AMERICAN INTERNATIONAL UNIVERSITY–BANGLADESH (AIUB)

FACULTY OF SCIENCE & TECHNOLOGY

DEPARTMENT OF PHYSICS

PHYSICS LAB 2

Summer 2020-2021

Section: X , Group: 07

LAB REPORT ON

To determine the acceleration due to gravity by means of a compound pendulum

Supervised By

Dr. Md. Nurul Kabir Bhuiyan

Submitted By

Name	ID	Contribution
1. Md. Fahtin Emtiaz Onik	19-40471-1	Introduction/Theory
2. Nafinur Leo	20-42195-1	Apparatus & Procedure
3. S.M. Ashikur Rahman	20-42833-1	Experimental Data (graph), Data Tables 2 & Discussion
4. S.M. Hosney Arafat Rizon	20-43019-1	Calculation, Result & References
5.		

Date of Submission: **June 6, 2021**

TABLE OF CONTENTS

1. Introduction/Theory

Bar Pendulum:

The bar pendulum consists of a metallic bar of about one meter long. A series of circular holes each of approximately 5 mm in diameter are made along the length of the bar. The bar is suspended from a horizontal knife-edge passing through any of the holes (Fig.). The knife edge, in turn, is fixed in a platform provided with the screws. By adjusting the rear screw, the platform can be made horizontal.

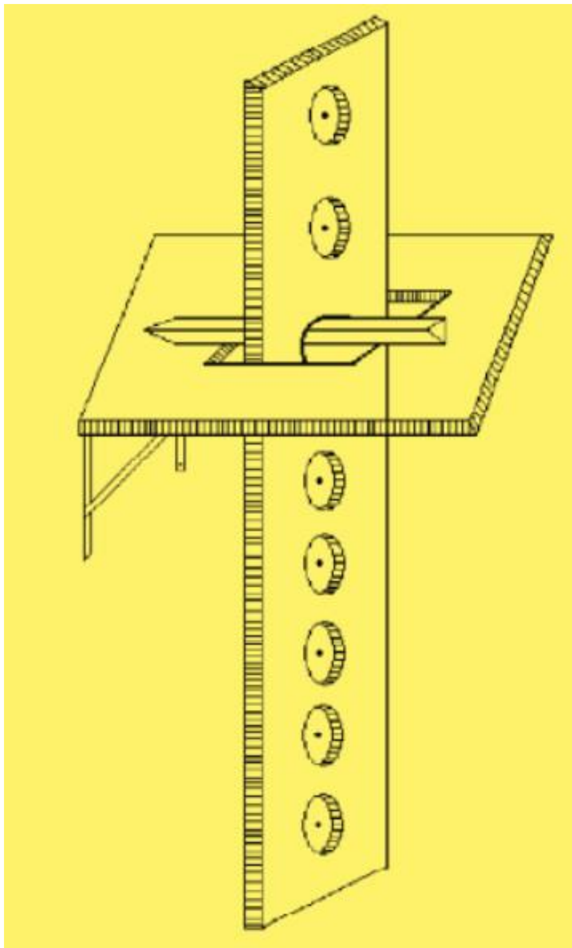


Fig: Bar Pendulum

A simple pendulum consists of a small body called a “bob” (usually a sphere) attached to the end of a string the length of which is great compared with the dimensions of the bob and the mass of which is negligible in comparison with that of the bob. Under these conditions the mass of the bob may be regarded as concentrated at its center of gravity, and the length of the pendulum is the distance of this point from the axis of suspension. When the dimensions of the suspended body are not negligible in comparison with the distance from the axis of suspension to the center of gravity, the pendulum is called a compound, or physical, pendulum. A rigid body mounted upon a horizontal axis so as to vibrate under the force of gravity is a compound pendulum. In Fig. a body of irregular shape is pivoted about a horizontal frictionless axis through P and is displaced from its equilibrium position by an angle θ. In the equilibrium position the center of gravity G of the body is vertically below P. The distance GP is l and the mass of the body is m. The restoring torque for an angular displacement θ is

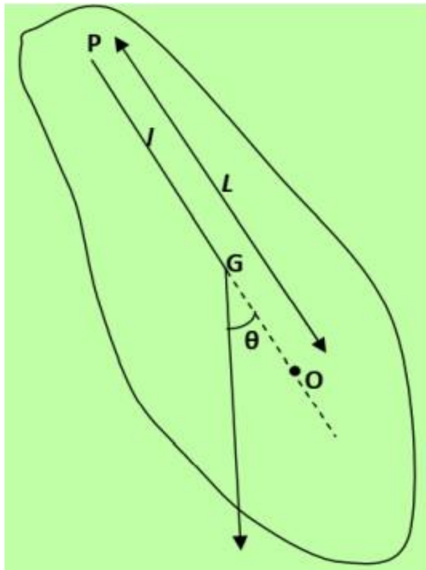


Fig. 1

τ = - mg I sinθ ... ...(1)

For small amplitudes ($\theta \approx \theta$),

$$I\frac{d^2\theta}{d^2t} = —mgl\theta, \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(2)$$

where I is the moment of inertia of the body through the axis P.

Eq. (2) represents a simple harmonic motion and hence the time period of oscillation is given by

$$T = 2\pi\sqrt{\frac{I}{-mgl}}. \ldots\ldots\ldots\ldots..(3)$$

Now $I = I_G + m1^2$, where IG is the moment of inertia of the body about an axis parallel with axis of oscillation and passing through the center of gravity G.

$I_G = mK^2$ ……………(4)

where K is the radius of gyration about the axis passing through .

$$T = 2\pi\sqrt{\frac{mK^2 + ml^2}{mgl}} = 2\pi\sqrt{\frac{\frac{k}{l}+l}{g}} \quad \ldots \ldots \ldots \ldots \ldots \ldots \ldots .. (5)$$

The time period of a simple pendulum of length L is given by

$$T = 2\pi\sqrt{\frac{L}{g}} \quad \ldots\ldots\ldots\ldots(6)$$

Comparing with Eq. (5) we get

$$L = l + \frac{K^2}{l} \quad \ldots\ldots\ldots\ldots\ldots\ldots(7)$$

This is the length of "equivalent simple pendulum". If all the mass of the body were concentrated at a point O (See Fig. l) such that $OP = \frac{K^2}{l} + l$, we would have a simple pendulum with the same time period.

The point O is called the 'Centre of Oscillation'. Now from Eq. (7)

$l^2 - lL + K^2 = 0$ ………………………..(8)

i.e. a quadratic equation in *l*. Equation 6 has two roots l_1 and l_2 such that

$$l_1 + l_2 = L$$

and

$$l_1 l_2 = K^2 \quad \ldots\ldots\ldots\ldots..(9)$$

Thus, both l_1 and 1_2 are positive. This means that on one side of C.G there are two positions of the center of suspension about which the time periods are the same. Similarly, there will be a pair of positions of the center of suspension on the other side of the C.G about which the time periods will be the same. Thus, there are four positions of the centers of suspension, two on either side of the C.G, about which the time periods of the pendulum would be the same. The distance between two such positions of the centers of suspension, asymmetrically located on either side of C.G, is the length *L* of the simple equivalent pendulum. Thus, if the body was supported on a parallel axis through the point O (see Fig. l), it would oscillate with the same time period T as when supported at P. Now it is evident that on either side of G, there are infinite numbers of such pair of points satisfying Eq. (9). If the body is supported by an axis through G, the time period of oscillation would be infinite. From any other axis in the body the time period is given by Eq. (5).

From Eq.(6) and (9), the value of g and K are given by

$$g = 4\pi \frac{L}{T^2} \quad \ldots\ldots\ldots\ldots\ldots\ldots.(10)$$

$$k = \sqrt{l_1 l_2} \quad \ldots\ldots\ldots\ldots\ldots\ldots...(11)$$

By determining L, 1_1 and 1_2 graphically for a particular value of T, the acceleration due to gravity g at that place and the radius of gyration *K* of the compound pendulum can be determined.

2. Apparatus

(i) A bar pendulum

(ii) A knife–edge with a platform

(iii) A precision stopwatch

(iv) A meter scale

(v) A small metal wedge

3. Procedure

(i) We have suspended that bar using the knife edge of the hook through a hole nearest to one end of the bar.

(ii) After then we allowed the bar to oscillate in a vertical plane with small amplitude (within 4^0 of arc).

(iii) We noted the time for 20 oscillations by a precision stopwatch by observing the transits of the vertical line on the bar through the telescope. Make this observation for three times and got the mean time t for 20 oscillations and also determine the time period T.

(iv) We also measured the distance d of the axis of the suspension, i.e. the hole from one of the edges of the bar by a meter scale.

(v) We repeated the operation (i) to (iv) for the other holes till center of gravity (C.G) of the bar is approached where the time period becomes very large.

(vi) Starting from the extreme top we inverted the bar and repeating operations (i) to (v) for each hole.

(vii) Finally, we have to draw a graph with the distance d of the holes as abscissa and the time period T as ordinate. Then the nature of graph will be as shown in Fig.

4. Experimental Data

Table 1: Observation for the time period and the distance of the point of suspension from CG for End- A.

Hole no	**Distance From CG L (cm)**	**Time for 20 Oscillation (s)**	**Mean time t (s)**	**Period T = t / 20 (s)**
1	45	(1) 25.27 (2) 23.72	24.495	1.633
2	40	(1) 23.03 (2) 23.09	23.06	1.588
3	35	(1) 22.90 (2) 22.91	22.905	1.517
4	30	(1) 22.76 (2) 22.33	22.545	1.503
5	25	(1) 22.48 (2) 22.85	22.665	1.511
6	20	(1) 22.34 (2) 23.11	22.725	1.545
7	15	(1) 22.06 (2) 23.50	22.78	1.583

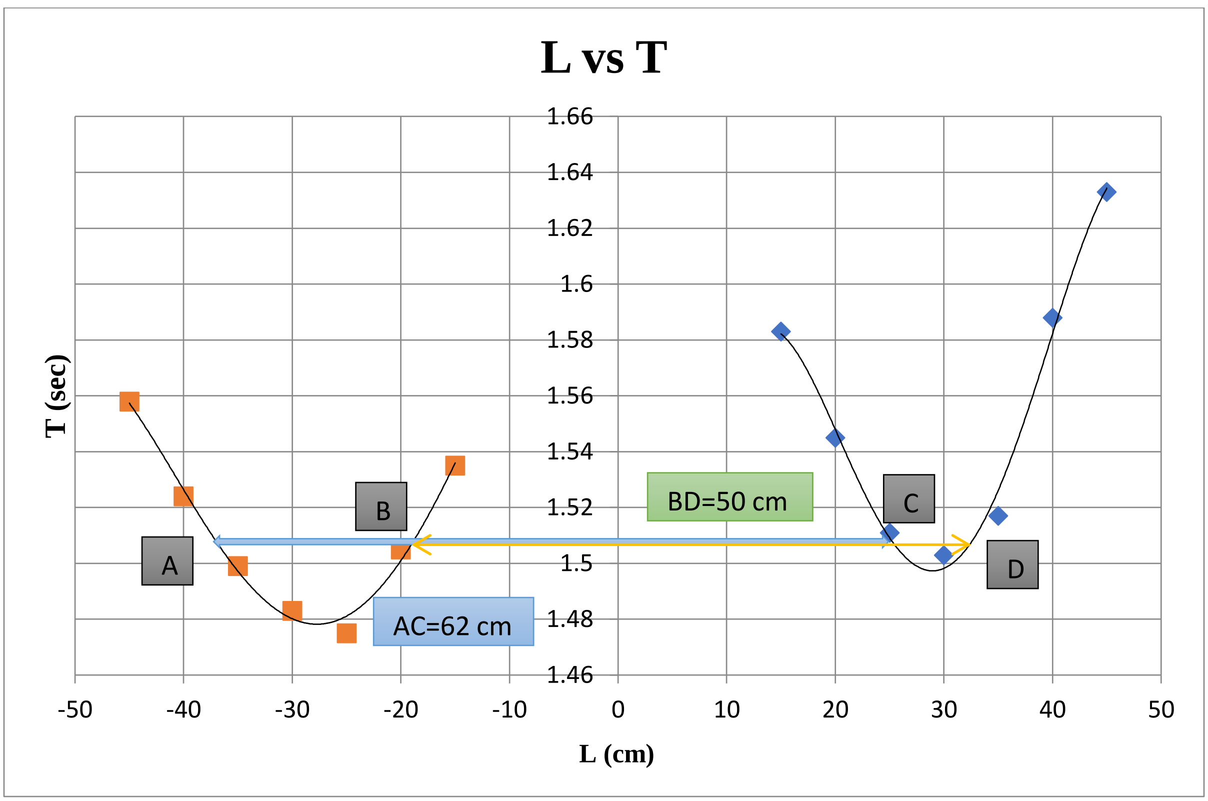
Table 2: Observation for the time period and the distance of the point of suspension from CG for End- B.

Hole no	**Distance From CG L (cm)**	**Time for 20 Oscillation (s)**	**Mean time t (s)**	**Period T = t / 20 (s)**
1	45	(1) 23.34 (2) 23.40	23.37	1.558
2	40	(1) 22.92 (2) 22.82	22.87	1.524
3	35	(1) 22.52 (2) 22.45	22.485	1.499
4	30	(1) 22.36 (2) 22.14	22.15	1.483
5	25	(1) 23.19 (2) 23.51	22.85	1.475
6	20	(1) 23.45 (2) 22.57	23.01	1.505
7	15	(1) 23.23 (2) 23.06	23.145	1.535

We drew the horizontal line ABCDE parallel to the X-axis. Here A,B,D and E represent the point of intersections of the line with the curves. Also noted that the curves are symmetrical line which meets the X-axis at the point G which gives the position of the C.G of the bar. This vertical line intersects with the line ABCDE at C. Determine the length AD and BE and find the length L of the equivalent simple pendulum from L= $\frac{AD+BE}{2} = \frac{L_X}{2}$.

We also find the time period T corresponding to the line ABCDE and then compute the value of g, drew several horizontal lines parallel to X- axis and adopting the above procedure get the value of g for each horizontal line . Then we calculated the mean value of g. Alternatively for each horizontal line obtain the value of L and T and draw a graph with T^2 as abscissa and L as ordinate. The graph would be a straight line. By talking a convenient point on the graph g may be calculated.

Similarly, to calculate the value of K, determine the length AC,BC or CD,CE of the line ABCDE and compute $\sqrt{AC \text{ X } BC}$ or$\sqrt{CDX\ CE}$ .Repeat the procedure for each horizontal line. Find the mean of all K.



5. Analysis and Calculation

From the T vs L graph:

Length AC = 62 cm; Length BD = 50 cm

Mean length, L = $\frac{AC+BD}{2} = \frac{62+50}{2}$ = 56 cm

Equivalent length of compound pendulum, L = 56 cm

Equivalent time period of compound pendulum, T = 1.50 sec.

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

$= 982.574\ cm/s^2$

6. Result

The acceleration due to gravity is $982.574\ cm/s^2$

7. Discussion

1. We ensured that the pendulum oscillates in a vertical plane and that there is no rotational motion of the pendulum.
2. The amplitude of oscillation should remain within 4 of arc.
3. We use a precision stop watch and note the time accurately as far as possible.
4. We make sure that there is no air current in the vicinity of the pendulum.

8. References

1. Fundamentals of physics: Resnick & Halliday
2. Practical physics: R.K.Shukla, Anchal Srivatasa, New age International (p) ltd,New Delhi
3. Eric J.Irons, America Journal of Ohysics Vol, Issue 5,pp.426(1947)