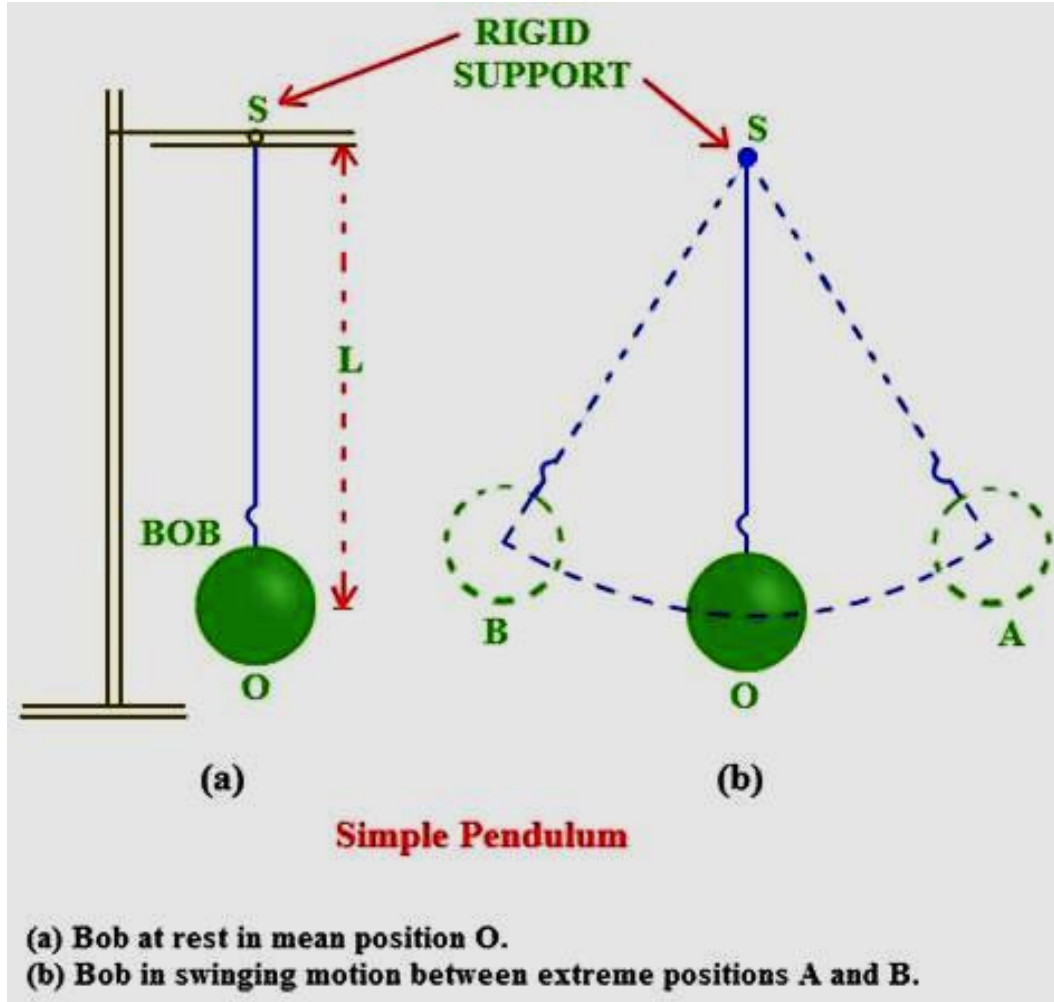
Figure 1: Variation of g inside, on the surface and outside of the earth.

Simple Pendulum



Simple pendulum is an arrangement of a metal bob attached by a light string and suspended vertically from a fixed support.

Simple Pendulum: Length and Time Period



Length, L :

Distance between the point of suspension to the mid point of the bob (point of oscillation).

Time Period, T :

Time to complete one oscillation.

Relationship:

$$T = 2\pi \sqrt{\frac{L}{g}}$$

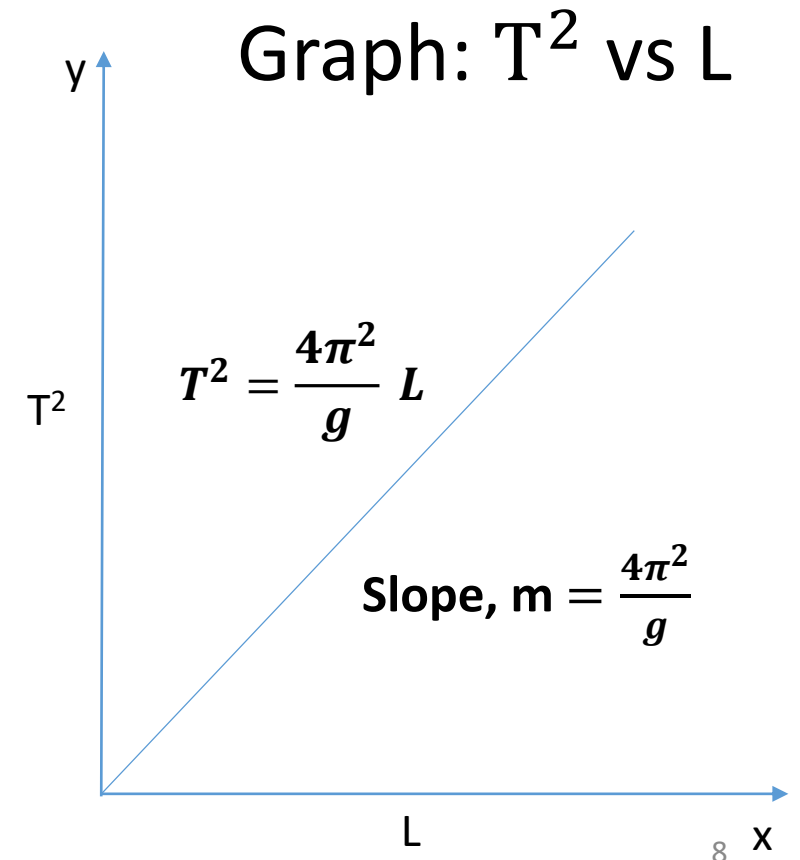
- The time period equation of a simple pendulum can be rearranged as

$$T^2 = \frac{4\pi^2}{g} L$$

- Comparing this equation with the state line equation that goes through the origin ($y = mx$) the value of acceleration due to gravity can be determined by

$$g = \frac{4\pi^2}{m}$$

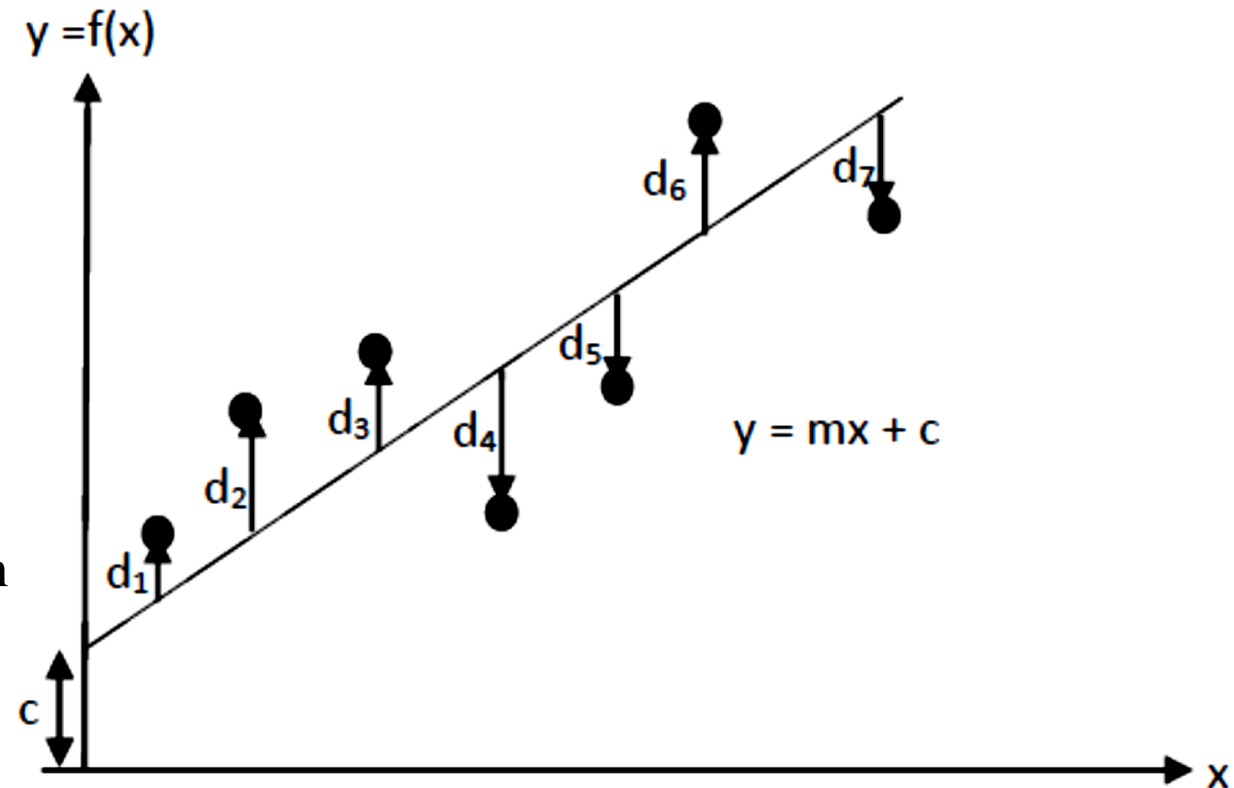
where m is the slope of the T^2 vs L graph.



Theory: Linear Least Square Regression Method

- For two types (independent and dependent) of variables x and $y = f(x)$ the linear least square regression method can be used for N number of data points to find the best fitted line (regression line) as the figure shows.

- Way to get the best fitted line by finding the minimum value of
$$D = d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2 + d_6^2 + d_7^2$$
according to the least square regression method.
The equation for the best fitted line is $y = mx + c$, where m is the slope and c is the interception in the y axis. Here the number of data points is taken as $N=7$.



- The formula for determining the slope of the regression line

$$m = \frac{\sum_i x_i y_i - \frac{(\sum_i x_i)(\sum_i y_i)}{N}}{\sum_i x_i^2 - \frac{(\sum_i x_i)^2}{N}} \quad (\text{slope equation})$$

and intercept $c = \bar{y} - m \bar{x}$, where \bar{x} and \bar{y} are mean value of x and y .

- In the slope equation:

$$\sum_i x_i = x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7,$$

$$\sum_i y_i = y_1 + y_2 + y_3 + y_4 + y_5 + y_6 + y_7,$$

$$\sum_i x_i y_i = x_1 y_1 + x_2 y_2 + x_3 y_3 + x_4 y_4 + x_5 y_5 + x_6 y_6 + x_7 y_7,,$$

$$(\sum_i x_i)^2 = (x_1 + x_2 + x_3 + x_4 + x_5 + x_6 + x_7)^2,$$

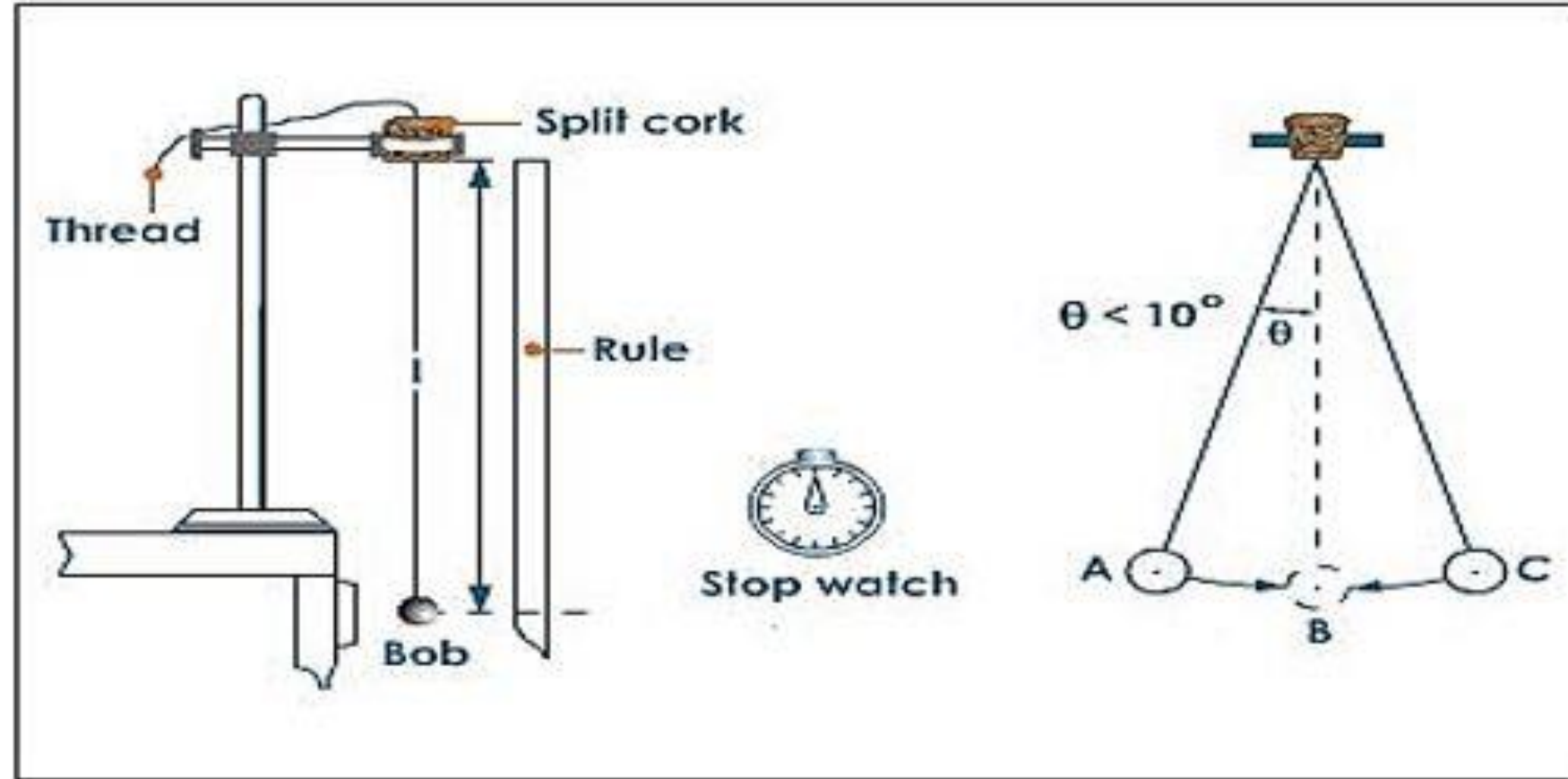
$$\sum_i x_i^2 = x_1^2 + x_2^2 + x_3^2 + x_4^2 + x_5^2 + x_6^2 + x_7^2$$

Apparatus:

- To construct a Simple Pendulum:
Metal bob, a piece of string, stand and clamp.
- Measurement of L & T:
Meter scale and stop watch.



Procedure: Measurement of L and T



- Attach a light piece of string with the hook of the metal bob. Find the length L of the pendulum with a meter scale from the point of suspension to the mid-point of the bob.
- Give a small angle (**less than 10 degrees**) swing to the pendulum. Find the time period, T . To do it, measure the total time for 20 oscillations and divide it by 20. Repeat the procedure for different lengths and record the data in table 1.1.

Procedure: Video Lecture



Experimental Data, Calculation and Result:

- From the sample data collect the data for your group.
- Complete all the column of data table 1.1 in the lab manual.
- Also draw a T^2 vs L graph in Excel.
- Complete all the analysis and calculation part to get the final result.

Discussion on Outcomes of the Lab:

- What is acceleration due to gravity?
- How a simple pendulum can be constructed and what are its criteria?
- How linear least square regression method (LLSRM) can be used to find the regression line? Why we need to learn it?
- How LLSRM method can be used to find slope and intersection for any number of data?
- How acceleration due to gravity can be calculated from the slope of the regression line?

For Further Study:

- **Fundamentals of Physics:** Acceleration due to gravity (Chapter 13, page 360), Simple pendulum (Chapter 15, page 425-426)
- **Video Link:**
 - Simple pendulum: 1. https://www.youtube.com/watch?v=02w9ISii_Hs
2. <https://www.youtube.com/watch?v=bJKEN43695k>
 - LLSRM: 1. https://www.youtube.com/watch?v=0T0z8d0_aY4
2. <https://www.youtube.com/watch?v=1C3olrs1CUw>

Submission of Lab Report:

- To write the lab report, follow strictly the template that have been uploaded.
- Convert the word file of the lab report to pdf and submit it as an assignment in the teams.
- The **deadline** to submit your lab report is the **lab day by 11:59 pm**.