Experiment 01

Title: To Determine the Value of g, Acceleration Due to Gravity, by Means of a Compound Pendulum

Theory:

Compound pendulum is a rigid body of any shape free to turn around a horizontal axis. If we consider a pendulum with M mass, there is a gravity of center G. Then it performs oscillations through horizontal axis. When the pendulum is at θ to the vertical axis the equation of motion of the pendulum is,

$$I\omega = Mgl\sin\theta$$

where ω is the angular accelaration produced, l is the distance OG and I is the moment of inertia of the pendulum about the axis of oscillations. For small amplitude of vibrations, $\sin\theta = \theta$

Figure: Compound Pendulum

so our equation becomes,

$$I\omega = Mgl\theta$$

Hence, the motion is simple harmonic, with period of vibrations,

$$T = 2\pi\sqrt{\frac{I}{Mgl}}$$

If k is the radius of guration of the pendulumn about an axis through G parallel to the axis of oscillation through O, from the parallel axes theorem,

$$I = M(k^2+l^2), \text{ and so}$$

$$T = 2\pi\sqrt{\frac{k^2+l^2}{gl}}$$

$$= 2\pi\sqrt{\frac{\frac{k^2+l^2}{l}}{g}}$$

And the periodic time of a simple pendulumn 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 pendulumn of 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

$$l^2 - lL + k^2 = 0$$

This gives two values of l (l_1 and l_2) for which the body has equal times of vibration.
From the theory of quadratic equations
$l_1 + l_2 = L$ and $l_1 l_2 = k^2$.

As the sum and products of two roots are positive, the two roots are both positive.
So there are two positions of the centre of suspension on the same side of CG about which the periods (T) would be same.
Same will happen on the other side of the graph. So the length will be the distance in-between. From the figure,

$$OG + OS = l_1 + l_2 = L$$

So here O and S are interchangable, and we get

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

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

Apparatus: A bar pendulum, a small metal wedge, a beam compass, a spirit level, a telescope with cross-wires in the eye-piece, stop watch, and a wooden prism with metal edge.

Description of the apparatus: The apparatus ordinally used in the laboratory is a rectangular used in the brass about 1 meter long. A series of holes are drilled along the bar at a certain intervals. By inserting the metal wedge in one of the holes and placing wedge on the support, the bar can be made to oscillate.

Procedure:

(i) Find out the center of the gravity by placing it on a wooden prism.

(ii) Put a chalk mark and put the metallic wedge in the first hole.

(iii) Set the bare to oscillate taking care to see that the amplitude of oscillations is not more than 5°. Note that the time for 50 oscillations by counting the oscillations when the line AB passes the inter-section of the cross-wires in the same direction.

(iv) Measure the length from the end A of the bar to the top of the first hole i.e. upto the point of suspension of the pendulum.

(v) In the same way suspend the bar at holes 2, 3, ... and note for 50 oscillation

(vi) When the middle point is passed, it will turn round. Then we have to continue measuring.

(vii) Now calculate the time period for 50 oscillation.

(viii) On a graph plot a graph with length and time period T.

(ix) Through the point on the graph paper corresponding to the centre of gravity of the bar, draw a vertical line.
Draw a second line ABCD along the abscissa i.e. $L = l_1 + \frac{k^2}{l_1}$.

$AG = l_1$

and $CG = \frac{k^2}{l_1}$

C being the centre of oscillation.

Similarly,

$GD = l_1$

$GB = \frac{k^2}{l_1} = l_2,$

B being the centre of oscillation.

From this $g = 4\pi^2 \frac{L}{T^2}$ can be calculated.

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

Error calculation:

$$\text{Percentage of error} = \frac{|\text{Exact value} - \text{Approximate value}|}{|\text{Exact value}|} \times 100$$

$$= \frac{|980.665 - 903.78|}{980.665} \times 100\ \%$$

$$= 7.8\ \%$$

Discussion:

① In measuring, an accurate stop watch have to be used.

② Graph paper should have sharp lines.

③ Amplitud must be less than 5°.

Experiment 02

Title: To Determine the refractive index of the material of a prism.

Theory: If A be the angle of the prism and δ_m that of minimum deviation which light of a given color undergoes by refraction through the prism in a principle section, then the refractive index of the material of the prism for light of the given color i.e., wavelength is given by the relation

$$\mu = \frac{\sin \frac{A+\delta_m}{2}}{\sin \cancel{\sin} \frac{A}{2}}$$

The expression for μ can be deduced in the following manner.

Let a ray PQ be incident on the first face of a prism and after passing through the principle plane of the prism, finally emerges out through the other face in the direction RS. Let θ and ϕ be the

respective angles of the incident and refraction at the first face. Likewise θ' and φ' be the angles for the second face. No to calculate the deviation SOT, is equal to the $(\theta-\varphi)+(\theta'-\varphi')$. But in the position of minimum deviation, the ray passes symmetrically through the prism so that $\theta=\theta'$ and $\varphi=\varphi'$

Therefore, the angle of minimum deviation

$$\delta_m = 2(\theta-\varphi) \quad \ldots\ldots (1)$$

From the figure, we can get,

$$\angle A = \varphi+\varphi' = 2\varphi \quad \ldots\ldots (11)$$

So, $\varphi = \frac{\angle A}{2}$

And combining (1) and (11), we can get

$$\theta = \frac{\delta_m + A}{2} \quad \ldots\ldots (111)$$

Hence, $\mu = \frac{\sin\theta}{\sin\varphi} = \frac{\sin\frac{\delta_m+A}{2}}{\sin\frac{A}{2}}$

$$\therefore \mu = \frac{\sin\frac{\delta_m+A}{2}}{\sin\frac{A}{2}}$$

Apparatus: Prism, white sheet, sodium lamp ... reading lens.

Procedure:

(1) Make all the necessary adjustments of the spectrometer including focussing for parallel rays.

(2) Determine the angle of the prism.

(3) To determine the angle of minimum deviation, place the prism on the prism table.

(4) Looking at the other face determine the position of the refracted image. Turn the table so that the deviation gradually decreases.

(5) Repeating above steps take several deviation along angle of incedence.

(6) Place the data on a graph where x axis will have angle of incidence and y axis will have deviation.

(7) Find out the minimum deviation and for that deviation find refractive index of the material of the prism.

Error calculation:

$$\text{Percentage of error} = \frac{|\text{Exact value} - \text{Approximate value}|}{|\text{Exact value}|} \times 100$$

$$= \frac{|1.509 - 1.5|}{|1.5|} \times 100\%$$

$$= 0.6\%$$

Discussion:

① Care must be taken while reading the value.

② Proper light should be used.