Experiment 1

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

Physics Lab 1

Spring 2021-22

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

Newton's Famous Story

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

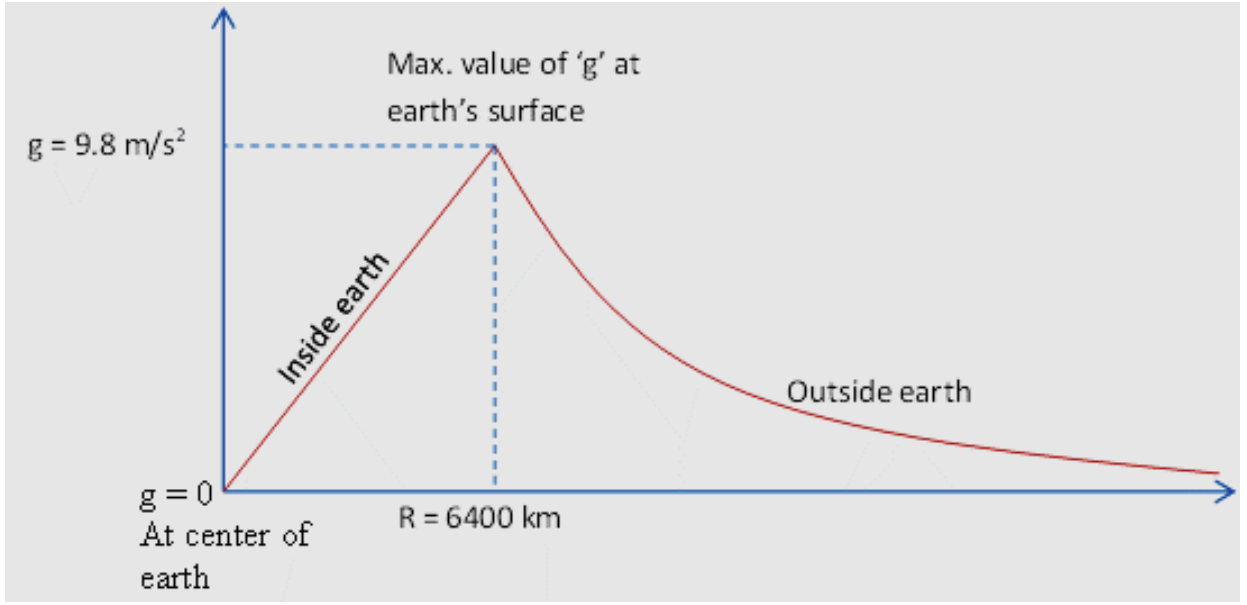
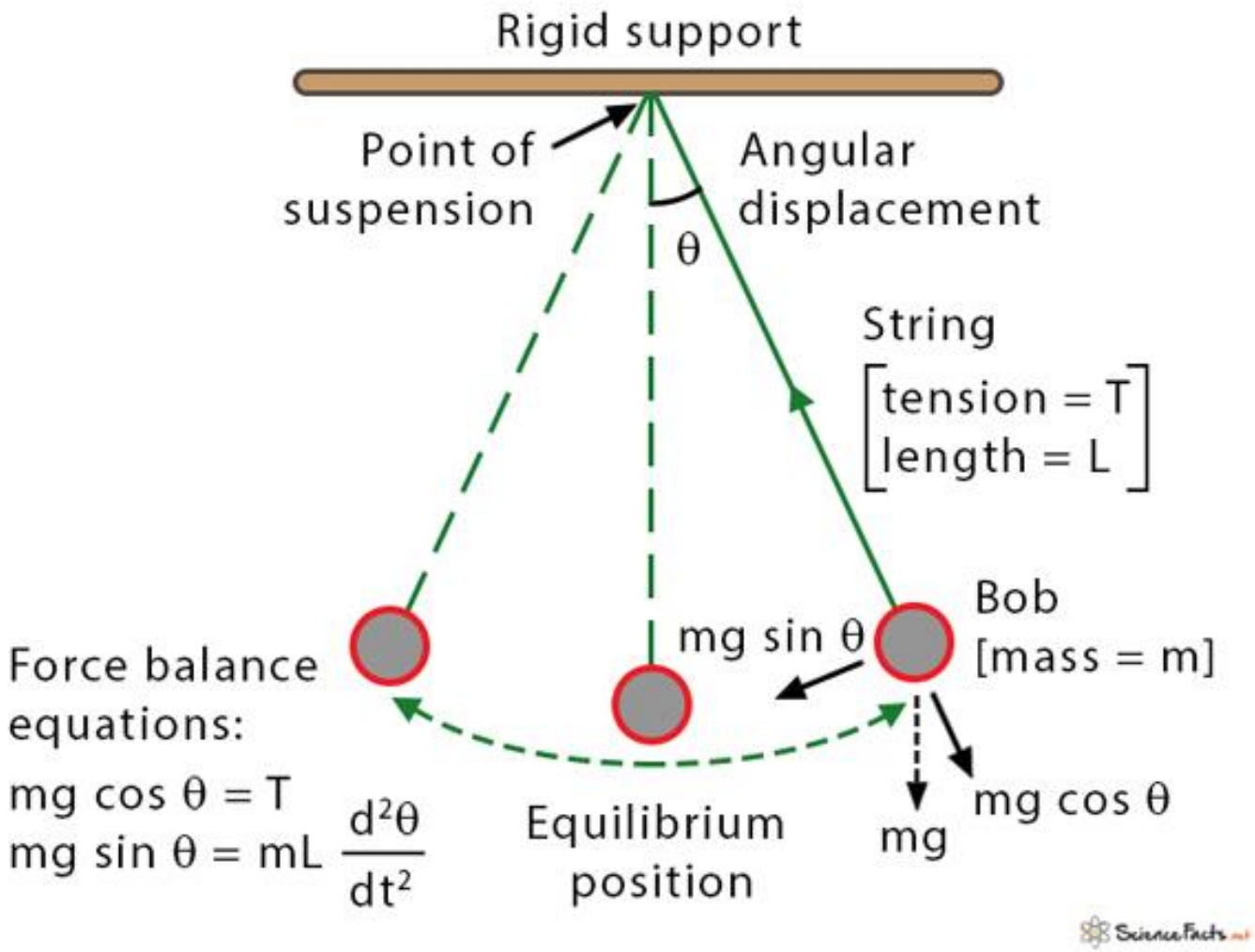


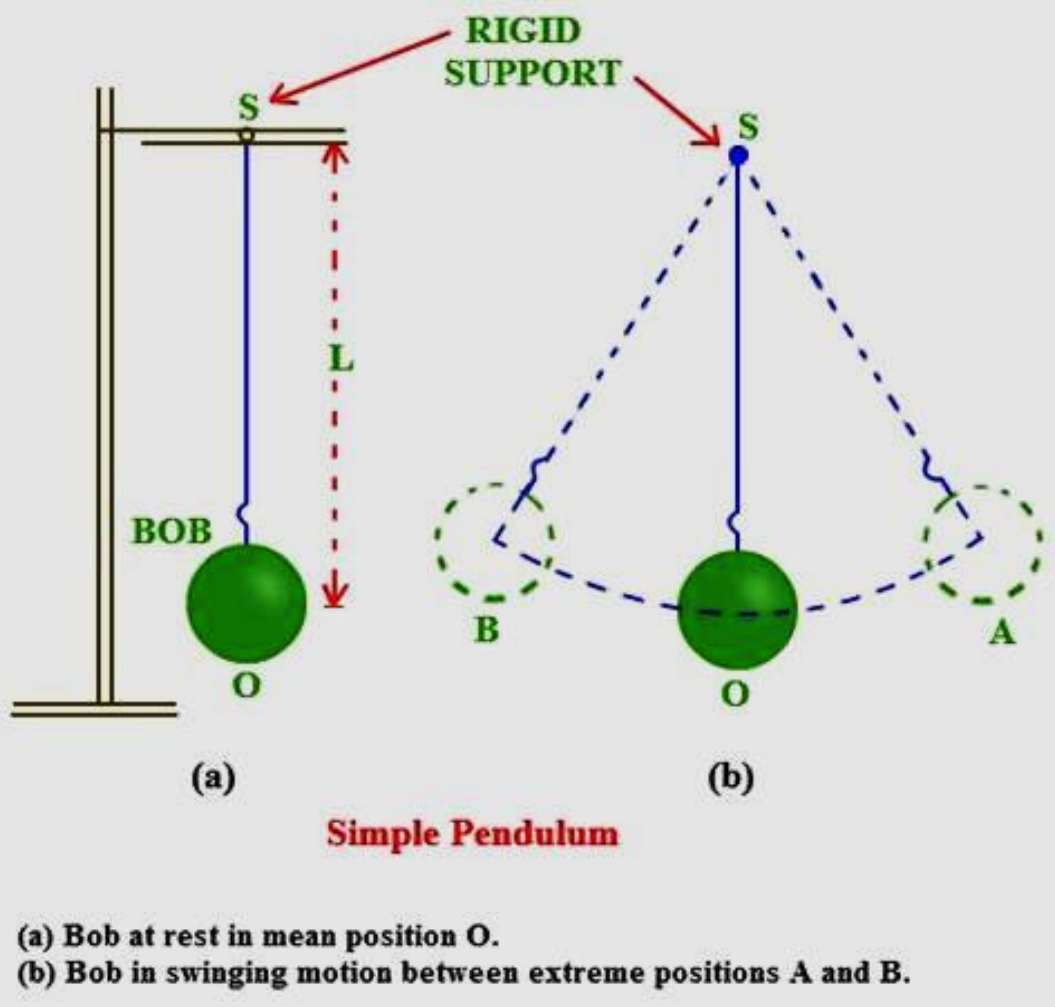
Figure 1: Variation of g inside, on the surface and outside of the earth.

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: Determination of g



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

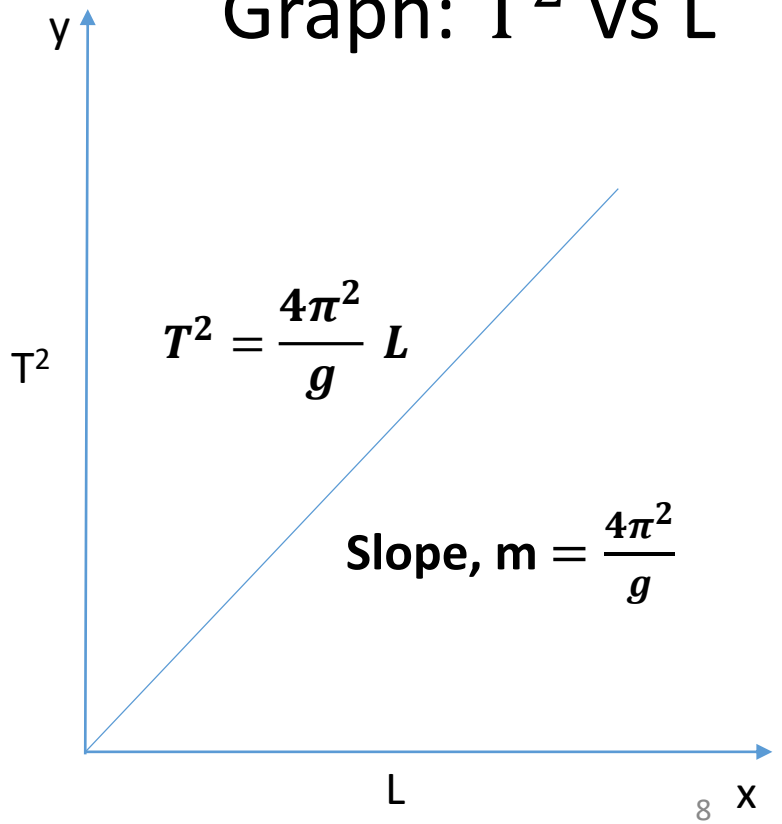
$$T^2 = \frac{4\pi^2}{g} L$$

- 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.

Graph: T^2 vs L



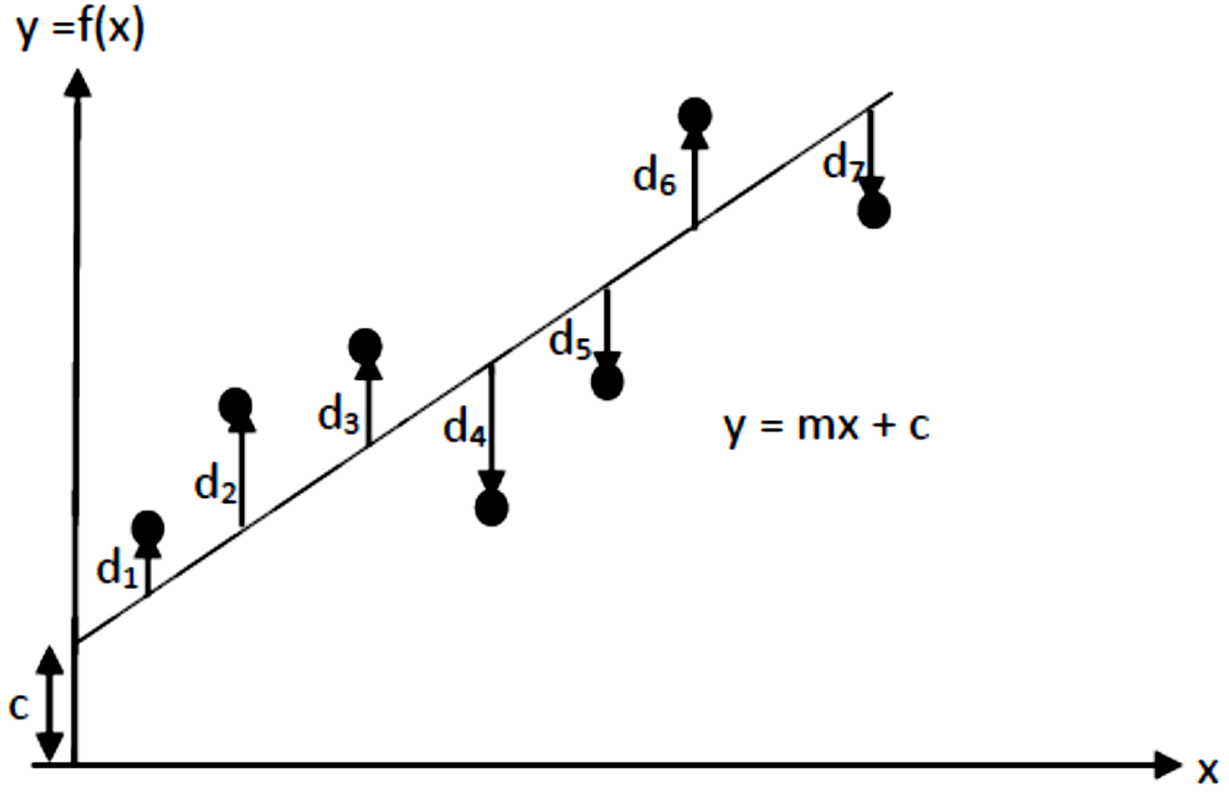
Theory: Linear Least Square Regression Method

- 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

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

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:

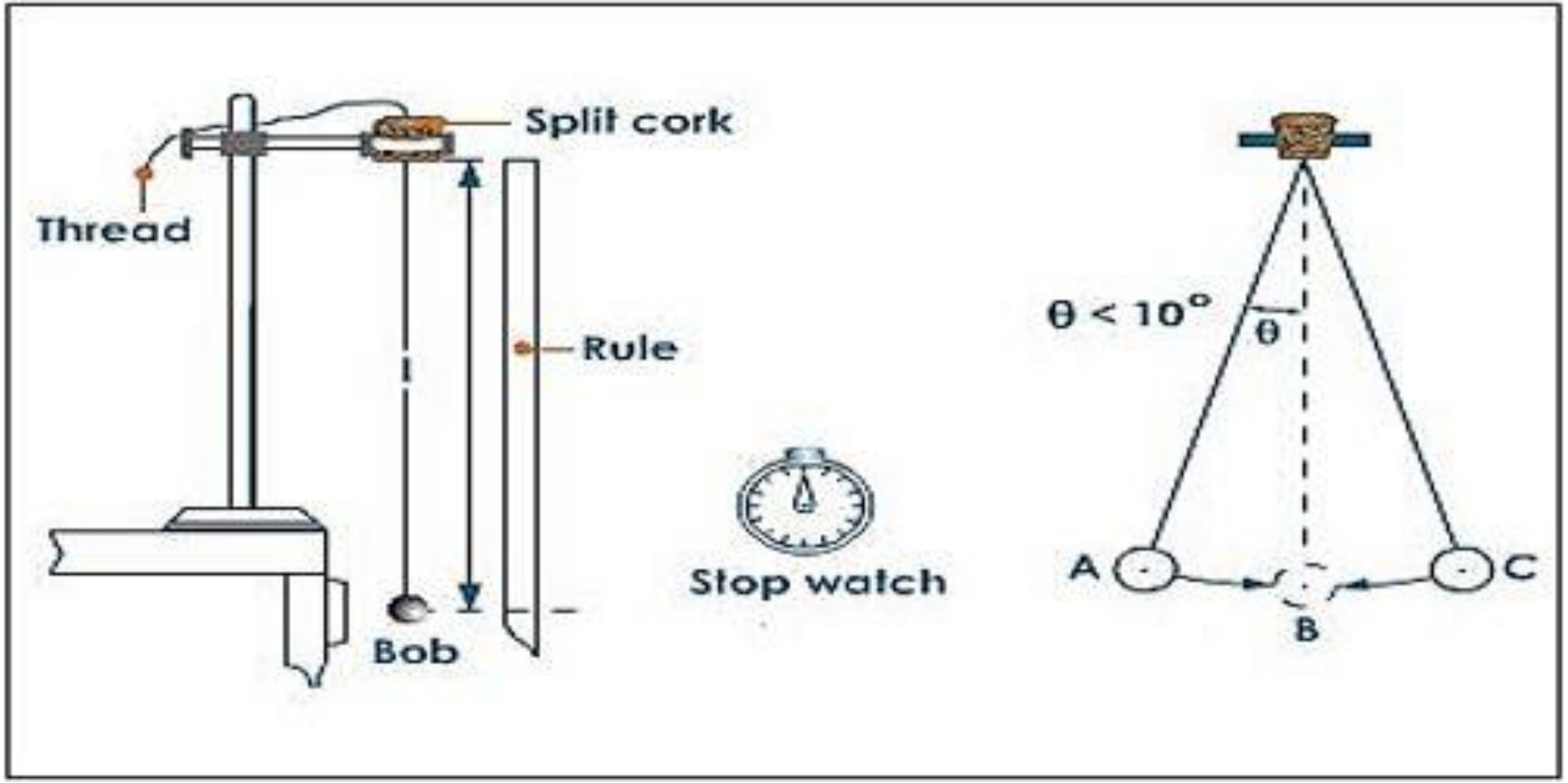
  Metal bob, a piece of string, stand and clamp.

- 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=02w9lSii_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 MS Teams.