AMERICAN INTERNATIONAL UNIVERSITY–BANGLADESH (AIUB)

FACULTY OF SCIENCE & TECHNOLOGY

DEPARTMENT OF PHYSICS

PHYSICS 1 LAB

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LAB REPORT ON

TO DETERMINE THE ACCELERATION DUE TO GRAVITY APPLYING LINEAR LEAST SQUARE REGRESSION METHOD BY USING A SIMPLE PENDULUM

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Submitted By

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2. Mahmuda Khatun	22-47016-1	Procedure and Experimental Data
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4. Md. Abu Towsif	22-47019-1	Theory and Apparatus

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1. Theory

The time period of small-angle oscillation of a simple pendulum (a metal bob attached by a light string and suspended vertically from a fixed support) can be shown to be

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

where L is the effective length (length from the point of suspension to the center of the bob) and time period (time of one complete oscillation) of a simple pendulum, respectively in a place where the acceleration due to gravity is g.

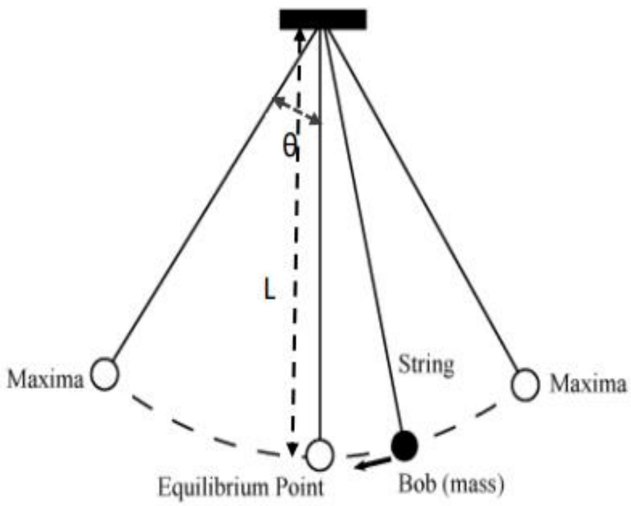

Figure 1: A swinging simple pendulum with an effective length L and amplitude θ

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.

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 fig. 2 shows.

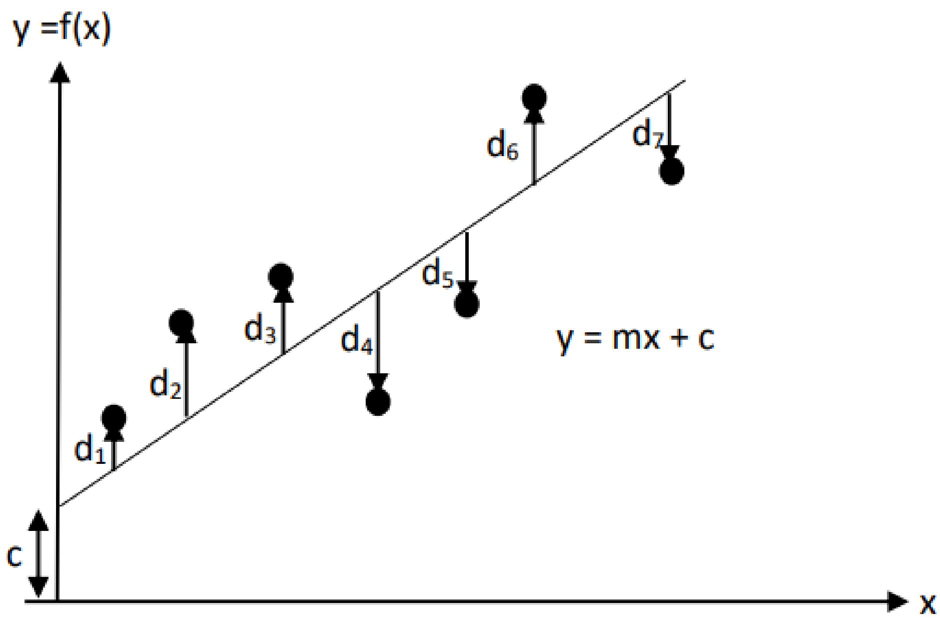

Figure 2: Way to get the best fitted line by finding the minimum value of D = $d_1^2 + d_2^2 + d_3^2 + d_4^2 + d_5^2 + d_6^2 + d_7^2$ according to the least square regression method. The equation for the best fitted line is y = mx + c, where m is the slope and c is the interception in the y axis. Here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

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

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

$\sum_i x_i y_i = x_1y_1 + x_2y_2 + x_3y_3 + x_4y_4 + x_5y_5 + x_6y_6 + x_7y_7$,

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

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

2. Apparatus

- Metal bob
- A piece of string
- Stand
- Clamp
- Meter scale and
- Stop watch

3. Procedure

1. First of all, we attached a light piece of string with the hook of metal bob. Then we found the length ,L of the pendulum with a meter scale from the point of suspension to the mid-point of the bob.
2. We gave a small angle (less than 10 degrees) swing to the pendulum and found the time period, T. To do it, we measure the total time for 20 oscillation and divide it by 20. Then repeated the procedure for different lengths and record the data in table 1 .
3. After that we found the regression line and from the value of slope found g from the relation: slope=$4\pi^2/g$.
4. At last we plotted the same graph in Excel and also found the value of g from the equation of the graph

5. Experimental Data

No. of Obs.	Effective Length L (cm)	Time for 20 Oscillations t (s)	Time period T = t/20 (s)	T^2 (s^2)	L^2 (cm^2)	$L.T^2$ ($cm.s^2$)
1	150	48.52	2.426	5.885	22500	882.75
2	140	46.78	2.339	5.471	19600	765.94
3	130	45.38	2.269	5.148	16900	669.24
4	120	43.81	2.190	4.796	14400	575.52
5	110	42.66	2.133	4.550	12100	500.5
6	100	39.78	1.989	3.956	10000	395.6
7	90	38.21	1.910	3.648	8100	328.32
$\sum$	840	-	-	33.454	103600	4117.87

Table 1 : Time periods T for different lengths L of the simple pendulum

6. Analysis and Calculation

N	$\sum_i x_i$	$\sum_i y_i$	$\sum_i x_i y_i$	$(\sum_i x_i)^2$	$\sum_i x_i^2$	m	c
7	840	33.454	4117.87	705600	103600	0.369	0.351
Equation : y = mx + c y = 0.0369x + 0.351							

Table 2: Finding the slope, m and intercept, c by using the linear least square regression method

A. The value of g using the LLSRM

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

$$= \frac{4117.87 - \frac{840 * 33.454}{7}}{103600 - \frac{705600}{7}}$$

$$= 0.0369$$

$$\bar{x} = \frac{\sum_i x_i}{N} = \frac{840}{7} = 120$$

$$\bar{y} = \frac{\sum_i y_i)}{N} = \frac{33.454}{7} = 4.779$$

Intercept, c = $\bar{y} - m\bar{x}$ = 0.351

Acceleration due to gravity by LLSRM, $g_L = \frac{4\pi^2}{m} = \frac{4*(3.14)^2}{0.0369}$ = 1068.79 cm/s^2 = 10.687 m/s^2

B. The value of g from the graph of Excel:

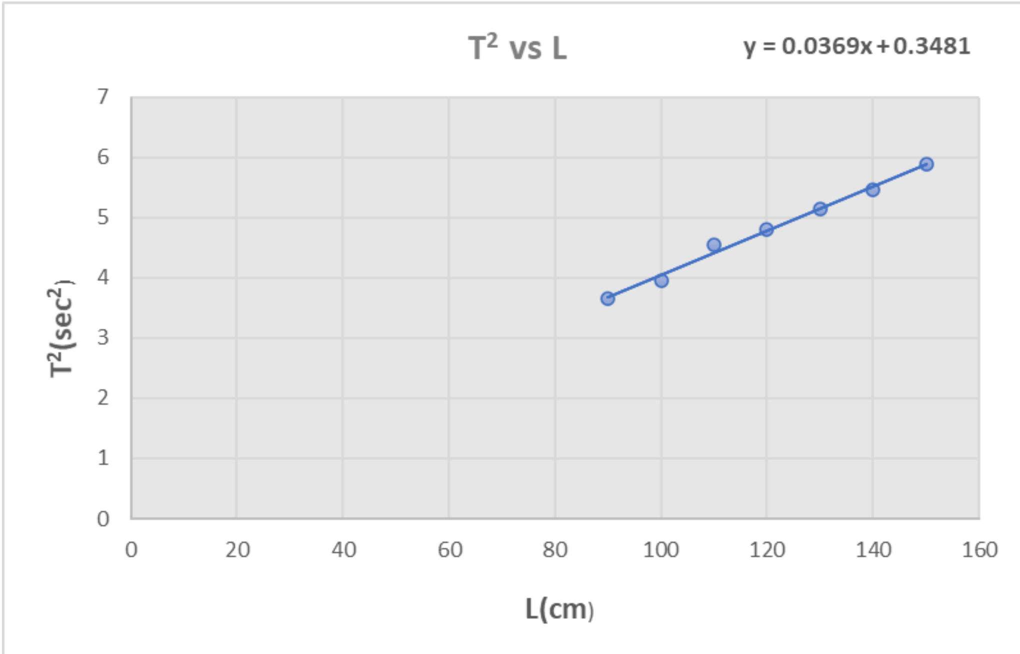

Figure 3: Graph of excel

Slope of the regression line, m = 0.0369

Acceleration due to gravity by Excel, $g_E = \frac{4\pi^2}{m} = \frac{4*(3.14)^2}{0.0369}$ = 1068.79 cm/s^2 = 10.687 m/s^2

C. Percentage of difference in g between Excel and LLSRM: $\frac{g_E \sim g_L}{g_E} \times 100$

$= \frac{1068.79 \sim 1068.79}{1068.79} \times 100$

= 0 %

7. Result

Method	**Value of g (m/s^2)**	**Comment**
LLSRM	10.687 m/s^2	The percentage of difference in g between Excel and LLSRM is 0%
Excel	10.687 m/s^2	

8. Discussion

We found the value of g (acceleration due to gravity) is 10.687 $m.s^{-2}$ through LLSRM method as well as 10.787 $m.s^{-2}$ through the excel graph. We can see that the values are same if we consider three digits after decimal. But we found the values of intercept c different. The value of intercept c is 0.351 through LLARM method where we found 0.3481 in the excel graph.

While measuring the oscillation of the bob, we had to make sure that the bob was moving freely. Sometimes the bob might not move freely because of some frictional problem. Also there might be some error while measuring the bob by slide calipers. We also should make sure that stand was properly straight.

9. References

- **Video Links**:
  - 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=1C3olrs1CU