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DEPARTMENT OF APPLIED SCIENCES & HUMANITIES

Laboratory Manual

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Experiment:

AIM:- To determine the moment of inertia of a flywheel

Apparatus:

A flywheel, different masses, a mass provided with a hook, a strong and thin cotton string, a meter rod, a Vernier callipers and a piece of chalk.

Theory:

Moment of Inertia

Consider a body of mass M rotating about the axis *YY'* with an angular velocity ω. Let the body be made up of a large number of particles of masses m_1, m_2, m_3 … having distances r_1, r_2, r_3 … from the axis *YY'*. All the particles move with the same angular velocity ω, but with different linear velocities v_1, v_2, v_3 …

The total kinetic energy of body is given by

$$E = \frac{1}{2}m_1v_1^2 + \frac{1}{2}m_2v_2^2 + \frac{1}{2}m_3v_3^2 \ \ldots$$

$$E = \frac{1}{2}m_1r_1^2\omega^2 + \frac{1}{2}m_2r_2^2\omega^2 + \frac{1}{2}m_3r_3^2\omega^2 \ldots$$

$$E = \frac{1}{2}\omega^2[m_1r_1^2 + m_2r_2^2 + m_3r_3^2 \ldots]$$

$$E = \frac{1}{2}\omega^2 \Sigma\, mr^2$$

$$E = \frac{1}{2}\omega^2 I$$

Here $I = \Sigma\, mr^2$ is called the moment of inertia of the body about the axis of rotation *YY'*. Thus, the moment of inertia of a body about an axis is the sum of the products of the mass and the square of the distance of different particles of the body from the axis of the rotation.

The S.I unit of moment of inertia is Kgm^2 and it plays the same role in rotatory motion as does the mass in translator motion. The moment of inertia of a body depends upon:

(i) The mass of body

(ii) The position of the axis of rotation

(iii) The distribution of mass within the body with respect to the axis.

Radius of the Gyration

It is the distance from the axis of rotation to a point at which the whole mass of a body may be supposed to be concentrated so as to have the same moment of inertia.

Thus if M is the mass of the body and *k* is the radius of gyration

Moment of Inertia $I = Mk^2$

But $$Mk^2 = \Sigma mr^2$$

$$k^2 = \frac{1}{M}[m_1r_1^2 + m_2r_2^2 + m_3r_3^2 \dots]$$

If body consists of n particles of equal mass m, then

$$k^2 = \frac{m[r_1^2 + r_2^2 + r_3^2 \dots]}{m + m + m \dots n\ times}$$

$$k^2 = \frac{m[r_1^2 + r_2^2 + r_3^2 \dots]}{mn}$$

$$k^2 = \frac{[r_1^2 + r_2^2 + r_3^2 \dots]}{n}$$

$$k = \sqrt{\frac{[r_1^2 + r_2^2 + r_3^2 \dots]}{n}}$$

Thus *k* can also be defined as the root mean square distance of the particles from the axis of the rotation.

Flywheel

A flywheel is simply a heavy wheel with a long axle supported in bearings such that it can rest in any position as it has its C.G. on axis of rotation. Its mass is mostly concentrated in the rim (which is outer periphery) and hence its moment of inertia is quite large.

A string whose one end is fixed on small peg on axle is wrapped around the axle. The other end of string carried a weight Mg at its other end. The length of the string is adjusted so that it gets detached from the axle as soon as the bottom of mass M touches the ground.

Now, the weight Mg falls from the height h, and loses potential energy Mgh. This energy is

(i) Partly converted into kinetic energy due to velocity v gained by the weight.

(ii) Partly converted into energy of rotation of flywheel.

(iii) Partly used up in overcoming the friction in rotation of flywheel.

Thus from the principle of conservation of energy we can say that

Decrease in P.E of mass = K.E gained by the mass + K.E gained by the flywheel + Work done against the friction

$$Mgh = \frac{1}{2}Mv^2 + \frac{1}{2}I\omega^2 + nF$$

Where h is the height through which the mass M is released, v is the velocity of mass M just before touching the ground, ω is the angular velocity of flywheel just before the mass M touches the ground, F is the energy per revolution used up in overcoming the friction forces and n is the number of revolutions that flywheel makes during the descent of mass M through the height h.

$$Mgh = \frac{1}{2}M(r\omega)^2 + \frac{1}{2}I\omega^2 + nF$$

Where r is the radius of the axle of the flywheel

Since we have to determine the moment of inertia I, so rest of the quantities in the equation should be known to us. All the quantities except F can be directly measures.

To find out F we will use an indirect way, let n_1 be the number of revolutions that the wheel makes after the fall of the weight and before coming to rest. Since the K.E possessed by the wheel is used up in overcoming friction in n_1 revolutions, these two can be equated.

$$n_1F = \frac{1}{2}I\,\omega^2$$

Substituting the value of F in equation 2, we have

$$Mgh = \frac{1}{2}mM + \frac{1}{2}I\omega^2 + \frac{n}{2n_1}I\omega^2$$

$$= \frac{1}{2}M(r\omega)^2 + \frac{1}{2}I\omega^2(1 + \frac{n}{n_1})$$

$$I = \frac{2Mgh - Mr^2\omega^2}{\omega^2(1 + \frac{n}{n_1})}$$

Since the wheel makes n_1 rotations (after the weight has been detached from the peg) before coming to rest and takes a total time t, the average angular velocity is 2πn/t. Now the motion of the wheel is uniformly retarded by the frictional forces at the axle and as the final velocity is zero, so its initial velocity must have been double the average velocity.

$$\omega = 2 \times \frac{2\pi n_1}{t}$$

Procedure:

1. Take a strong and thin string whose length should be slightly less than the height of the axle from the floor. Make a loose loop at the one end of the string and slip it on the peg P, on the axle of the flywheel.
2. Tie a suitable mass, M, to the other end of the string and adjust the length of the string, such that loop is just on the point of slipping from the peg P when mass is about to touch the ground.
3. Note the position of lower surface of mass M on a scale fixed behind on the wall, let us say B. Make a chalk mark on the wheel behind the pointer C in this position.
4. Now rotate the wheel and wrap the string around the axle evenly, without any overlapping of wrapping.
5. Stop rotating when the mass M is slightly below the rim of the wheel and mark the position of mass on the scale fixed behind it on the wall. Let us say this point is A.
6. Count the number of turns the flywheel has been rotated to lift the mass from point B to point A and let it be n. The wheel will thus make n revolutions before the thread is detached.
7. Now get ready to take observations, Hold a stop watch and allow the mass to descend.
8. As soon as the weight M strikes the ground, start the stop watch and also start counting the number of revolutions made by the wheel before coming to rest, stop the stopwatch when wheel stops and note down the number of revolutions and time t.
9. Repeat the process for the same height, but now making the wheel to rotate in opposite direction.
10. Repeat the experiment with two more different masses or for different heights of mass.
11. Measure the diameter of the axle in two mutual perpendicular directions with Vernier calipers and determine the mean radius.

It is quite possible that in additions to the complete rotations made by the wheel, there may be a fraction of rotation. To estimate this, measure the distance along the circumference by which the chalk march has advanced beyond the pointer C by means of a thread. Divide this distance by the circumference of the wheel W. This gives the fraction which is to be added to n_1.

Observations:

Least Count of the stop watch: ……. s

Vernier Constant of the Callipers: … … … cm

Table 1: Diameter of the axle:

S.No	Diameter of the Axle (cm) Measured in mutually perpendicular directions			Mean Diameter of the axle D (cm)	Mean radius of the Axle R (cm)
	Reading 1 (cm)	Reading 2 (cm)	Reading 3 (cm)		
1					

Observation Table 2:

S. No	Mass M (g)	Height h (cm)	n	n_1			t (s)			*I* (g- cm_2)
				clock wise	anti clock wise	Mean	clock wise	anti clock wise	Mean	
1.										
2.										
3.										
4.										

$$Mean\ I = \frac{I_1 + I_2 + \quad ..I_N}{N}$$

Calculations:

$$I = \frac{2Mgh}{\left(\frac{4\pi n_1}{t}\right)^2\left(1+\frac{n}{n_1}\right)} - \frac{Mr^2}{\left(1+\frac{n}{n_1}\right)}$$

Result:

Moment of Inertia of flywheel about its axle = … g cm^2

Precautions and Source of Errors:

Minimize the friction in the flywheel. Oil the bearings if required.

The length of the string should be just less the height of the axle from the floor.

The loop slipped over the peg should be loose enough to be detached easily.

The flywheel should start on its own without any push given to it.

The timing and counting of rotations should start from the instant the weight goes off the peg.

The string should be thing and should be wound evenly.

Experiment:

AIM:-

(i) To plot a graph between the distance of the knife-edge from the centre of the gravity and the time period of bar pendulum

(ii) To determine the value of g by a bar pendulum.

Apparatus:

Bar pendulum, a small metal wedge, metre scale, stop watch, a sprit level, a rigid fixed support on the wall

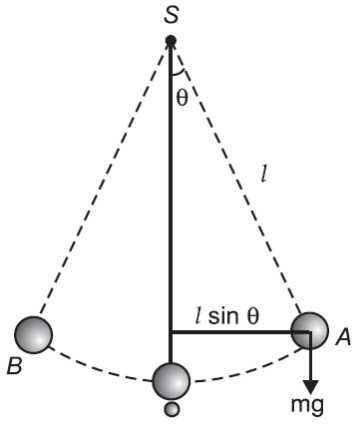
Theory and Formula

Gravity Measurement

The concept of Gravity was given by Isaac Newton when he witnessed an apple falling from a tree in an orchard. Newton's observation caused him to ponder why apple always fall straight to the ground (rather than sideways or upward) and inspired him to eventually develop his laws of universal gravitation, which he published in year 1687, in his landmarked work the "Principia" featuring the "Three laws of motion".

Acceleration due to gravity, which is denoted by 'g', is defined as the acceleration with which a freely falling body moves towards the earth under the action of gravity. The value of g is not constant instead Its value changes from place to place on the earth's surface, being minimum at equator and maximum at poles. As we go above or below the earth's surface its value decreases. Its average value is taken as 9.81 m s^{-2} at sea level and 45º latitude. In M.K.S. system its unit is ms^{-2} and its dimensions are $[M^0L^1T^{-2}]$.

Now, suppose you are asked to find out the value of 'g' at some place on the earth, then how would you measure this gravity? Or how would you design the experiment? We can design an experiment using a simple or compound pendulum and with a little mathematics we can find out the value of acceleration due to gravity. *Think of some other ways which can be used to determine g.*



SIMPLE HARMONIC MOTION and PENDULUM

When a particle moves under the action of a force which is directed towards a fixed point in its line of motion and is directly proportional to the distance of the particle from the fixed point, its motion is said to be simple harmonic.

Simple Pendulum

A simple pendulum consists of a heavy mass suspended by an inextensible light weight flexible string. The motion of a pendulum is simple harmonic only if the angle of swing is very small, so that we can approximate sin(θ) ≈ θ

The acceleration due to gravity can be easily determined using a simple pendulum. The time period *T* of simple pendulum of length *l* is given by

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

If time period (*T*) and length of the pendulum (*l*) are known, acceleration due to gravity (g) can easily be determined.

Although simple pendulum is easy to use but it has certain accuracy issues while using it for measurement of 'g'. In actual practice the suspended mass is not a point mass but has a certain size. The string is also not perfectly inextensible and also has some weight and a finite moment of inertia. The string and bob do not move as one rigid body, a relative motion at corners of swing, occurs between the bob and the string. The length of the string also changes as the pendulum vibrates.

Compound Pendulum

An alternate and more accurate option to measure 'g', is compound pendulum. A compound pendulum is a rigid body AB of any shape and mass M, which is free to oscillate about a horizontal axis passing through it. The point about which rigid body oscillate is called *point of suspension*. The distance between *point of suspension* and *center of gravityG* is denoted by *l.*

When the body is displaced through a small angle θ, the center of gravity G shifts to G'. If the pendulum is released now, then under the influence of force Mg which acts vertically downwards a restoring couple starts acting on it and pendulum begins to oscillate.

The moment of restoring couple or torque

$$\tau = -Mg \times SG$$

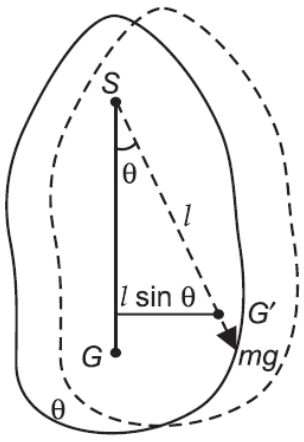
$$\tau = -Mgl\,sin\theta$$

If theta is small then $sin\theta \approx \theta$

$$\tau = -Mgl\,\theta$$

If I is the moment of inertia of body about O then we have

$$Torque = Moment\ of\ Inertia \times Angular\ acceleration$$



$$\tau = I \times \alpha = I\frac{d^2\theta}{dt^2}$$

Where α is angular acceleration of body about O.

$$\frac{d^2\theta}{dt^2} = -\frac{Mgl}{I}\theta$$

$$T = 2\pi\sqrt{\frac{angular\ displacement}{angular\ acceleration}} = 2\pi\sqrt{\frac{\theta}{Mgl\theta/I}} = 2\pi\sqrt{\frac{I}{Mgl}}$$

If I_G be moment of inertial of the given rigid body about an axis through G, parallel to the given axis, the moment of inertia about O is given by

$$I = I_G + Ml^2$$
$$= Mk^2 + Ml^2$$
$$= M(k^2 + l^2)$$

Where *k is the radius of gyration*

Substituting it in the formula for time period *T*

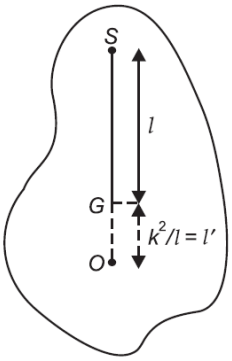
$$T = 2\pi\sqrt{\frac{M(k^2 + l^2)}{Mgl}}$$

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

L= $(\frac{k^2}{l} + l)$ is called length of an equivalent simple pendulum

Centre of Suspension, Centre of Oscillation and Interchangeability

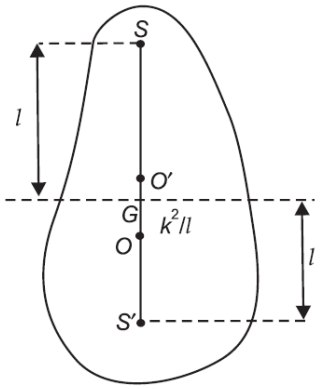
The formula for time period of compound pendulum shows that the length of an equivalent simple pendulum (L) is greater than the distance between *center of suspension* and *center of gravity* (*l*) by an amount k^2/l. The point on other side of *centre of gravity*, which is at a distance of ($l + k^2/l$) from the center of suspension is called *centre of oscillation.*



$$OC = OG + GC = l + l' = l + \frac{k^2}{l} = L$$

$$T = 2\pi\sqrt{\frac{(l' + l)}{g}} = 2\pi\sqrt{\frac{L}{g}}$$

Interchangeability of Centre of Suspension, Centre of Oscillation



The compound pendulum can be inverted by interchanging the *centre of suspension* and *centre of oscillation*. Such inversion does not change the time period of the pendulum because the total length of the pendulum *L* remains same. Let us see the effect of interchanging the *centre of suspension* and *centre of oscillation*.

L= OG + GC, where *l=OG* and *l'=GC= k^2/OG= k^2/l*, this gives *L =l+l'= l+ k^2/l*

No after inverting the pendulum,

new_l=CG=l'= k^2/l, and

$$length\ of\ equivalent\ pendulum = (new_l) + (k^2/(new_l))$$

$$length\ of\ equivalent\ pendulum = \frac{k^2}{l} + \frac{k^2}{(k^2/_l)}$$

$$length\ of\ equivalent\ pendulum = \frac{k^2}{l} + l$$

$$length\ of\ equivalent\ pendulum = L$$

In fact there are four points two on each side of center of gravity on the line of *center of suspension* and *centre of oscillation*, about which the time period remains same.

Radius of gyration

Since

$$l' = \frac{k^2}{l}$$

$$k^2 = ll'$$

$$k = \sqrt{ll'}$$

Minimum value of Time Period

Since

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

For T to be minimum, the value of $\left(\frac{k^2}{l} + l\right)$ should be minimum, which means

$$\frac{d}{dl}\left(\frac{k^2}{l}+l\right)=0$$

$$-\frac{k^2}{l^2}+1=0$$

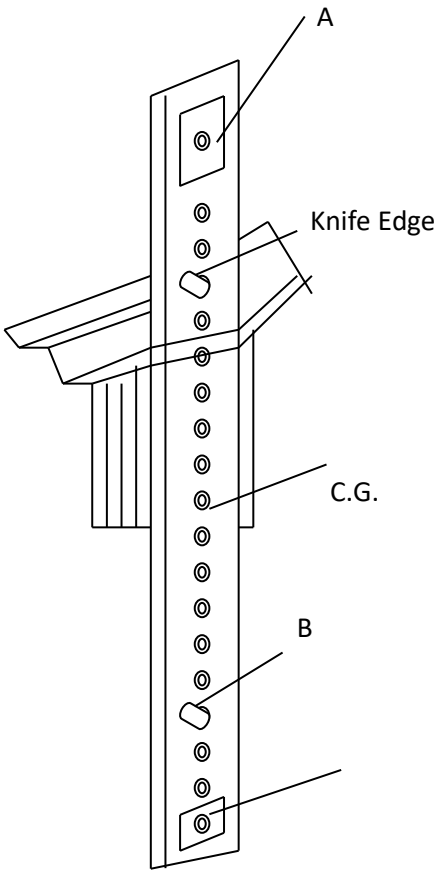
$$l=k$$

Thus time period of pendulum is minimum, when the distance between *point of suspension* and *center of gravity* is equal to *radius of gyration (k)*.

$$T_{min}=2\pi\sqrt{\frac{2k}{g}}$$

Bar Pendulum

A bar pendulum is the simplest form of a compound pendulum. It consist of a uniform metal bar about a meter long with equally spaced holes drilled along its length on either side of its centre of gravity (C.G). Two knife edges are placed symmetrically on either side of the C.G as at A and B.



The bar is allowed to oscillate about a horizontal knife edge passing through each of holes in turn starting from one end and the time period is noted for each case. Now, If a graph is plotted between distance of the knife edge from centre of gravity and corresponding time period (T), it will have the shape as shown in fig 2.

If a horizontal line ABCDE is drawn, it cuts the graph in the points A, B, D, and E about which the time period is same.

For ***A*** as *centre of suspension*, ***D*** is the *centre of oscillation.*

And for ***E*** as *centre of suspension*, ***B*** is the *centre of oscillation*.

The distance ***AD*** and ***BE*** thus giving the length of equivalent simple pendulum ***L***. If ***T*** is the corresponding time period then

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

And thus by finding the ***L and T***, the acceleration due to gravity ***g*** can be determined.

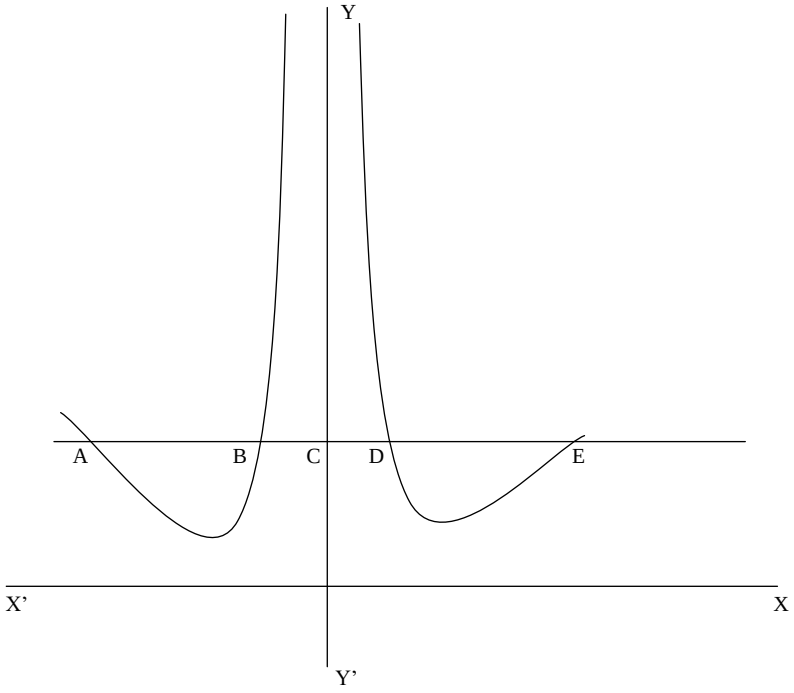
Further

The radius of gyration

$$k = \sqrt{ll'}$$

Where *l = (AC+CE)/2* and *l'= (BC+CD)/2*

And Moment of Inertia $I = Mk^2$, where *M* is the mass of the bar pendulum



4. PROCEDURE

- Find and mark the centre of gravity (say G) of bar by balancing it on a sharp edge.
- Fix the knife edge in outermost holes on the either end of bar parallel to each other with sharp edges pointing towards G.
- Check with a sprit level that glass plates fixed on the rigid bracket on the wall are horizontal.
- Suspend the pendulum by placing the knife-edge on the glass plate.

- Displace the bar slightly (3-5 degree) and release it so that it will start oscillating.
- Note the time for 20 oscillations and also measure the distance of the hole from the C.G. of the bar.
- Repeat the observations with knife-edges in the 2^{nd}, 3^{rd}, 4^{th}, … 9^{th} till you reach middle hole.
- Now suspend the bar from the knife edge on the side B.
- Note the time taken for 20 oscillations with knife-edges in the 1^{st},2^{nd}, 3^{rd}, 4^{th} , … 9^{th} holes and measure the distance of the hole from the C.G. of the bar.
- Draw the graph between time period (for one oscillation) and distance from the c.g.
- Draw the horizontal lines ABCDE and A'B'C'D'E' and do the calculations.
- Find the mass of the pendulum to determine the moment of Inertia.

5. OBSERVATIONS

Least count of the stop watch = ---------- seconds

Least count of the meter scale = ---------- m

Least count of Vernier calipers = ----------cm

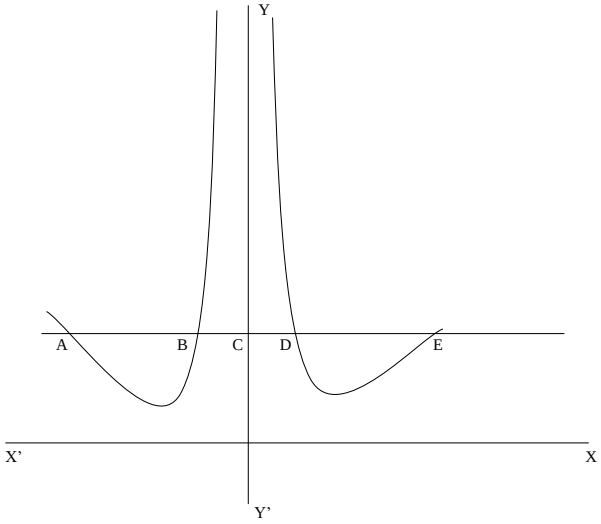
Mass of the bar pendulum = ---------- Kg

S.No.	Side A					Side B				
	Time for 20 oscillations			Time Period T	Distance from C.G.	Time for 20 oscillations			Time Period T	Distance from C.G.
	1	2	Mean			1	2	Mean		
1										
2										
3										
4										
5										

6										
7										
8										
9										

6. CALCULATIONS

Plot the graph between time period and distance from c.g.Taking time period along in the X-axis and the distance from the c.g along the y-axis. Draw JN parallel to X-axis to cut the graph at point J, K, R, M, and N



(A) For Accelerations due to gravity g:

From the line *ABCDE*

$$L = \frac{AD + BE}{2} = \ldots\ldots cm$$

$$T = \ldots\ldots\ldots sec$$

$$g = \frac{4\pi^2 L}{T^2} = \ldots\ldots cm\ s^{-2}$$

(B) For radius of gyration

From the line *ABCDE*

$$k = \frac{AC + CE}{2}$$

$$l' = \frac{BC + CD}{2}$$

$$k = \sqrt{ll'} = \ \ldots\ldots cm$$

(C) For Moment of Inertia I

Mass of the pendulum (*M*) = …….kg

Radius of gyration (*k*)= …….m

I = mk² = …….kg-m²

Log Error :

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

$\log g = \log 4\pi^2 + \log L - \log t^2$

$= \log 4\pi^2 + \log L - 2\log t$

Differentiating:

$$\frac{\Delta g}{g} = \frac{\Delta L}{L} + 2\frac{\Delta t}{t}$$

7. RESULT

(a) The acceleration due to gravity g = ---------m/s^2

(b) Radius of gyration = ----------m.

(c) Moment of inertia = ----------kg-m^2

8. PERCENTAGE ERROR

Standard value of acceleration due to gravity g = 9.8m/s^2

$$\frac{Standard\ Value - Observed\ Value}{Standard\ Value} \times 100\ \% = \ \ldots\ldots\ldots\ \ldots\ \ldots.\%$$

9. PRECAUTIONS AND SOURCES OF ERROR

1. The amplitude of the vibration should be small, ($<5^o$).
2. The bar pendulum should be hanged in a vertical plane and knife-edge should be in horizontal plane
3. Time period of oscillation should be noted after 4-5 oscillations so that irregularities of oscillations subside.
4. The time of oscillations should be counted at least for 20 oscillations.
5. The knife-edge should be sharp.
6. Two knife–edge should lie symmetrically w.r.t. C.G. of the bar.
7. The vibration of the bar pendulum should be vertical.
8. Disturbance by wind should be as minimum as possible.

EXPERIMENT:

AIM: To determine the value of acceleration due to gravity at a place, by means of Kater's reversible pendulum.

Apparatus used: A Kater's pendulum, a stop watch, a telescope and Sharp knife edges.

Theory and Formula used:

Gravity Measurement

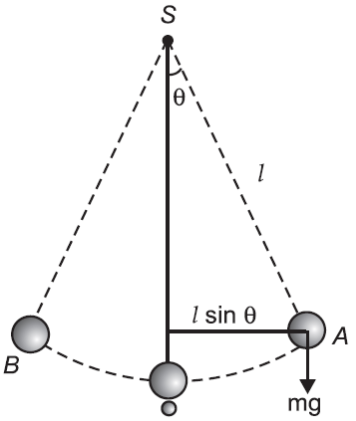
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Now, suppose you are asked to find out the value of 'g' at some place on the earth, then how would you measure this gravity? Or how would you design the experiment? We can design an experiment using a simple or compound pendulum and with a little mathematics we can find out the value of acceleration due to gravity. *Think of some other ways which can be used to determine g.*

SIMPLE HARMONIC MOTION and PENDULUM

When a particle moves under the action of a force which is directed towards a fixed point in its line of motion and is directly proportional to the distance of the particle from the fixed point, its motion is said to be simple harmonic.



Simple Pendulum

A simple pendulum consists of a heavy mass suspended by an inextensible light weight flexible string. The motion of a pendulum is simple harmonic only if the angle of swing is very small, so that we

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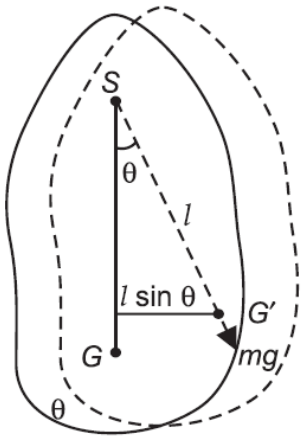
$$T = 2\pi\sqrt{\frac{l}{g}}$$

If time period (*T*) and length of the pendulum (*l*) are known, acceleration due to gravity (g) can easily be determined.

Although simple pendulum is easy to use but it has certain accuracy issues while using it for measurement of 'g'. In actual practice the suspended mass is not a point mass but has a certain size. The string is also not perfectly inextensible and also has some weight and a finite moment of inertia. The string and bob do not move as one rigid body, a relative motion at corners of swing, occurs between the bob and the string. The length of the string also changes as the pendulum vibrates.

Compound Pendulum

An alternate and more accurate option to measure 'g', is compound pendulum. A compound pendulum is a rigid body AB of any shape and mass M, which is free to oscillate about a horizontal axis passing through it. The point about which rigid body oscillate is called *point of suspension*. The distance between *point of suspension* and *center of gravityG* is denoted by *l.*



When the body is displaced through a small angle θ, the center of gravity G shifts to G'. If the pendulum is released now, then under the influence of force Mg which acts vertically downwards a restoring couple starts acting on it and pendulum begins to oscillate.

The moment of restoring couple or torque

$$\tau = -Mg \times SG$$

$$\tau = -Mgl\,sin\theta$$

If theta is small then $sin\theta \approx \theta$

$$\tau = -Mgl\,\theta$$

If I is the moment of inertia of body about O then we have

$$Torque = Moment\ of\ Inertia \times Angular\ acceleration$$

$$\tau = I \times \alpha = I\frac{d^2\theta}{dt^2}$$

Where α is angular acceleration of body about O.

$$\frac{d^2\theta}{dt^2} = -\frac{Mgl}{I}\theta$$

$$T = 2\pi\sqrt{\frac{angular\ displacement}{angular\ acceleration}} = 2\pi\sqrt{\frac{\theta}{Mgl\theta/I}} = 2\pi\sqrt{\frac{I}{Mgl}}$$

If I_G be moment of inertial of the given rigid body about an axis through G, parallel to the given axis, the moment of inertia about O is given by

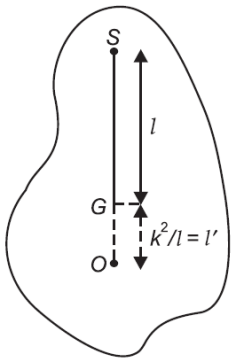
$$I = I_G + Ml^2$$
$$= Mk^2 + Ml^2$$
$$= M(k^2 + l^2)$$

Where *k is the radius of gyration*

Substituting it in the formula for time period *T*

$$T = 2\pi\sqrt{\frac{M(k^2 + l^2)}{Mgl}}$$

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



L= $(\frac{k^2}{l} + l)$ is called length of an equivalent simple pendulum

Centre of Suspension, Centre of Oscillation, and Interchangeability

The formula for time period of compound pendulum shows that the length of an equivalent simple pendulum (L) is greater than the distance between *center of suspension* and *center of gravity* (*l*) by an amount k^2/l. The point on other side of *centre of gravity*, which is at a distance of ($l + k^2/l$) from the center of suspension is called *centre of oscillation.*

$$OC = OG + GC = l + l' = l + \frac{k^2}{l} = L$$

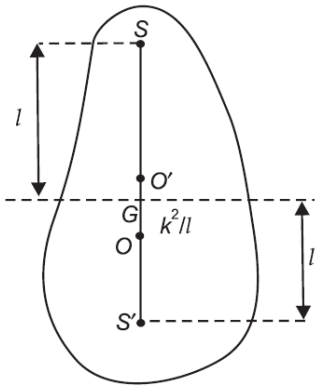
$$T = 2\pi\sqrt{\frac{(l' + l)}{g}} = 2\pi\sqrt{\frac{L}{g}}$$

Interchangeability of Centre of Suspension, Centre of Oscillation

The compound pendulum can be inverted by interchanging the *centre of suspension* and *centre of oscillation*. Such inversion does not change the time period of the pendulum because the total length of the pendulum *L* remains same. Let us see the effect of interchanging the *centre of suspension* and *centre of oscillation*.

L= OG + GC, where *l=OG* and *l'=GC= k^2/OG= k^2/l*, this gives *L =l+l'= l+ k^2/l*

No after inverting the pendulum,



new_l=CG=l'= k^2/l, and

$$length\ of\ equivalent\ pendulum = (new_l) + (k^2/(new_l))$$

$$length\ of\ equivalent\ pendulum = \frac{k^2}{l} + \frac{k^2}{(k^2/_l)}$$

$$length\ of\ equivalent\ pendulum = \frac{k^2}{l} + l$$

$$length\ of\ equivalent\ pendulum = L$$

In fact, there are four points two on each side of center of gravity on the line of *center of suspension* and *centre of oscillation*, about which the time period remains same.

Radius of gyration

Since

$$l' = \frac{k^2}{l}$$

$$k^2 = ll'$$

$$k = \sqrt{ll'}$$

Minimum value of Time Period

Since

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

For T to be minimum, the value of $\left(\frac{k^2}{l} + l\right)$ should be minimum, which means

$$\frac{d}{dl}\left(\frac{k^2}{l}+l\right)=0$$

$$-\frac{k^2}{l^2}+1=0$$

$$l=k$$

Thus time period of pendulum is minimum, when the distance between *point of suspension* and *center of gravity* is equal to *radius of gyration (k)*.

$$T_{min}=2\pi\sqrt{\frac{2k}{g}}$$

Formula used

The value of '*g*' can be calculated using kater's pendulum with the help of the following formula:

$$g=\frac{8\pi^2}{\left[\frac{T_1^2+T_2^2}{l_1+l_2}+\frac{T_1^2-T_2^2}{l_1-l_2}\right]}=\frac{8\pi^2}{\left[\frac{T_1^2+T_2^2}{l_1+l_2}\right]}$$

Neglecting the $\left[\frac{T_1^2-T_2^2}{l_1-l_2}\right]$ term

where

*T*1 = time period about one knife edge

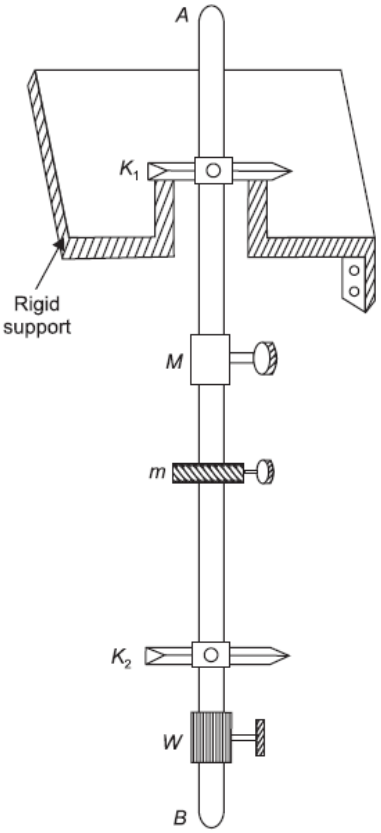
*T*2 = time period about the other knife edge

*l*1 = distance of one knife edge from centre of gravity of the pendulum

*l*2 = distance of the other knife edge from the centre of gravity of the pendulum.

(*l*1 + *l*2) = distance between two knife edges.

Description of apparatus: A Kater's pendulum is a compound pendulum in the form of a long rod, having two knife edges *K*1 and *K*2 fixed near the ends facing each other but lying on opposite sides of the centre of gravity. The position of the centre of gravity of the bar can be altered by shifting the weights *M* and *m* upwards or downwards, which can be slided and fixed at any point. The smaller weight *m*, having a micrometer screw arrangement is used for the finer adjustment of the final position of centre of gravity. The centre of gravity lies un-symmetrically between *K*1 and *K*2 due to the weight *w*, fixed at one end. Kater's pendulum is shown in Fig.



Theory: Kater's pendulum is a compound pendulum of special design. For such a pendulum, if it is possible to get two parallel axes of suspension on either side of the centre of gravity (C.G.) about which the periods of oscillation of the pendulum are the same, then the distance between those axes will be the length *L* of the equivalent simple pendulum.

If *T* is the equal periodic time, then

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

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

Now, an accurate determination of *g* does not require the tedious process of making the two periods exactly the same. It is sufficient if the two periods are made nearly equal.

If *T*1 and *T*2 represent two nearly equal periods about the axes of suspension, and *l*1 and *l*2 represent respectively the distances of the two axes of suspension from the C.G. of the pendulum then

$$T_1 = 2\pi\sqrt{\frac{(\frac{k^2}{l_1}+l_1)}{g}} \text{and} T_2 = 2\pi\sqrt{\frac{(\frac{k^2}{l_2}+l_2)}{g}}$$

Where *k* is the radius of gyration of the pendulum about an axis passing through its C.G.

Thus

$l_1 g T_1^2 = 4\pi^2(l_1^2 + K^2)$and $l_2 g T_2^2 = 4\pi^2(l_2^2 + K^2)$ ……eqn. (2)

On subtracting the two equations we obtain

$$g(l_1T_1^2 - l_2T_2^2) = 4\pi^2(l_1^2 - l_2^2)$$

$$\frac{4\pi^2}{g} = \frac{(l_1T_1^2 - l_2T_2^2)}{(l_1^2 - l_2^2)} = \frac{1}{2}\left[\frac{T_1^2 + T_2^2}{l_1 + l_2} + \frac{T_1^2 - T_2^2}{l_1 - l_2}\right]$$

$$g = \frac{8\pi^2}{\left[\frac{T_1^2+T_2^2}{l_1+l_2} + \frac{T_1^2-T_2^2}{l_1-l_2}\right]}$$

……eqn. (3)

Above equation is the working formula of the experiment and shows that by measuring *l*1 and *l*2 and finding the periods *T*1 and *T*2, the acceleration due to gravity *g* can be determined. If *T*1 and *T*2 are very nearly equal and there is a considerable difference between *l*1 and *l*2 i.e., the *CG* is not nearly midway between the knife edges, (which is an essential feature of the Kater's pendulum) the second term will be very small compared with the first. Hence an approximate knowledge of (*l*1 – *l*2) will be sufficient and so it need not be measured very accurately.

Procedure:

1. Place one of the knife edges of the pendulum on a rigid support so that the metallic cylinder is in the downward direction. Draw a vertical sharp mark along the length of the pendulum and focus the sharp mark through a low power telescope by keeping it at a distance in front of the pendulum. Allow the pendulum to oscillate through a very small amplitude and observe the oscillations through the telescope.

2. Measure the time taken for a small number of oscillations (say 20) by means of a precision stop watch. Now, place the pendulum on the second knife-edge, and after allowing it to oscillate measure the time taken for the same number of oscillations. The times in the two cases may be widely different.

3. Shift the position of the weight *M* in one direction and measure again the times for the same number of oscillations as before when the pendulum oscillates first about the knife edge *K*1 and then about the knife-edge *K*2. If the shift of the weight *M* increases the difference in the times of oscillations about the two knife-edges then shift the position of the weight *M* in the opposite direction. Otherwise shift the weight *M* in the same direction by a small amount and repeat operation (2).

4. The shifting of the weight *M* and the repetition of operation (2) are to be continued till the two times are nearly equal.

5. Repeat the process now with more number of oscillations (say, 10, 20, etc). Until the time for 50 oscillations about the two knife-edges are very nearly equal. Note these two very nearly equal times. While observing times for more than 20 oscillations, the equality of the two times is to be approached by finer adjustments attached with the weight *m* and shifting it precisely.

6. Measure the time for 50 oscillations about each knife-edge three times and then calculate the mean time for 50 oscillations about each of the knife-edges. From these, determine the time periods *T*1 and *T*2 about the knife-edges.

7. Now place the pendulum horizontally on a sharp wedge which is mounted on a horizontal table to locate the C.G. of the pendulum. Mark the position of the C.G. and measure the distances of the knife-edges, i.e., *l*1 and *l*2 from the C.G. by a metre scale.

8. Substituting the values of *l*1, *l*2, *T*1 and *T*2 in Eq. (3) calculate *g*.

OBSERVATIONS

Least count of the stop watch = ---------seconds

Least count of the meter scale = -------m

(i) Time periods ($T_1$and T_2) about the knife-edges K_1 and K_2

S. No.	Time taken for 20 oscillations about K_1 t_1 (sec)	Time taken for 20 oscillations about K_2 t_2 (sec)	Time period T_1 = $t_1/20$	Time period T_2 = $t_2/20$
1				
2				
3				

Average T_1 = ……s

Average T_2 = ……s

(ii) Distance of knife edge K_1 from C. G. l_1 = ……m

Distance of knife edge K_2 from C. G. l_2 = ……m

CALCULATIONS

T_1 = ……seconds

T_2 = ……seconds

l_1 = ……m

l_2 = ……m

$$g = \frac{8\pi^2}{\left[\frac{T_1^2+T_2^2}{l_1+l_2} + \frac{T_1^2-T_2^2}{l_1-l_2}\right]}$$

Now putting the value of T_1, T_2, l_1 and l_2 find out the value of 'g'.

'g' = ------ m/ s^2

RESULT

The value of 'g' the acceleration due to gravity = ------ m/ s^2

PERCENTAGE ERROR

Standard value of g = 9.8 m/s^2

$$\frac{Standard\ Value - Observed\ Value}{Standard\ Value} \times 100 = \text{-------}\%$$

PRECAUTIONS AND SOURCES OF ERROR

1. Knife edges should be horizontal and parallel to each other so that the oscillations are confined in a vertical plane and the pendulum remains in a stable position.
2. The amplitude of oscillation must be kept very small so that the motion is truly simple harmonic.
3. The stop watch should be accurate.
4. The distance between the knife edges should be measured accurately correct to a millimeter.
5. The motion of the pendulum should be in a vertical plane. While taking the time, start taking the observations after two oscillations to avoid any irregularity of motion.
6. The time for a good number of oscillations should be taken for the final observation.
7. The weight W and W^1 should be placed symmetrically from the ends of the rod to avoid error due to air drag.
8. The center of gravity should be found carefully without disturbing the weights on the rod.

EXPERIMENT:

AIM: To determine the wavelength of sodium light using a plane diffraction grating

APPARATUS:

A spectrometer, a spirit level, a sodium lamp, an eye-piece, a diffraction grating with clamping arrangement etc.



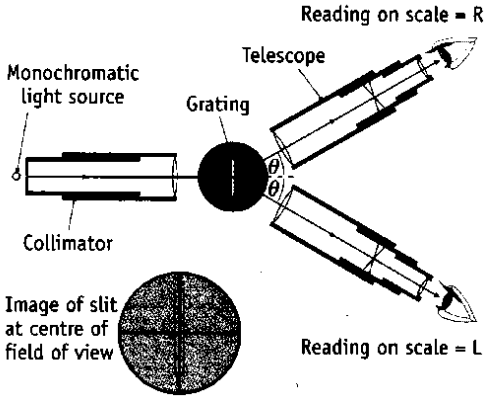


Fig: Spectrometer

THEORY: -

A diffraction grating is an optical instrument consists of a large number of parallel, closely spaced slits, which splits and diffracts light into several beams travelling in different directions. The directions of these beams depend on the spacing of the grating and the wavelength of the light so that the grating acts as the dispersive element.

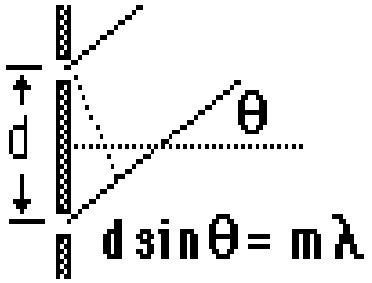
When light of a single wavelength, like the 589.3 nm from sodium lamp (or 632.8nm red light from a helium-neon laser) strikes a diffraction grating it is diffracted to each side in multiple orders,The condition for maximum intensity is the same as that for the double slit or multiple slits, but with a large number of slits the intensity maximum is very sharp and narrow, providing the high resolution for spectroscopic applications. The peak intensities are also much higher for the grating than for the double slit.

On the other hand if light of different wavelengths is incident on a diffraction grating, it is diffracted at different angles (each wavelength of input beam spectrum is sent into a different direction, producing a spectrum), each slit in the grating acts as a point source propagating in all directions. The light in a particular direction θ is made up of the interfering components from each slit,

producing sharp intensity maxima. long-wave light is deviated more than short-wave light. Generally, the phases of the waves from different slits will vary from one another, and will cancel one another out partially or wholly.

However, when the path difference between the light from adjacent slits is equal to the wavelength, λ, the waves will all be in phase. This occurs at angles ϑ_m which satisfy the relationship $d\sin\vartheta_m/\lambda=|m|$ where d is the separation of the slits and m is an integer. Thus, the diffracted light will have maxima at angles $\vartheta_m$given by

$$d\ \sin\theta_m = m\lambda.$$



So when a parallel beam of monochromatic light is incident normally on a grating, the transmitted light gives rise to primary maxima in certain directions given by the relation.

$$(a+b)\sin\theta = n\lambda$$

or, $$\lambda = \frac{(a+b)Sin\theta}{n}$$

Where,

$a+b$ = Grating element

$\theta =$ Angle of diffraction

n = Order of principal maxima

EXPERIMENTAL SETUP

A) Adjustment of Spectrometer

The following adjustments should be done:

I) The optical axes of telescope and collimator should be perpendicular to the axis of rotation of the turn table and should meet at the same point.

This adjustment is done by the manufacturer.

II) Adjustment of the turn table:

1. The prism table is levelled with the help of three screws beneath the prism table. A spirit level is placed along the line joining the screws and the two screws are moved till the air

bubble moves in the middle. Now place the spirit level along a line perpendicular to the previous line and adjust the third screw such that again the air bubble appears in the middle. Here one thing should be remembered that first two screws should not be touched this time. The prism table is now levelled.

2. The second method which is generally used is **optical levelling** of the prism table. In this method the prism is placed on the prism table with its refracting edge at the centre of the prism table and one of its polished surface perpendicular to the line joining the two levelling screws P and Q as shown in fig 1(a).

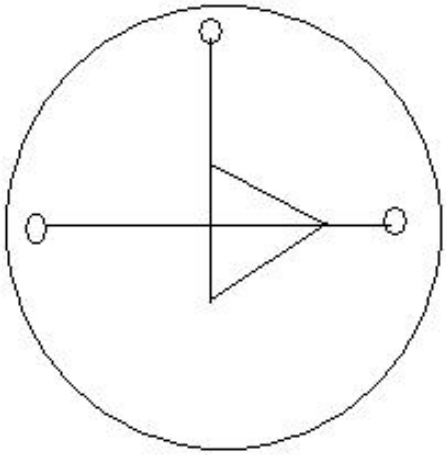


fig 1(a)

Now rotate the prism table in such a way that refracting edges AB and AC face towards the collimator and light falling on the prism is usually reflected from both the sides as in fig 1(b).

The telescope is moved to the one side to receive the light reflected from the face AB and the levelling screws P and Q are adjusted to obtain image in the central field of view of the telescope. Again the telescope is moved to the other side to receive light reflected from face AC and remaining third screw R is adjusted till image becomes in central field of view of this telescope. The prism table is now levelled

III) Schuster's method for focusing the telescope and collimator:

a) First of all prism is placed on the prism table and then adjusted for minimum deviation position. The spectrum is now seen through the telescope.

(Note: The turn table is rotated such that the light from the collimator may fall on the face AB and emerge through the face AC so that the spectrum is visible in the field of view of the telescope. Now, if the prism table is slightly rotated in the either direction till the refracted image of slit (spectrum) is obtained. The spectrum during the rotation of the table moves in one direction and it begins to retrace the path from a certain position when the rotation is still continued in the same direction. At this position, the rays suffer minimum deviation.)

b) The prism table is rotated slightly away from this position towards the collimator and spectrum is viewed focusing collimator on the spectrum.

c) Again rotate the prism table on the other side of minimum deviation position i.e. towards the telescope and focus telescope for best image of the spectrum.

d) The process of focusing the collimator and telescope is continued till the slight rotation of prism table does not make the image to go out of focus. This means that both the collimator and the telescope are now individually set for parallel rays.

IV) Grating should be normal to the axis of collimator:

1. Collimator and telescope are arranged in a line and the image of the grating is focused on the vertical cross-wire.
2. The telescope is then rotated through 90^0 from this position.
3. The prism table is now rotated till the image of the slit, formed by reflection from the grating is thrown on the cross-wire.
4. The turn table is then rotated through 45^0 or 135^0 from this position. The plane of the grating thus becomes normal to the collimator axis.

(Figures 1-4)

ADJUSTMENT OF GRATING FOR NORMAL INCIDENCE

(STEP 4-5)

Step 1

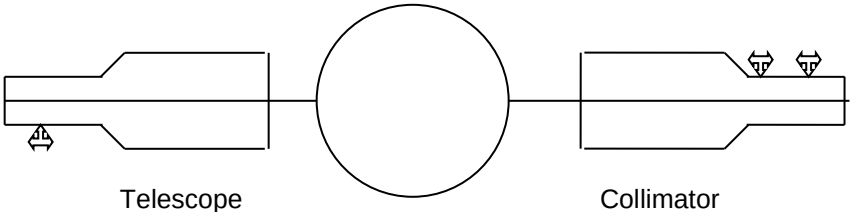


Fig1

Step 2

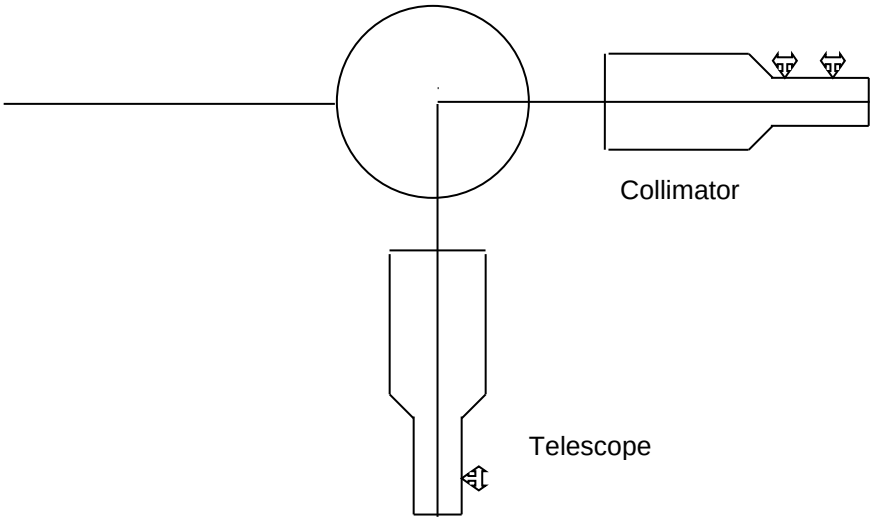


Fig 2

Step 3

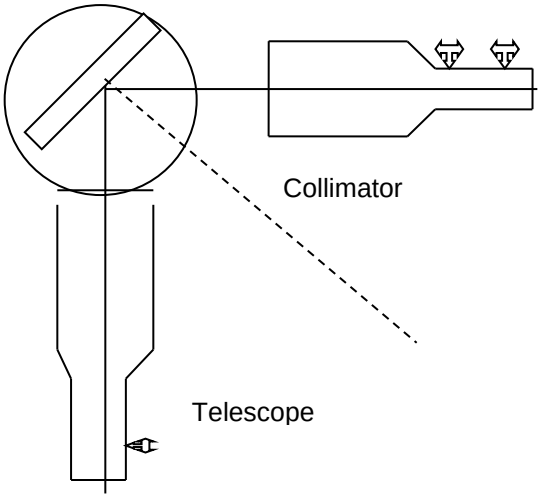


Fig 3

Step 4

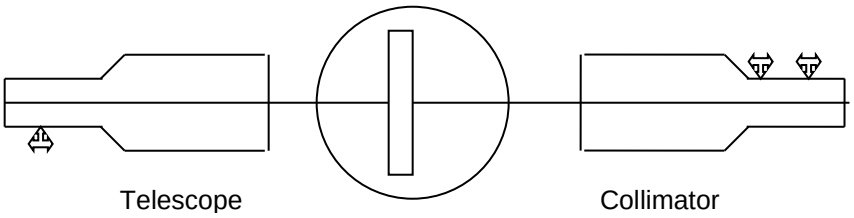


Fig 4

Step 5

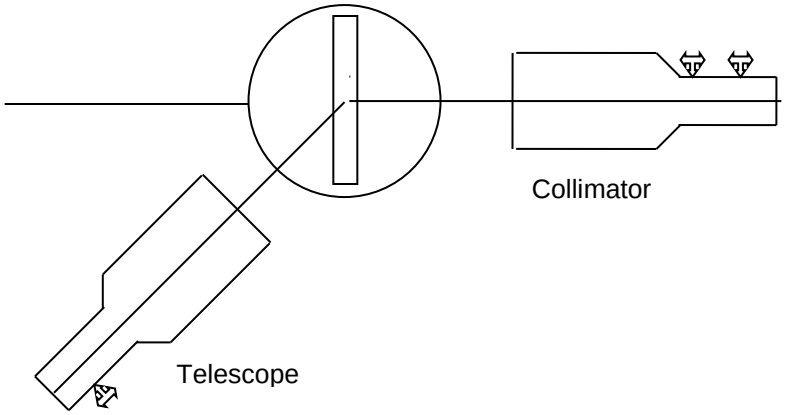
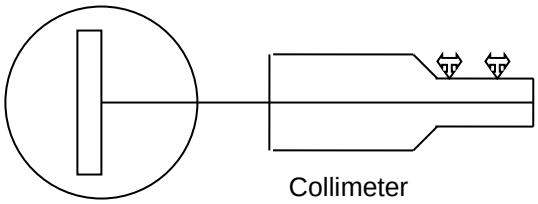


Fig 5

After doing all the adjustments view the image of slit through telescope. Now remove the grating keeping eyes on eye-piece. Image of the slit should remain in the same place and should not shift in position.



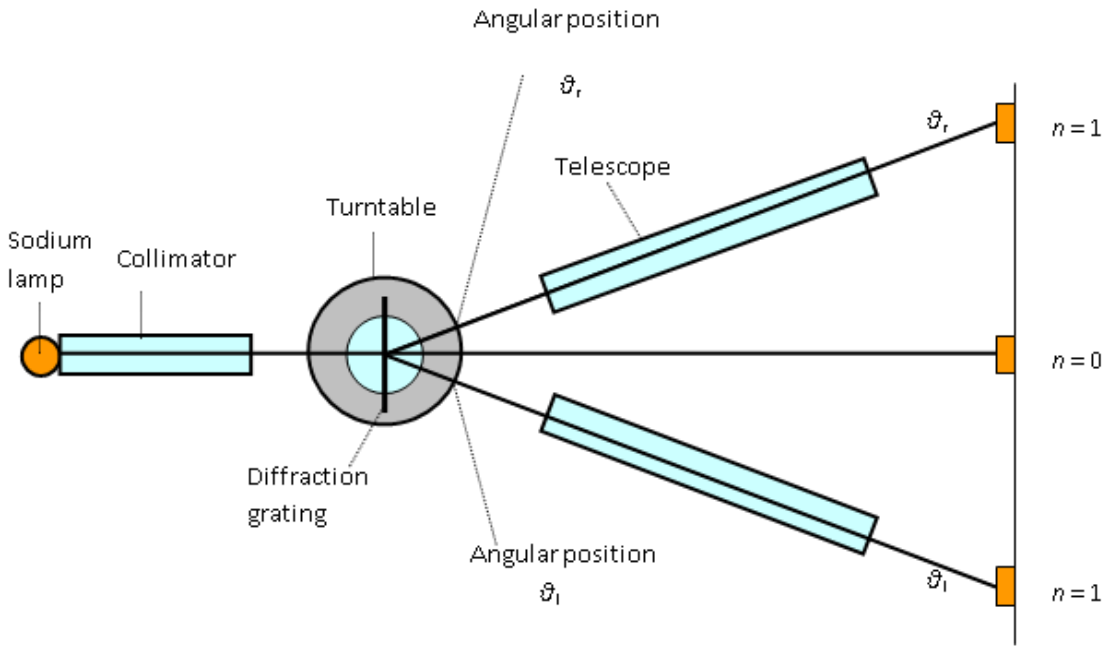


Fig 6

Procedure:

Various Adjustments of Spectrometer

1. **Setting of Eye Piece:** Adjust the position of the eye – piece of the telescope so that the cross-wires are clearly visible. Focus the telescope so that the on a distant object and set it for parallel rays. Level the spectrometer by the leveling screw and then the prism table with two screws in the hole.
2. **Fixing of Grating:** Fix the grating stand on the circular table with two screws in the holes drilled on one of the lines parallel to the line joining two of the screws meant for the purpose. say P and Q. The face of the stand to which the clamps are attached should be at the centre of the table. Take out the grating carefully from the box, holding it from the edge and without touching its surface, fix it very carefully to the frame with its ruled surface. Fix it very carefully to the frame with its ruled surface towards the telescope.
3. ***Optical leveling of the grating table:*** Rotate the table so that the plane of the grating is approximately inclined at an angle of 45 to the axis of the collimator. Rotate the telescope to receive the reflected light from the grating surface. If the image of the slit is not symmetrical with respect to horizontal cross-wire, adjust with the help of third screw R. In this position the plane of the grating will be vertical. Rotate the table carrying the grating so that the plane of grating is approximately perpendicular to the axis of the collimator. Look for the first order spectrum on one side of the direct image of the slit. Turn the telescope so

that the vertical cross-wire coincides with the first order diffracted image. If this image is not symmetrical w.r.t. the horizontal cross-wire adjust it with the help of one of the screws, P or Q. In this position the grating lines are parallel to the other side so that the vertical cross-wire again coincides with the first ordered diffracted image.

4. ***Setting the grating normal to the incident light:*** Place the telescope in line with the collimator. So that the vertical cross-wire falls exactly in the centre of the image of the slit. Note the scale reading. Add 90 to it and place the telescope at this reading to set it perpendicular to the axis of collimator clamp it in this position.

   Rotate the grating table till the phone face of the grating is facing both the collimator and the telescope and turn the table very slowly till the centre of the slit falls exactly on the vertical cross-wire. In this position the plane of grating is inclined at an angle of 45 to the incident light. Note the reading. Turn the table through 45 from this position so that the plane of grating is normal to the incident light with its plane face towards collimator. The grating is now set normal to the incident light with its ruled surface away from the collimator. Clamp the table in this position.

5. Place the eye in front of collimator and move it towards the telescope till the first order diffracted image is visible. Observe the image through telescope. Clamp the telescope in this position. If the resolving power of grating is sufficiently high two distinct narrow lines corresponding to the wavelength 5890 A^0 and 5896 A^0 will lie side by side in the field of view. Ordinarily the two line will appears as on in the first order spectrum. Turn the tangent screw of the telescope till the vertical cross-wire coincides with the centre of the image of the slit. Note the reading on both verniers. Similarly observe the first order spectrum on the other side of the direct image & note reading on both the verniers.

6. Note the reading of the verniers by setting the telescope on the scond order diffracted image on either side of the direct light.

7. Repeat the above observations three times.

8. Note the number of lines per inch as marked on the grating and replace it carefully in box with ruled surface upwards.

OBSERVATIONS:

(1) Observation for adjustment of the grating :

Least Count of the spectrometer = ……. = degrees

(2) Observations for the grating element:

Number of lines per inch on the grating = ……..

Grating element $(a+b) = \dfrac{2.54\ cm}{number\ of\ lines\ per\ inch}$

= .....cm

S.No.	Order of spectrum	Vernier	Telescope reading		Angle of diffraction		Mean
			Left	Right	Left	Right	
1	Ist order	V_1 V_2					
2	IInd order	V_1 V_2					

Calculations:-

Grating element = (a+b) = $\dfrac{2.54}{N}$

= ----------

Ist order (n = 1)

$n\lambda = (a+b)\sin\theta_1$

= ----------

IInd order (n = 2)

$n\lambda = (a+b)\sin\theta_2$

= ----------

Mean $(\lambda) = \dfrac{\lambda_1 + \lambda_2}{2}$ = ----------

% **error** = ----------

Result: Mean wavelength of sodium light from the lamp is 5719 A^0.

PRECAUTIONS:

1. The grating should not be touched with hand or rubbed. It should always be held by means of fingers kept on the opposite edges of the grating.
2. Grating should be perfectly normal to the axis of the collimator.
3. The turn – table must be leveled optically.
4. While recording observations the telescope should be rotated in the same direction in order to avoid backlash error.
5. The slit should be as narrow as possible.
6. All the preliminary adjustments of the spectrometer must be made before starting the experiment.
7. While taking observations the turn table must remain clamped.
8. Both verniers should be read.

Sources of error:

1. The spectrometer is not properly adjusted.
2. Error may be due to parallax.
3. If the reading is not taken overhead the spectrometer.
4. Reading may not be taken taking care of precautions.

EXPERIMENT:

Aim: To find the refractive index of the material of given prism using a spectrometer.

Apparatus:

A spectrometer, a spirit level, a source of monochromatic light, a glass prism, a wooden screen with a circular aperture, an eye-piece and an electric lamp.

Theory:

A prism is a homogeneous, transparent medium such as glass enclosed by two plane refracting surfaces inclined at an angle. The angle between the 'refracting surfaces' is called the refracting angle or the 'angle of prism'. The section cut by a plane perpendicular to the refracting surfaces is called the 'principal section' of the prism. Let *ABC* be the principal section of a glass prism. The angle *A* is the refracting angle of the prism. Let a monochromatic ray of light *PQ* be incident on the face *AB*. This ray is refracted towards the normal *NQE* and travels in the prism along *QR*. The refracted ray *QR* bends away from the normal *MRE* at *AC* and emerges along *RS* into the air. Thus *PQRS* is the path of the light ray passing through the prism. Let *i*be the angle of incidence and *r* the angle of refraction at *AB*; and *r'*the angle of incidence and *i'*the angle of emergence at *AC*. Let δbe the angle between the incident ray *PQ* produced forward and the emergent ray *RS* produced backward. δis called the 'angle of deviation'.

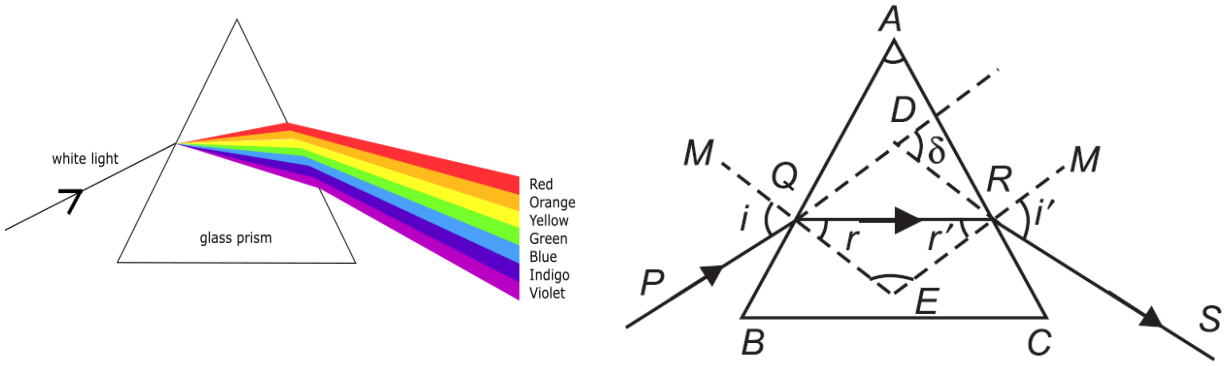


Fig: 1 (a) Dispersion of different components of white light, **(b)**Deviation of an Incident ray on passing through the prism

Angle of Minimum Deviation and refractive index of prism

For a given prism, the angle of deviation depends upon the angle of incidence of the light-ray falling on the prism. If a light-ray is allowed to fall on the prism at different angles of incidence (but not

less than 30°) then for each angle of incidence, the angle of deviation will be different. If we determine experimentally the angles of deviation corresponding to different angles of incidence and then plot *i*against δ, then we shall get a curve as shown in Fig. 1. It is seen from the curve that as the angle of incidence *i*increases, the angle of deviation δ first decreases, becomes minimum for a particular angle of incidence and then again increases. Thus, for one, and only one particular angle of incidence the prism produces minimum deviation. The minimum angle of deviation is represented by δ_m. In the position of minimum deviation, the angle of incidence *i*and the angle of emergence *i'*are equal.

In Fig. 1, for the ray *PQRS*, the angle of incidence is *i*and the angle of emergence is *i'*.Let the angle of deviation δbe minimum, i.e., $\delta = \delta_m$. If the path of the ray is reversed (*SRQP*), then the angle of incidence will be *i'*and the angle of emergence will be *i*and δwill still be minimum. Thus δis minimum for two angles of incidence *i*¢ and *i*. But δcan be minimum only for one angle of incidence. Therefore, it is clear that *i*= *i'*.

Let μbe the refractive index of glass with respect to air. Applying snell's law for therefraction of light at the points *Q* and *R*, we have

$$\mu = \frac{\sin i}{\sin r} = \frac{sin\, i'}{\sin r'}$$

Therefore, if *i'*= *i*, then *r'*= *r*. Thus in the position of minimum deviation ∠*AQR* and ∠*ARQ*are equal. Hence if the angles of the base of the prism are equal, then in the position ofminimum deviation, the light passes in the prism parallel to the base.

Refractive Index of the PRISM

As we know

$$\mu = \frac{\sin i}{\sin r}$$

In Δ*QDR*, we have

$\delta = \angle DQR + \angle DRQ$

$= (i - r) + (i' - r')$

$= (i + i') - (r + r')$ ...(1)

In the quadrilateral *AQER*,∠*AQE* and ∠*ARE* are right angles. Hence the sum of the angles

A and*E* is 180º.

$$A + E = 180º$$

In Δ*QER* $r + r' + E = 180º$

From these two equations, we have

$r + r' = A$ ...(2)

Substituting this value of $r + r'$ in Eq (1), we have

$\delta = i + i' - A$ ...(3)

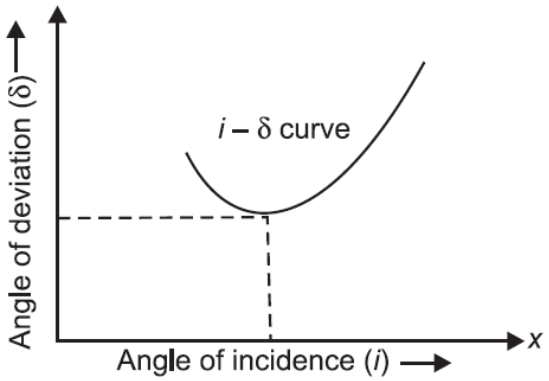
If the prism is in the position of minimum deviation, then

$i' = i$, $r' = r$, and $\delta = \delta_m$

Hence from the equations (2) and (3), we have

$2r = A$ or $r = A/2$

and $\delta_m = 2i - A$ or $i = (A + \delta_m)/2$



Thus, by Snell's law,

$$\mu = \frac{\sin i}{\sin r}$$

Substituting the value of *i* and *r*, we get

$$\mu = \frac{\sin\left[\frac{A+\delta_m}{2}\right]}{\sin\left(\frac{A}{2}\right)}$$

...(4)

Thus, knowing the angle of minimum deviation and the angle of prism, the refractive index of the material of the prism can be calculated.

Instrument Description

Spectrometer

The instrument that you are using in this experiment is called prism spectrometer. The prism spectrometer is an instrument designed to separate the wavelengths of a light source into its various spectral components and to measure these wavelengths. A schematic diagram of a prism spectrometer is shown in Fig. 1. It consists of a collimator, a telescope, a circular prism table and a graduated circular scale along with two verniers. The light to be examined is rendered parallel by a collimator consisting of a tube with a slit of adjustable width at one end and a convex lens at the other. The aperture limits the light coming from the source to a narrow rectangular slit. The collimator has to be focused by adjusting the position of the slit until it is at the focal point of the lens. The parallel beam of light from the collimator passes through a glass prism standing on a prism-table which can be rotated, raised or lowered, and levelled. Prism is the dispersive element in this experiment, grating is another dispersive element which can also be used instead of prism. The prism deviates the component colors of the emitted light by different amounts and the spectrum so produced is examined by means of a telescope, which is mounted on a rotating arm and moves over a divided angular scale. The angle between the collimator and telescope are read off by the circular scale.

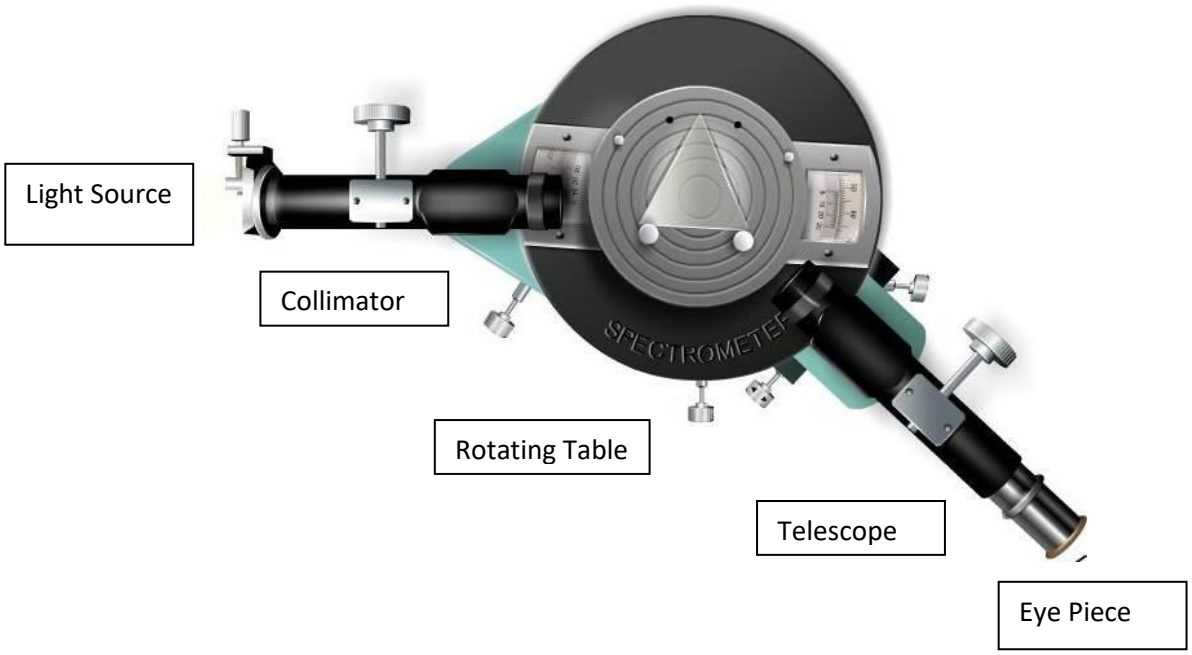


Fig 2: Prism Spectrometer

Our source of light is a mercury gas discharge tube that acts in much the same way as a familiar fluorescent lamp. To the naked eye the light emitted by the mercury tube appears to be nearly white. However, viewed through a spectrometer, the light is separated into distinct spectral components or lines. Each spectral line corresponds to a single wavelength of light. Since the index of refraction is dependent on the wavelength, each wavelength will be refracted through a different angle. The amount by which the visible spectrum spreads out into its constituent colors depends on how rapidly the refractive index of the prism material varies with the wavelength of the radiation, i.e. **dn/dλ** . This quantity is called the **dispersion** and is of prime importance in spectroscopy, since if the dispersion is small, radiation of slightly differing wavelengths cannot be resolved into separate and distinct spectral lines.

With the spectrometer we can measure the minimum angle of deviation δ_m for each wavelength. Then using Equation 4 we can calculate the index of refraction for each wavelength. A description of the few lines and their corresponding wavelengths is given in table below. From your data and the wavelengths below you can construct a plot of the index of refraction, n, vs. wavelength, l.

#	color	wavelength (nm)	brightness
1	yellow	579.0	bright
2	yellow	577.0	bright
3	green	546.1	bright
4	blue	435.8	bright
5	violet	407.8	faint
6	violet	404.7	bright

The detailed description of the each part of the spectrometer is given below.

(i) **Collimator (*C*):** It consists of a horizontal tube with a converging achromatic lens at one end of the tube and a vertical slit of adjustable width at the other end. The slit can be moved in or out of the tube by a rack and pinion arrangement using the focus knob and its width can be adjusted by turning the screw attached to it. The collimator is rigidly fixed to the main part of the instrument and can be made exactly horizontal by adjusting the leveling screw provided below it. When properly focused, the slit lies in the focal plane of the lens. Thus the collimator provides a parallel beam of light.

(*ii*) **Prism table (*P*):** It is a small circular table and capable of rotation about a vertical axis. It is provided with three leveling screws. On the surface of the prism table, a set of parallel, equidistant lines parallel to the line joining two of the leveling screws, is ruled. Also, a series of concentric circles with the centre of the table as their common centre is ruled on the surface. A screw attached to the axis of the prism table fixes it with the two verniers and also keep it at a desired height. These two verniers rotate with the table over a circular scale graduated in fraction of a degree. The angle of rotation of the prism table can be recorded by these two verniers. A clamp

and a fine adjustment screw are provided for the rotation of the prism table. It should be noted that a fine adjustment screw functions only after the corresponding fixing screw is tightened.

(*iii*) **Telescope (*T*):** It is a small astronomical telescope with an achromatic doublet as the objective and the Ramsden type eye-piece. The eye-piece is fitted with cross-wires and slides in a tube which carries the cross-wires. The tube carrying the cross wires in turn, slides in another tube which carries the objective. The distance between the objective and the cross-wires can be adjusted by a rack and pinion arrangement using the focus knob. The Telescope can be made exactly horizontal by the leveling screws. It can be rotated about the vertical axis of the instrument and may be fixed at a given position by means of the clamp screw and slow motion can be imparted to the telescope by the fine adjustment screw.

(*iv*) **Circular Scale (*C.S.*):** It is graduated in degrees and coaxial with the axis of rotation of the prism table and the telescope. The circular scale is rigidly attached to the telescope and turned with it. A separated circular plate mounted coaxially with the circular scale carries two verniers, *V*1 and *V*2, 180° apart. When the prism table is clamped to the spindle of this circular plate, the prism table and the verniers turn together. The whole instrument is supported on a base provided with three leveling screws. One of these is situated below the collimator.

Precision of angular measurement in the spectrometer

In most of the spectrometers, the circular main scale is graduated from zero to 360 degrees; each division on this scale is equal to one half of a degree (i.e. 30 minutes). There are 30 divisions on each of the vernier scales (1) and (2). When the zero of either of the vernier scales matches with a division on the main scale, the 30th division on that vernier coincides with another main scale division. Careful observation indicates that there are 29 main scale divisions between these zero and 30th divisions of the vernier scale. This implies that each vernier division corresponds to (29/30) of a main scale division and that the angular measurements can be made to a precision of one minute (i.e., the difference between the values of one main scale division and one vernier scale division). Remember that one minute equals 1/60 th of a degree.

ESSENTIAL ADJUSTMENTS OF SPECTROMETER:

The following essential adjustments are to be made step by step in a spectrometer experiment: Leveling the apparatus means making (*a*) the axis of rotation of the telescope vertical, (*b*) the axis of the telescope and that of the collimator horizontal, and (*c*) the top of the prism table horizontal. The following operations are performed for the purpose.

(*i*) Leveling of telescope: Place a spirit level on the telescope tube making its axis parallel to that of the telescope. Bring the air bubble of the spirit level halfway towards the centre by first turning the two base leveling screws (i.e. leaving the base leveling screw below collimator) and then turning

the telescope leveling screw. Now rotate the telescope through 180° and adjust the base and telescope leveling screws. Repeat the operations several times so that the bubble remains at the centre for both positions of the telescope. Next place the telescope in the line with the collimator and bring the air bubble of the spirit level at the centre by turning the base leveling screw below the collimator. Again check the first adjustment for the previous orientations of telescope. The axis of the rotation of the telescope has thus become vertical and the axis of the telescope has become horizontal.

(*ii*) Leveling of collimator: Remove the spirit level from the telescope. Place it on the collimator along its length. Bring the air bubble of the spirit level at the centre by adjusting the collimator leveling screw provided below the collimator. This makes the axis of the collimator horizontal.

(*iii*) Leveling of the prism table: Place a spirit level at the centre of the prism table and parallel to the line joining two of the leveling screws of the prism table. Bring the air bubble of the spirit level at the centre by turning these two screws in the opposite directions. Now place the spirit level perpendicular to the line joining the two screws and bring the bubble at the centre by adjusting the third screw. This makes the top of the prism table horizontal.

(iv) Focusing of Eyepiece, Telescope and Collimator

Focusing the eyepiece on the cross-hairs

Rotate the telescope towards any illuminated background. On looking through the eye-piece, you will probably find the cross-wires appear blurred. Move the eye-piece inwards or outwards until the cross-wire appears distinct.

Adjustments of telescope to receive parallel rays

Turn the telescope towards a distant object (e.g. a far off building) and adjust the telescope to see a clear well-defined image of the distant object. If the initial adjustment of the cross hairs was good, the image of the distant object will remain fixed against the image of cross hairs as the eye is moved slightly from side to side. That is, there is no parallax between the images of the cross hairs and the distant object , and thus the two coincide with the focal plane of the telescope. Otherwise there is relative motion between the image of the cross hairs and that of the distant object and the adjustments must be repeated. This method of focusing by the elimination of parallax is universal in the use of optical instruments.

Adjustments of the collimator to provide parallel incident rays

Swing the telescope so that it is aligned with the collimator. There are two knobs under the telescope. One of these is to fix the telescope relative to the collimator and the other for fine alignment of the telescope with respect to the collimator. Note that there is another set of knobs for the prism table. One of them is to fix the prism table at any position and the other is used for

finer adjustments. The slit side of the collimator should face the light source. Illuminate the collimator slit with the mercury light source. Make the slit width narrow and bring the slit into sharp focus while viewing through the eyepiece side of the telescope and by adjusting the collimator only. Again use the absence of parallax between the slit image and the cross hairs.

After these adjustments have been made, care must be taken that they are not disturbed during the entire experiment.

(v) Optical leveling of a prism: The leveling of a prism makes the refracting faces of the prism vertical only when the bottom face of the prism, which is placed on the prism table, is perpendicular to its three edges. But if the bottom face is not exactly perpendicular to the edges, which is actually the case, the prism should be leveled by the optical method, as described below:

(a) Illuminate the slit by sodium light and place the telescope with its axis making an angle of about 90° with that of the collimator.

(b) Place the prism on the prism table with its vertex coinciding with that of the table and with one of its faces (faces *AB* in Fig. 2) perpendicular to the line joining two of the leveling screws of the prism table.

(c) Rotate the prism table till the light reflected from this face *AB* of the prism enters the telescope. Look through the telescope and bring the image at the centre of the field of the telescope by turning the two screws equally in the opposite directions.

(d) Next rotate the prism table till the light reflected from the other face *AC* of the prism enters the telescope, and bring the image at the centre of the field by turning the third screw of the prism table.

(vi) Focusing for Parallel rays by Schuster's method*:*

Schuster's is the best method of focusing the telescope and the collimator for parallel rays within the space available in the dark room. In order to focus the telescope parallel light rays are required and this in turn requires a properly adjusted collimator. For this reason the adjustment of the telescope and the collimator are usually done together.Schuster's method is based on the fact that the effect of the prism on the divergence of the beam is different on opposite sides of this minimum deviation position (see Fig. 2). The emergent beam will be less divergent (or more divergent) than the incident beam as the angle of incidence is increased (or decreased) from the minimum deviation value (i.e. as the apex A in Fig.2 is rotated towards, or away from, the telescope). This property of the prism can be used to obtain an accurately collimated beam. The method is explained below:

To focus using Schuster's method, place the prism on the prism table with its center coinciding with the center of the table and with its refracting edge vertical. Rotate the prism table so that one of

the refracting faces of the prism is directed towards the collimator and light from the collimator is incident on the retracting face at an angle of about 45 degrees to the face. Look through the other refracting face of the prism for the refracted beam which is bent towards the base of the prism.

You will see with the naked eye the image of the slit formed by refraction through the prism. Slightly rotating the prism table, first in one direction and then in the other, you will also see that the image moves. Now turn the prism table in the proper direction so that the image of the slit moves towards the direct path of rays from the collimator and reaches the position of minimum deviation. At this position of the prism, the image will move away from the direct path of rays in whatever direction the prism table is turned. Next bring the telescope between the prism and the eye and move it slightly this way or that so that you can see the image of the slit in it. Slightly rotate the prism table so that you find the image through the telescope exactly at the position of minimum deviation. Displace the telescope from this position in a direction away from the direct path of rays. For this position of the telescope, the image of the slit can be brought on the cross-wires for two positions of the prism. In one position, the angle of incidence of the prism is larger than that at minimum deviation and in the other position it is smaller. In the former position, the refracting edge of the prism is nearer to you than at minimum deviation, and in the latter it is more remote from you. The former position of the prism is called the slant position and the latter position is called the normal position. Next perform the following operations :

1. Bring the image on the cross-wires of the telescope by rotating the prism table in such a way that the refracting edge of prism is nearer to you (the prism is at the slant position) than at minimum deviation. Focus the image by rack and pinion arrangement of the telescope, i.e. the instrument nearer to you. The image now becomes very narrow.
2. Next rotate the prism table in the opposite direction. The refracting edge of the prism will move away from you. Go on rotating the prism table until the image, moving towards the position of minimum deviation, turns back and reaches the cross-wires again. Keeping the prism at this position, i.e. at the normal position, focus the image by the rack and pinion arrangement of the collimator, i.e., the instrument away from you. The image is now very wide.

Repeat the operations 1 and 2 several times in succession till the image remains sharp for both the positions of the prism. The telescope and the collimator are then focused for parallel rays.

MNEMONIC: The operations in Schuster's method can be easily remembered as follows : When the refracting edge of the prism is nearer to you, focus the image by the telescope, i.e. The instrument nearer to you. When the refracting edge of the prism is away from you, focus by the collimator, i.e. the instrument away from you. Or simply, near-near, away-away.

Experimental Procedure

1. Do all the step wise adjustments of prism spectrometer as explained above.
2. The determination of μ consists of measuring A and δ_m.

$$\mu = \frac{\sin\left[\frac{A+\delta_m}{2}\right]}{\sin\left(\frac{A}{2}\right)}$$

3. To find the angle of the prism (A) by rotating the telescope method, place the prism on spectrometer table in such a way that edge A faces the collimator. That allows the light from narrow slit to fall partly on face AB, and partly on other face AC. Thus the telescope will receive rays from the direction AO on one side and AK on the other. The telescope has to be turned by an angle KAO in turning from one direction to other. Measure the angle KAO by turning the telescope and to find out A take the half of it.

   ∠KAO = 2 ∠A

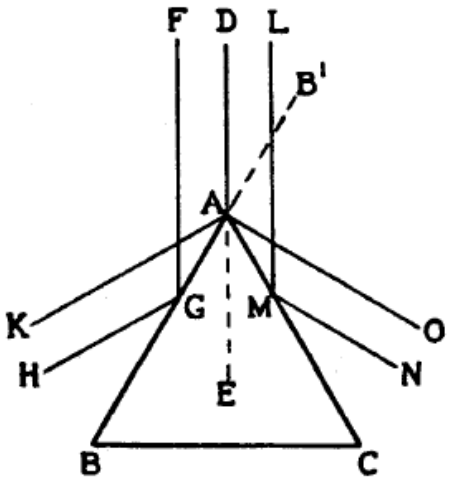


Fig: 3

4. To find the δ_m place the prism on the prism table againso that its centre coincides with the centre of the table and one of the reflecting faces say AB is perpendicular to the line joining the two screw P and Q. rotate table so that light from the collimator is incident on the reflection face AB and after refraction passes out of the face AC.

5. Look through AC and locate the position of the refracted image with the naked eye. Bring the telescope in this position. Adjust its position till the image of the slit falls on the cross-wire. Now turn the prism-table in such a direction that the telescope has to be moved towards the line of the field of view. As the prism table is rotated in this way the angle of deviation decreases. When the position of minimum deviation is reached the image becomes stationary and further rotation of the table makes it move in the backward direction. The direction of the telescope is finally adjusted till the image is on the cross wire in the stationary position from which it turns back in whichever direction the prism is rotated. Clamp the telescope and the table. The minimum deviation position is correct if the image remains stationary when the tangent screw of the table is given one rotation either way. Note the reading on both the vernier scales V_1 and V_2.
6. Keep the table fixed and remove the prism gently. Turn the telescope and bring it in line with the collimator and clamp it. Work the tangent screw of the telescope so that the image of the slit falls exactly on the vertical cross-wire. Take the reading on both the vernier scales.
7. Repeat the experiment, take three such observations for each color and find the angle of minimum deviation for bright red and greenish blue line of the neon spectrum.

Observations:

Side	V_1			V_2		
	Main scale	Vernier scale	Actual	Main scale	Vernier scale	Actual
AB						
AC						

Least count of vernier = $\frac{1}{60}$ degree.

θ_1 = ----------

θ_2 = ----------

Mean value of θ = ---------- ∴ Angle of prism = $\frac{\theta}{2}$ = ----------

For angle of minimum deviation.

S. no.	Colour	MSR	VSR	Actual
1	Violet			
2	Indigo			
3	Green			
4	Yellow			
5	Orange			
6	Red			

Calculation:

$$\mu = \frac{\sin\left[\frac{A + D_m}{2}\right]}{\sin\frac{A}{2}} = \text{----------}$$

$$\mu_v = \frac{\sin\left[\frac{A + D_v}{2}\right]}{\sin\frac{A}{2}} = \text{----------}$$

$$\mu_r = \frac{\sin\left[\frac{A + D_r}{2}\right]}{\sin\frac{A}{2}} = \text{----------}$$

$$w = \frac{\mu_v - \mu_r}{\mu - 1} = \text{----------`}$$

Precautions:

1. The axis of the telescope, the collimator and the plane of the prism table should be horizontal.
2. The position of the eye piece should be adjusted so that the cross wires are clearly visible without any strain.
3. The telescope should be focused for infinity and the collimator should be adjusted to give a parallel beam of light.
4. The slit should be narrow.
5. The position of minimum deviation should be noted when the image of the slit remains stationary even when the tangent screw of the table is given one rotation either way.

EXPERIMENT:

AIM: To determine the Young's modulus of the material of a given beam supported on two knife edges and loaded at the middle point.

Apparatus used: Two parallel knife edges on which the beam is placed, a hook to suspend weights, a meter scale, Spherometer, 500gm weights, d.c .source , bulb or galvanometer, wires, screw gauge, vernier callipers and a meter scale.

Formula: The following formula is used for the determination of Young's modulus (*Y*) for a beam material.

$$y = \frac{Mgl^3}{4Ybd^3}$$

Where

M = load suspended from the beam,

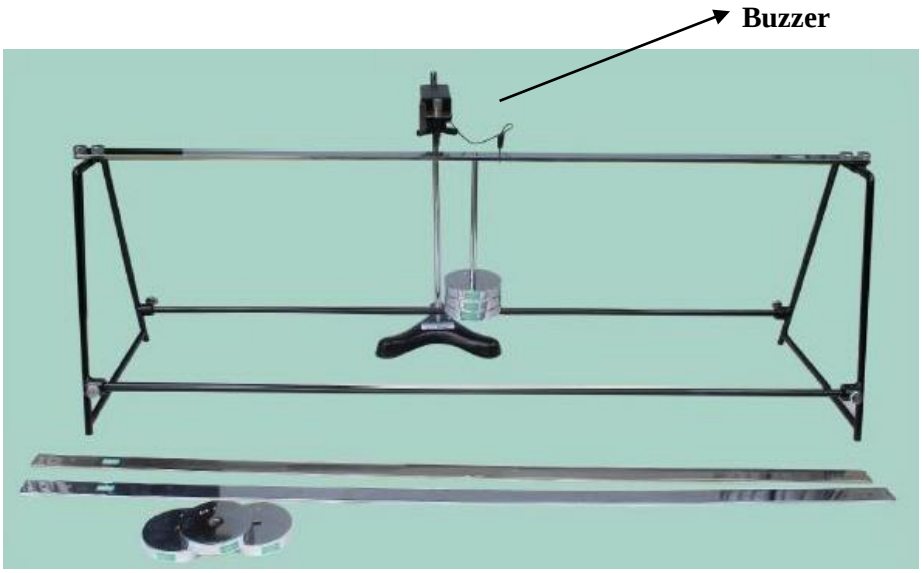
g= acceleration due to gravity,

l = length of the beam between the two knife edges,

b = breadth of the beam,

δ = Y=depression of the beam in the middle

d = thickness of the beam



Theory: Let a beam be supported horizontally on two parallel knife edges *A* and *B* (Figure 1), distance *l* apart and loaded in the middle *C* with weight *W*. The upward reaction at each knife edge being *W/*2 and the middle part of beam being horizontal, it may be taken to be combination of the two inverted cantilevers *CA* and *CB*, each of effective length *l/*2 fixed at *C* and bending upward

under a load *W/2* acting on *A* and *B*. Let the elevation of *A* and *B* above *C* or the depression of *C* below *A* and *B* be 'y'

Consider the section *DB* of the cantilever *CB* at a distance *x* from its fixed end *C* (Figure 3.9). Bending couple due to load w/2 is

$$= \frac{w}{2}\left(\frac{l}{2} - x\right)$$

The beam being in equilibrium, this must be just balanced by the bending moment (or the moment of the resistance to bending) $\frac{YI_g}{R}$, where *R* is the radius of curvature of the section at *D* and *I*g is the geometrical moment of inertia of the cross-section of the beam about an axis passing through the centre of the beam and perpendicular to it. Therefore, we have

$$\frac{YI_g}{R} = YI_g \frac{d^2y}{dx^2} = \frac{W}{2}\left(\frac{l}{2} - x\right)$$

Since $\frac{1}{R} = \frac{d^2y}{dx^2}$

Which on integration gives

$$\frac{dy}{dx} = \left[\frac{W}{2YI_g}\right]\left[\frac{lx}{2} - \frac{x^2}{2}\right] + c$$

Since at *x* = 0, $\frac{dy}{dx}$, we have *c* = 0 and therefore,

$$\frac{dy}{dx} = \left[\frac{W}{2YI_g}\right]\left[\frac{lx}{2} - \frac{x^2}{2}\right]$$

$$dy = \left[\frac{W}{2YI_g}\right]\left[\frac{lx}{2} - \frac{x^2}{2}\right]dx$$

Which on further integration between the limits x=0 and x=l/2 gives

$$y = \left[\frac{W}{2YI_g}\right]\left[\frac{l^3}{16} - \frac{l^3}{48}\right]$$

$$y = \frac{Wl^3}{48YI_g}$$

If the cross-section of the beam be rectangular of breadth '*b*' and thickness '*d*', we have$I_g = \frac{bd^3}{12}$Hence above equation can now be written as

$$y = \frac{Wl^3}{4Ybd^3}$$

or

$$y = \frac{Mgl^3}{4Ybd^3}$$

Where *M* is he mass suspended from the hook. The depression y of the mid-point is noted directly with the help of cathetometer.

Procedure:

(1) Measure the length of bar between knife edges using meter scale. This will give you value of *l*.

(2) Find out the least count of screw gauge and zero error in it.

(3) Using screw gauge, measure the thickness of bar/beam.It will provide the value ofd.

(4) Find out the least count and zero error of Vernier calipers.

(5) Using Vernier calipers,measure the breadth of beam.It will provide the value of b.

(6) Find the least count of spherometer.

(7) Suspend the hanger with a graduated scale attached to it,on the mid-point of the beam. Now rotate the spherometer. As soon as it touches the beam, the buzzer produce sound . Stop the rotation of spherometer and note its reading.This gives zero mass depression.

(8) Now load 500 gm on hanger. At this position, the buzzer will not produce sound . Further rotate the spherometer till the buzzer just produce sound. Stop the rotation of spherometer and note its reading. This gives depression for 500gm.

(9) Increase the mass on hanger till 2500gm in interval of 500gm and note the spherometer readings at the situation of buzzer produce sound. This will give you the depressions at different masses.

(10)Note the same reading of depression, for M=2500gmin case of decreasing load.

(11)Nowremovethe500gm mass from hanger and rotate the spherometer in opposite direction till the buzzer just becomes off. Note the spherometer readings at the situation. This provides you the value of depression for 2000gm mass at load decreasing case.

(12)Similarly decrease the load upto zero mass in steps of 500gm and note the spherometer readings at the just off situation of bulb.This will give you the depressions at different masses in case of load decreasing.

(13) In the process of(7)-(12),you have recorded the depressions (spherometer reading) for different masses in case of load increasing and decreasing. Take the mean of spherometer readings for load increasing and decreasing for each masses.

(14)Now calculate the difference of mean spherometer reading of each mass with zero mass reading. This will provide the relative depression for each masses with respect to zero mass.

(15)Find out depression for 1500gm.This can be obtained by taking difference among1st & 4th, 2nd & 5th and 3rdand 6th. Put all the values in given formula and calculate the value of ***Y***.

(16)Plot graph in mass and relative depression and find out its slope.The slope of graph gives the value of $\tan\theta=\delta/M$. Put all the value in the given formula and calculate the value of ***Y***.

(17)Take mean of both calculated values of *Y*. This provides the final value of Young modulus of material of beam.

Observations:

(1)Length of beam between knife edges (l)=……..cm

(2)Least count of screw gauge= $\frac{pitch}{Number\ of\ \text{divisions on circular scale}}$=…….cm

(3)Zero error in screw gauge=……..gm

(4)Table for thickness(d) of beam:

Sr. no.	M.S. (cm)	C.S. (div)	un-corrected diameter (T= MS + CSx LC) (cm)	Mean un-corrected diameter (T: cm)	corrected diameter (d=T±zero error) (cm)
1.					
2.					
3.					
4.					

(5)Least count of Vernier calipers = $\frac{value\ \text{of one divisionon main scale}}{Number\ of\ \text{divisions on vernier scale}}$……..cm

(6)Zero error in Vernier calipers=……..cm

(7)***Table for breadth of beam:***

Sr. no.	M.S. (cm)	V.S. (div)	un-corrected breadth (T=MS+VSxLC) (cm)	Mean un-corrected breadthr (d:cm)	corrected breadth (b=T±zeroerror) (cm)
1.					
2.					
3.					
4.					
5.					

(8)Table for mass and depression:

Sr. no.	Mass M (gm)	Spherometer reading			Depression δ (cm)	Depression (δ) for M=1500gm (cm)	Mean δ for M=1500gm (cm)
		For load increasing y_1 (cm)	For load decreasing y_2 (cm)	Mean y (cm)			
1.	0			A	δ_1=A-A	$\delta_4-\delta_1$	
2.	500			B	δ_2=B-A		
3.	1000			C	δ_3=C-A	$\delta_5-\delta_2$	
4.	1500			D	δ_4=D-A		
5.	2000			E	δ_5=E-A	$\delta_6-\delta_3$	
6.	2500			F	δ_6==F-A		

Calculation:

$$Y = \frac{gl^3M}{4bd^3}\delta$$

(Using table and graph data of M/ δ, calculate the two values of Young Modulus with log method and find out their mean.)

Results: The Young Modulus of material of beam=…….N/m^2

Maximum possible error: Taking log and differentiating formula of Y, we get

$$\frac{\partial Y}{Y} = \frac{3\partial l}{l} + \frac{\partial b}{b} + \frac{3\partial d}{d} + \frac{\partial \delta}{\delta}$$

So, Maximum possible error= $\frac{\partial Y}{Y} x100$

Precautions:

1. The knife edges should be rigid and fixed on rigid support.
2. The knife edges should beat equal distances from the center of bar/beam.
3. The weights should be placed and removed gently on the hanger.
4. The load on beam should not exceed the elastic limit of beam.
5. To avoid the back less error, the circular scale of screw gauge and spherometer should be moved in one direction.

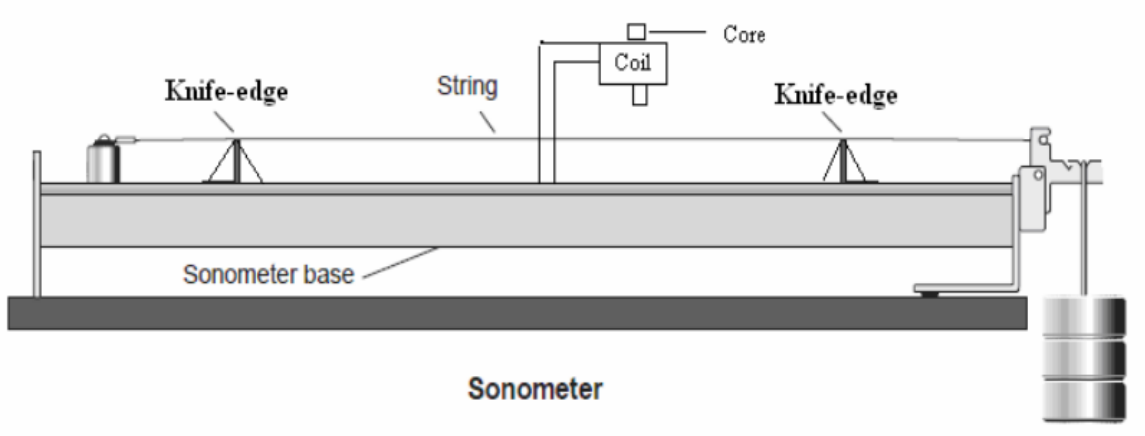
Experiment

AIM: To determine the frequency of AC mains using Sonometer.

Apparatus Used: Sonometer with metallic wire, Inbuilt AC supply, electromagnet, meter scale, slotted half kg weights, two Knife edges.

Theory and Formula Used:

A **Sonometer** is a device which consists of a thin wire stretched over two bridges that are usually mounted on a sound board and which is used to measure the vibration frequency, tension, density, or diameter of the wire, or to verify relations between these quantities.



Sonometer

Electromagnet:

An electromagnet is a type of magnet in which the magnetic field is produced by the flow of electric current. The magnetic field disappears when the current ceases. A wire with an electric current passing through it generates a magnetic field around it of strength proportional to the amount of current. The main advantage of an electromagnet over a permanent magnet is that the magnetic field can be rapidly manipulated over a wide range by controlling the amount of electric current. However, a continuous supply of electrical energy is required to maintain the field.

Frequency of AC mains:

The utility frequency or mains frequency is the frequency at which alternating current (AC) is transmitted from a power plant to the end user.

To find the frequency of AC Mains using an electro-magnet and a sonometer, the AC is passed through the primary of a step-down transformer (220-230 to 4-6 volts).The two ends of the secondary coil of the step-down transformer are connected to the two ends of the windings of the electro-magnet which consists of a coil of insulated copper wire wound over a soft iron core provided with an insulated handle. As the A.C. From the secondary of the step- down transformer passes through the electro-magnet it gets magnetized twice in each

cycle, first with one of its faces as a north pole and then with the same face as the south pole. The electro-magnet is kept close to and vertically above the sonometer steel wire. The wire is attracted and pulled twice in each cycle of the A.C. Mains supply; once when the end of the electromagnet just above the wire is a north pole and again after half a cycle when this end is a south pole. In other words, the natural frequency (*f*) of the sonometer wire is double the frequency (*n*) of the A.C. Mains. The natural frequency of the wire is given by

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

where, *l*=length of the sonometer wire between two knife edges when it is thrown into resonant vibrations

T=tension in the wire

m=mass per unit length of the wire.

The frequency of the ac mains is given by

$$n = \frac{f}{2} = \frac{1}{4l}\sqrt{\frac{T}{m}}$$

Procedure:

1. Assemble the setup as shown in the figure.

2. Firstly tie the wire, as its one end fixed and other end passing over pulley carrying a hanger of weights.

3. Mount the L-clamp of coil with the screws of sonometer base at a distance 2-3 mm above the wire.

4. The core of electromagnet should lie at the center of coil.

5. Now connect mains cord between mains and sonometer.

6. Take two patch cords from the accessory box and connect the 6 V AC supply from sonometer to the coil with polarity.

7. Now hang the weight of 1000 gms to the hanger connected with one end of steel wire.

8. Switch on the AC supply.

9. Now adjust two knife edges by slowly increasing the distance between them so that you get some vibrations in wire.

10. Now slowly adjust both knife edges for maximum vibration in the wire.

11. Note the length (l_1) of wire between two knife edges by given meter scale.

12. Also note load (W) in kg (including the weight of hanger).

13. Now increase load by 500 gms and again get the position of maximum vibration by adjusting both knife edges.

14. Again note the length (l_1) of wire between two knife edges for the increased load.

15. Repeat the same procedure by increasing weight by 500 gms and take reading of $l_1$for maximum vibration.

16. Note all values in observation table below

17. Repeat the steps 7to15, adjusting two knife edges by slowly decreasing the distance between them so that you get maximum vibrations in wire for every observation.

18. Note the values of length l_2 for respective loads and compute mean length, l.

Observations:

Mass per unit length of the wire (*m*) = ……kg/m

S.No	Load in kg (W)	Tension in Newton (W×9.8)	Resonating length of the wire (cm)			Frequency $f = \frac{1}{2l}\sqrt{\frac{T}{m}}$ (Hz)
			Distance between the bridges increasing (l_1)	*Distance between the bridges decreasing* (l_2)	*Mean resonating length* (l)	
1.						
2.						
3.						
4.						

Mean f=…..Hz

Calculations:

Using the formula

$$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$$

Compute frequency of vibration of the wire for each observation and find out the mean frequency.

The frequency of ac mains is given by

$$n = \frac{f}{2}$$

Result: The frequency of AC mains=…….Hz.

Standard result: The frequency of AC mains = 50 Hz.

Percentage error:

$$\frac{\text{Standard value - calculated value}}{\text{Standard value}} \times 100$$

= …….%

Standard value for frequency of ac mains = 50 Hz

Precautions and sources of error:

(i) The wire should be of a uniform area of cross-section, free from kinks and should be tight.
(ii) The observation should start with minimum distance between the two Knife edges.
(iii)The resonance position should be obtained by first slowly increasing the distance between knife edges and then slowly decreasing it.
(iv)The weight of hanger should always be included in the load.
(v) The pulley should be free from friction.
(vi)The electromagnet should be clamped 2-3 mm vertically above the center of the sonometer wire.