EAST WEST UNIVERSITY

Physics Lab

Department of MPS

Course Name: Engineering Physics -1

Course Code : PHY 109 LAB

Section No :

Group No :

Experiment No :

Name of the Experiment:

Date of allocation :

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Submitted To :

Student's ID :

Student's Name:

Name of the Experiment:

To determine the value of **g**, the **acceleration due to gravity** by means of a **compound pendulum.**

Theory :

Compound pendulum is a rigid body of any shape free to turn about a horizontal axis. In the figure-1, let **O** be the point of suspension of the body (compound pendulum) through which passes a horizontal axis, perpendicular to the plane of paper, about which the body oscillates. Point **G** is the center of gravity of the body. Let the body be displaced through an angle θ. Then the couple acting on the body due to its weight Mg will obviously, be $Mgl\sin\theta$, tending to bring back into its original position (vertical position). Where l = **OG.**

If the angular acceleration produced in the body by this couple be $\frac{d\omega}{dt}$, the couple will also be equal to $I\frac{d\omega}{dt}$, where I is the Moment of inertia of the body about an axis through the point of Suspension and perpendicular to the plane of paper.

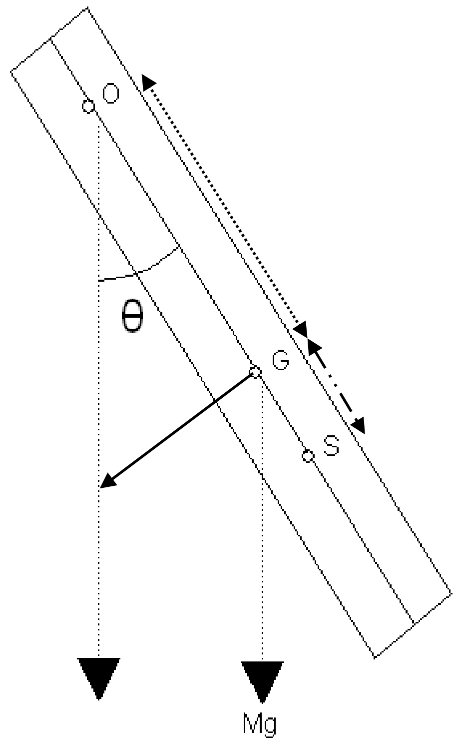


Figure –1: Compound Pendulum

So that, $I\frac{d\omega}{dt} = -Mgl\sin\theta = -Mgl\theta$ ……………….(1) ; [θ being small]

Or , $\frac{d\omega}{dt} = -\frac{Mgl\theta}{I} = -\mu\theta$ …………………………….(2)

Thus , the angular acceleration ($\frac{d\omega}{dt}$) of the body is proportional to its angular displacement(θ). The body, therefore, executes a S.H.M. For S.H.M. we know that

Acceleration = $-\omega^2$ × displacement …………………………….(3)

From equation (2) and (3), we have

$\omega^2 = \frac{Mgl}{I}$ or, $\left(\frac{2\pi}{T}\right)^2 = \frac{Mgl}{I}$, therefore, $T = 2\pi\sqrt{\frac{I}{Mgl}}$ ……………….(4)

If **K** is the radius of gyration of the pendulum about an axis through **G** parallel to the axis of oscillation through **O**, from the Parallel Axes Theorem,

$$I = M(k^2 + l^2)$$

And so $T = 2\pi\sqrt{\frac{k^2 + l^2}{gl}} = 2\pi\sqrt{\frac{\frac{k^2 + l^2}{l}}{g}}$ ……………………………………(1)

Since the periodic time of a simple pendulum is given by

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

The period of the rigid body (compound pendulum) is the same as that of a simple pendulum length

$$L = \frac{k^2 + l^2}{l}$$

This length L is known as the length of the **simple equivalent pendulum**. The expression for **L** can be written as a quadratic equation in (*l*). Thus from (2),

$$L^2 - l\,L + k^2 = 0 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

This gives two values of ***l*** **(** l_1 and l_2 **)** for which the body has equal times of vibration(time period). From the theory of quadratic equation,

$$l_1 + l_2 = L \quad \text{and} \quad l_1.l_2 = k^2$$

As the sum and product of two roots are positive, the two roots are both positive. This means that there are two positions of the center of suspension on the same side of center of gravity (**C.G**.) about which the periods (**T**) would be same.

Similarly there will be two more points of suspension on the other side of the **C. G.,** about which the time periods (**T)** will again be the same. Thus, there are altogether four points, two on either side of the **C.G.,** about which the time periods of the pendulum are the same (**T**).
The distance between two such points, asymmetrically situated on either side of the **C. G**., will be the length (**L**) of the simple equivalent pendulum. If the length OG in figure 1, is l_1 and we measure the length

$GS = \frac{k^2}{l_1}$, along OG produced, then obviously $\frac{k^2}{l_1} = l_2$

Or, $\quad OS = OG + GS = l_1 + l_2 = L$

The period of oscillation about either **O or S** is the same.
The point **S** is called the center of oscillation. The points **O and S** are interchangeable i.e., when the body oscillates about **O or S**, the time period is the same. If this period of oscillation is **T**, then from the expression.

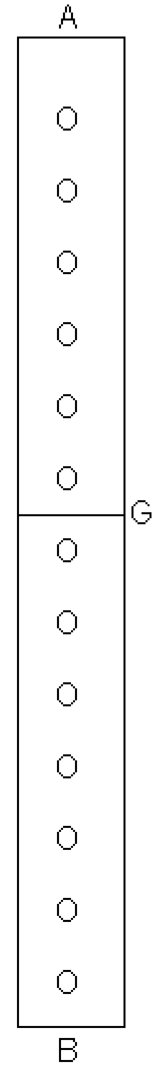
$T = 2\pi\sqrt{\frac{L}{g}}$ we get, $g = 4\pi^2 \cdot \frac{L}{T^2}$

By finding **L** graphically and determining the value of the period **T**, the acceleration due to gravity **(g)** at the place of the experiment can be determined.

<u>Apparatus:</u> A bar pendulum, a small metal nail, a sprit level, stopwatch, and a prism

Description of the apparatus :

The apparatus used in the laboratory is a rectangular bar AB of wood about 1 meter long. A series of holes is drilled along the bar at intervals of **5** cm (Figure – 2). By inserting the metal nail in one of the holes the bar may be made to oscillate.



Procedure :

(i) Find out the position of center of gravity G of the bar (meter scale) by balancing it on the prism. Write this value in (A) of **data sheet.**

(ii) Label one end of the bar as **end A** and other end as **end B**. Insert the metal nail in the first hole of the bar towards **end A** and place the nail on the support so that the bar can turn round(oscillate) the support.

(iii) Set the bar to oscillate taking care to see that the amplitude of oscillations is not more than 5°. Determine the time for 30 oscillations by counting the oscillations when the line AB passes the equilibrium position of the oscillation.**[** Suppose the pendulum has passed the equilibrium position (the position of the pendulum when it is at rest) so **time period** is the time taken by the pendulum to pass the equilibrium position again in the same direction.**]** Write this value in table (**B)** of **data sheet.**

(iv) Measure the length from the **end A** of the bar to the top of the **first hole** i.e., up to the point of suspension of the pendulum. Write this value in **(B)** of **the data sheet.**

(v) In the same way, suspend the bar at **holes 2**, and take time for **30 oscillations**. Also measure distance from the **end A** for **hole 2**. Write this value in **(B)** of **the data sheet.**

(vi) Do the same thing for holes numbers **3, 4,5,6,7 and 8**. Write this value in **(B)** of **data sheet. Don't need** to use holes numbers **9, 10 and 11**.

(vii) Now do the same thing for hole numbers **12, 13, 14, 15, 16, 17,18and 19**. For **12** numbers hole reverse the meter rule so that the **end B** is now on the **top**. But continue measuring distances from the point of suspension (hole) to the **end A.**

(viii) Now calculate the time-period **T** from the time recorded for **30** oscillations. On a nice and large graph paper, plot a curve with **length** (distance of hole from end A) as abscissa (**X-axis**) and **period T** as ordinate (**Y-axis**).

(ix) Through the point on the graph paper corresponding to the center of gravity of the bar (at 50 cm), draw a vertical line. Draw a second line **ABCDE** parallel to the abscissa **(X-axis)** which will cut the graph at points **A, B, D and E**. **AD** or **BE** is the length of the equivalent simple pendulum i.e., $\mathbf{L = l_1 + (k^2/ l_1)}$. **AC** = l_1 **and CD** = $(k^2/l_1) = l_2$. **D** being the center of oscillation. Similarly, $CE = l_1$ *and* $CB = (k^2/ l_1) = l_2$, **B** being the center of oscillation. From this, $\mathbf{g = 4\pi^2 (L/T^2)}$ can be calculated.

(x) By drawing another line **A'B'C'D' E'** calculate another value of **g**.

Data Sheet:

(A) Center of gravity of the meter scale =…………………cm

(B) Table for the **time period T** and the **distance** of the **point of suspension** from **end A**.

	Hole No From **end A**	Distance from **end A** l cm	Time for **30** oscillations t sec	Mean Time Period $T = t / 30$ Sec
End A	1	5		
	2	10		
	3	……		
	4	…		
	5	…		
	6	…		
	7	…		
	8	40		
End B				
	12	60		
	13	65		
	14	…		
	15	…		
	16	…		
	17	….		
	18	90		
	19	95		

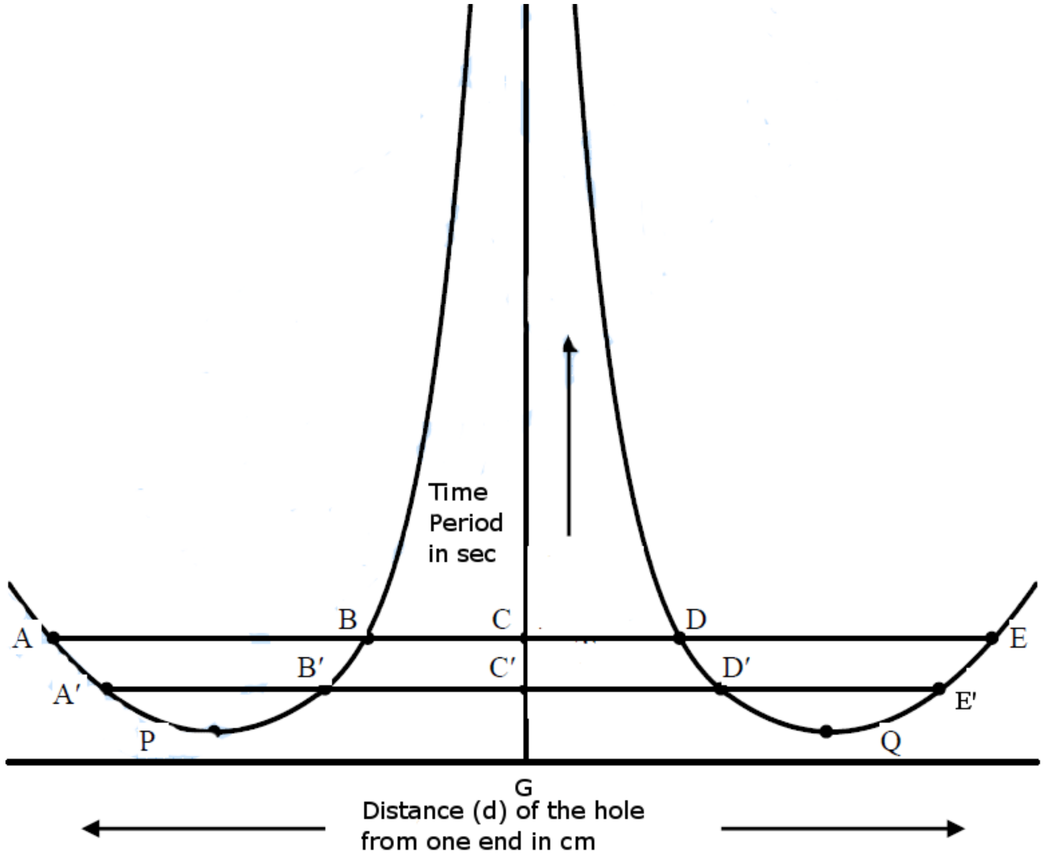


Figure: Graph of time period against distance

Calculation:

Method of measuring length (L):
(From graph)

Length, **AD** = ...…………. cm.

Length, **BE** = …………….. cm.

Mean length, **L** = **(AD+BE) / 2** =………………………cm = ………………m

Corresponding time-period from the graph. (Time corresponding the **ABCDE** line)

T = ... ………sec.

$\mathbf{g} = 4\pi^2 \frac{L}{T^2}$ = …………………………..…….. =……………………………….. m/sec²

Discussions:

(i) Distances are to be measured from the end A or the point G, preferably from A.

(ii) In measuring time an accurate stopwatch should be used.

(iii) Oscillations should be counted whenever the line of the bar crosses the equilibrium position, in the same direction.

(iv) Oscillations should be counted after a few Oscillations (2 or 3 Oscillations).

(v) Graph paper used should have sharp lines and accurate squares and should be sufficiently large to draw smooth and large curves.

(vi) For 30 oscillations the amplitude of oscillations must not be more than 5°, from my point of view for 30 oscillations amplitude of oscillations should be a bit greater than 5° but not less than that.

(vii) Error due to the yielding of support, air resistance, and irregular knife-edge should be avoided.

(viii) Determination of the position of G only helps us to understand that AG= l_1, and GC = $(K^2/ l_1) = l_2$ and is not necessary for determining the value of 'g'.

(ix) For the lengths corresponding to the points **A, B, D & E** the period is the same.

(x) At the lowest points of the curves **P and Q** the center of suspension and the center of oscillation coincide. It is really difficult *to* locate the points **P and Q** in the graph and so **K** is calculated from the relation.

K= √ (CA.CB) = √ (CD. CE)

Reference : Practical physics(for degree student)written by Dr. Giasuddin Ahmad and Md. Shahabuddin

Sample oral Questions and Answers:

1. What is a compound pendulum?

   Ans : Compound pendulum is a rigid body of any shape free to turn about a horizontal axis.

2. Which is superior-- compound pendulum or a simple pendulum?

   Ans : The ideal conditions of a simple pendulum cannot be attained in practice. In a compound pendulum the length of an equivalent simple pendulum can be determined and hence the value of ‘g’ can be accurately found out. The compound pendulum oscillates as a whole and due to its heavy mass, goes on oscillating for a long time. Hence compound pendulum is superior to simple pendulum.

3. What do you mean by center of suspension and center of oscillation?

   Ans: It is possible to find out two points on the opposite side of the center of gravity of the pendulum such that the periods of oscillation of the pendulum about these points are equal. One point is called the center of suspension and the other point is called the center of oscillation.

4. What is the length of the equivalent simple pendulum?

   Ans: The distance between the center of suspension and the center of oscillation is called the length of the equivalent simple pendulum.

5. What are the defects of the compound pendulum?

   Ans : (1)The compound pendulum tends to drag some air with it and this increase the effective mass and hence the moment of inertia of the moving system.

   (2) The amplitude of oscillation is finite which needs some correction.