B. TECH PHYSICS LABORATORY MANUAL

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Contents

EXPERIMEN NO. 1

Aim:

To determine the acceleration due to gravity (g) by using a Bar pendulum and also determine radius of gyration about an axis through the center of gravity for the bar pendulum.

Apparatus Required:

(i) A bar pendulum, (ii) a knife–edge with a platform, (iii) a sprit level, (iv) a precision stop watch, and (v) a meter scale.

Theory:

A simple pendulum consists of a small body called a “bob” (usually a sphere) attached to the end of a string the length of which is great compared with the dimensions of the bob and the mass of which is negligible in comparison with that of the bob. Under these conditions the mass of the bob may be regarded as concentrated at its center of gravity, and the length of the pendulum is the distance of this point from the axis of suspension. When the dimensions of the suspended body are not negligible in comparison with the distance from the axis of suspension to the center of gravity, the pendulum is called a compound, or physical, pendulum. A rigid body mounted upon a horizontal axis so as to vibrate under the force of gravity is a compound pendulum.

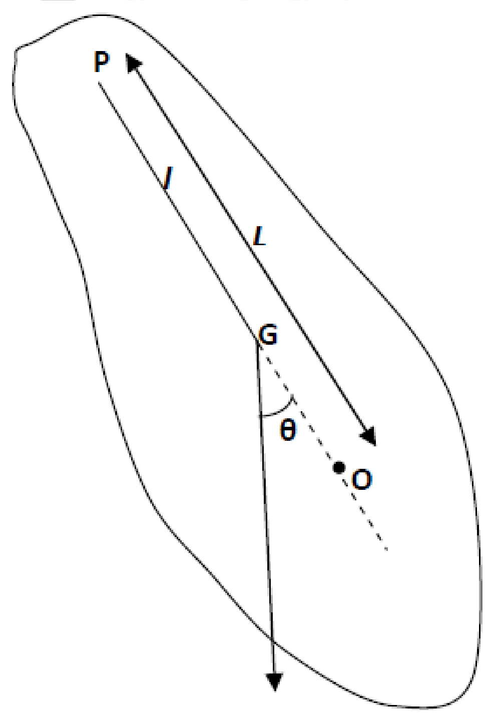


Fig. 1

In Fig.1 a body of irregular shape is pivoted about a horizontal frictionless axis through P and is displaced from its equilibrium position by an angle θ. In the equilibrium position the center of gravity G of the body is vertically below P. The distance GP is l and the mass of the body is m.

The restoring torque for an angular displacement θ is

$$\tau = -mgl\sin\theta \qquad \ldots\ldots\ldots\ldots\ldots..(1)$$

For small amplitudes ($\theta \approx 0$),

$$I\frac{d^2\theta}{dt^2} = -mgl\theta \qquad \ldots\ldots\ldots\ldots\ldots..(2)$$

where I is the moment of inertia of the body through the axis P. Eq. (2) represents a simple harmonic motion and hence the time period of oscillation is given by

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

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

$$I_G = mK^2 \qquad \ldots\ldots\ldots\ldots\ldots(4)$$

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

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

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

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

Comparing with Eq. (5) we get

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

This is the length of "equivalent simple pendulum". If all the mass of the body were concentrated at a point O (See Fig.1) such that $P = l + \frac{K^2}{l}$, we would have a simple pendulum with the same time period. The point O is called the 'Centre of Oscillation'. Now from Eq. (7)

$$l^2 - lL + K^2 = 0 \qquad \ldots\ldots\ldots\ldots\ldots\ldots(8)$$

i.e. a quadratic equation in l. Equation (8) has two roots l_1 and l_2 such that

$$l_1 + l_2 = L$$

And $$l_1 l_2 = K^2 \qquad \ldots\ldots\ldots\ldots\ldots(9)$$

Thus both l_1 *and* l_2 are positive. This means that on one side of C.G there are two positions of the centre of suspension about which the time periods are the same. Similarly, there will be a pair of positions of the centre of suspension on the other side of the C.G about which the time periods will be the same. Thus there are four positions of the centers of suspension, two on either side of the C.G, about which the time periods of the pendulum would be the same. The distance between two such positions of the centers of suspension, asymmetrically located on either side of C.G, is the length L of the simple equivalent pendulum. Thus, if the body was supported on a parallel axis through the point O (see Fig. 1), it would oscillate with the same time period T as when supported at P. Now it is evident that on either side of G, there are infinite numbers of such pair of points satisfying Eq. (9). If the body is supported by an axis through G, the time period of oscillation would be infinite. From any other axis in the body the time period is given by Eq. (5). From Eq.(6) and (9), the value of g and K are given by

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

$$K = \sqrt{l_1 l_2} \qquad \text{................(11)}$$

By determining L, l_1 and l_2 graphically for a particular value of T, the acceleration due to gravity g at that place and the radius of gyration K of the compound pendulum can be determined.

Description of the apparatus:

The bar pendulum consists of a metallic bar of about one meter long. A series of circular holes each of approximately 5 mm in diameter are made along the length of the bar. The bar is suspended from a horizontal knife-edge passing through any of the holes (Fig. 2). The knifeedge, in turn, is fixed in a platform provided with the screws. By adjusting the rear screw the platform can be made horizontal.

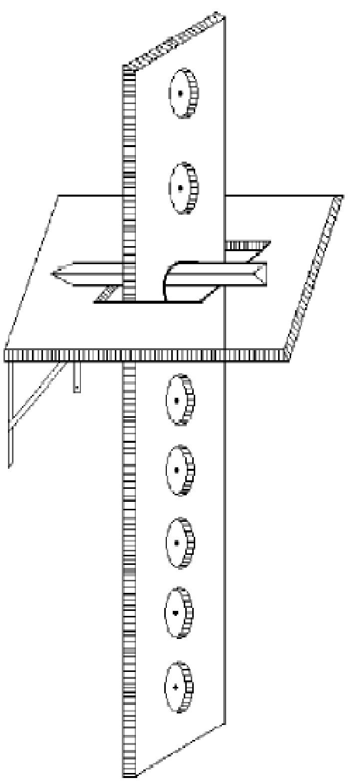


Fig. 2

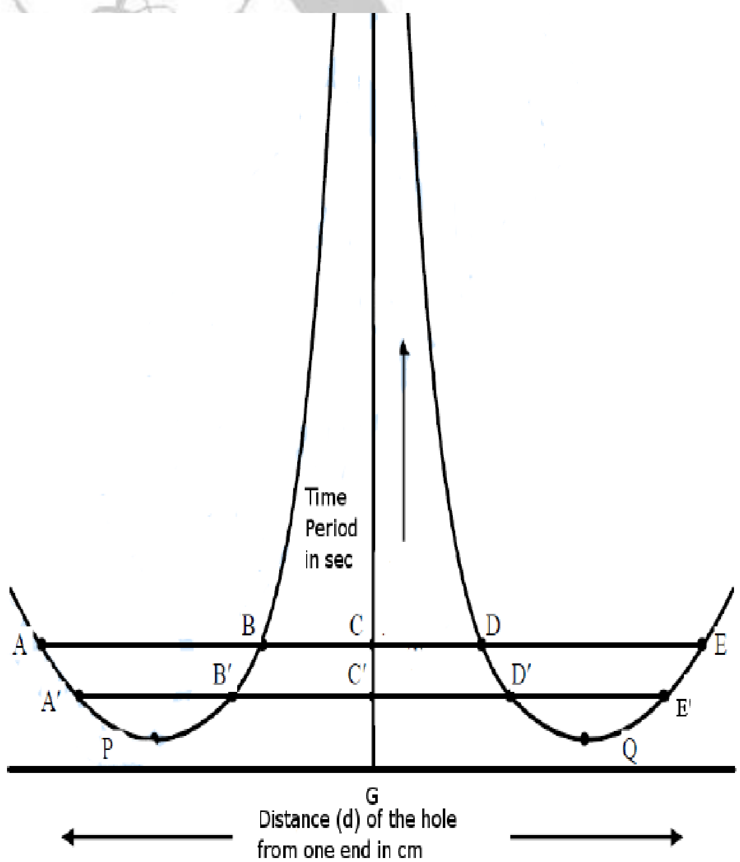


Fig. 3

Procedure:

(i) Suspend the bar using the knife edge of the hook through a hole nearest to one end of the bar.

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

(iii) Note the time for 20 oscillations by a precision stop-watch. Make this observation three times and find the mean time t for 20 oscillations. Determine the time period T.

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

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

(vi) Invert the bar and repeat operations (i) to (v) for each hole starting from the extreme top.

(vii) Draw a graph with the distance d of the holes as abscissa and the time period T as ordinate. The nature of graph will be as shown in Fig. 3.

Draw the horizontal line ABCDE parallel to the X-axis. Here A, B, D and E represent the point of intersections of the line with the curves. Note that the curves are symmetrical about a vertical line which meets the X-axis at the point G, which gives the position of the C.G of the bar. This vertical line intersects with the line ABCDE at C. Determine the length AD and BE and find the length L of the equivalent simple pendulum from

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

Find also the time period T corresponding to the line ABCDE and then compute the value of g. Draw several horizontal lines parallel to X-axis and adopting the above procedure find the value of g for each horizontal line. Calculate the mean value of g.

Alternatively, for each horizontal line obtain the values of L and T and draw a graph with T2 as abscissa and L as ordinate. The graph would be a straight line. By taking a convenient point on the graph, g may be calculated.

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

Observations:

Table 1-Data for the T versus d graph

Serial no of holes from one end		Distance d of the hole from one end (cm)	Time for 20 oscillations (sec)	Mean time t for 20 oscillations (sec)	Time period T = t/20 (sec)
One side of C.G	1.	…………..	………….. ………….. …………..	…………..	…………..
	2.	……………	………….. ………….. …………..	…………..	…………..
	3.	…………….	………….. ………….. …………..	…………..	…………..
	4.	……………	………….. ………….. …………..	…………..	…………..
	5.	……………	………….. ………….. …………..	…………..	…………..
	6.	……………	………….. ………….. …………..	…………..	…………..
Other side of C.G	1.	……………	………….. ………….. …………..	…………..	…………..
	2.	……………	………….. ………….. …………..	…………..	…………..
	3.	……………	………….. ………….. …………..	…………..	…………..
	4.	……………	………….. ………….. …………..	…………..	…………..
	5.	……………	………….. ………….. …………..	…………..	…………..
	6.	……………	………….. ………….. …………..	…………..	…………..

TABLE 2- The value of g and *K* from T vs. d graph

No. of obs.	L (cm)	T (sec)	$g = 4\pi^2 \frac{L}{T^2}$ (cm/sec^2)	Mean 'g' (cm/sec^2)	*K* (cm)	Mean '*K*' (cm)
1. ABCDE 2. 3.	(AD+BE)/2	.. .. ..	.. .. ..	..	$\sqrt{AC \times BC}$ or $\sqrt{CD \times CE}$	..

Standard value of acceleration due to gravity at …………..g =…….cm./sec^2

Calculate the %error by using the formula

$$\%error = \frac{standard\ value - calculated\ value}{standard\ value} \times 100\%$$

=………………………%

Result/Conclusion:

The acceleration due to gravity obtained using a bar pendulum is………..m/sec^2 with error of …………% and the radius of gyration of given bar pendulum is ……..meter.

Precautions:

(i) Ensure that the pendulum oscillates in a vertical plane and that there is no rotational motion of the pendulum.
(ii) The amplitude of oscillation should remain within 4° of arc.
(iii) Use a precision stop-watch and note the time accurately as far as possible.
(iv) Make sure that there is no air current in the vicinity of the pendulum.

References:

1. Fundamentals of Physics: Resnick & Halliday
2. Practical physics: R.K. Shukla, Anchal Srivatsava, New Age International (P) Ltd, New Delhi
3. Eric J. Irons, American Journal of Physics, Vol. 15, Issue 5, pp.426 (1947)

EXPERIMEN NO. 2

Aim :

To study the formation of Newton's rings in the air-film in between a plano-convex lens and a glass plate using nearly monochromatic light from a sodium-source and hence to determine the radius of curvature of the plano-convex lens.

Apparatus required:

A nearly monochromatic source of light sodium vapour lamp), A plano-convex lens with large radius of curvature, An optically flat glass plates, A traveling microscope, Magnifying lens with torch.

Theory:

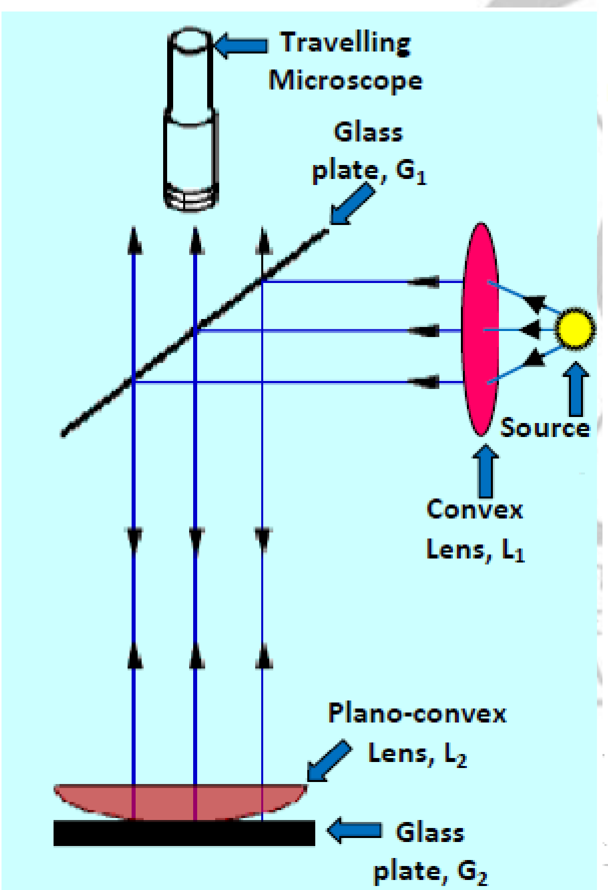


Fig. 1 Experimental set-up to observe Newton's ring

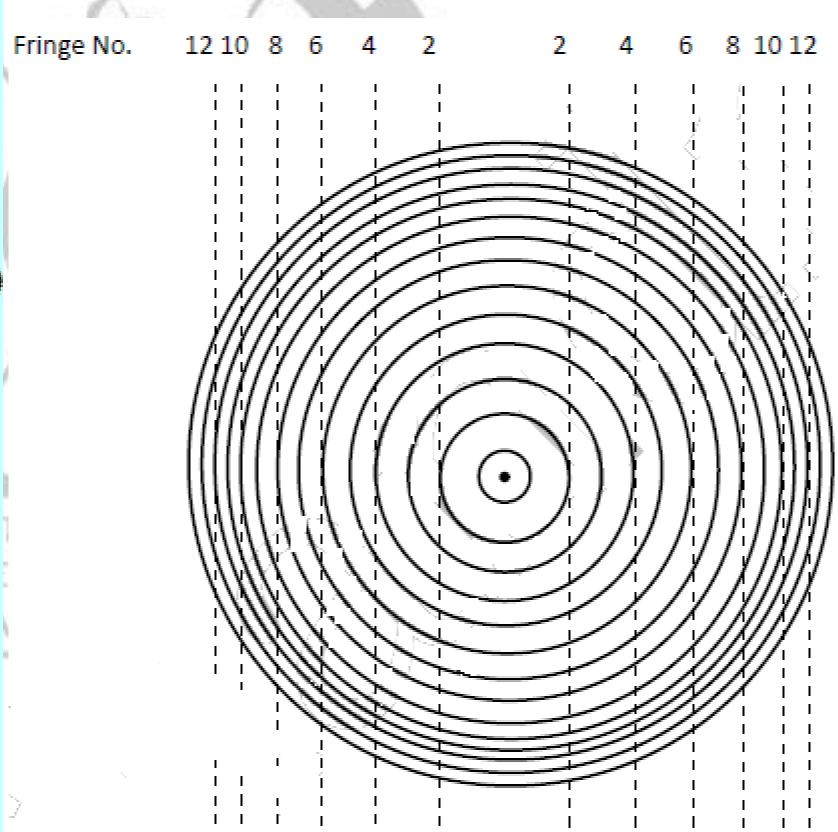


Fig. 2. Newton's rings

When a parallel beam of monochromatic light is incident normally on a combination of a plano-convex lens L_2 and a glass plate G_2, as shown in Fig.1, a part of each incident ray is reflected from the lower surface of the lens, and a part, after refraction through the air film between the lens and the plate, is reflected back from the plate surface. These two reflected rays are coherent, hence they will interfere and produce a system of alternate dark and bright rings with the point of contact between the lens and the plate as the center. These rings are known as Newton's ring.

The diameter of Newton's n^{th} dark ring is given by

$$D_n = \sqrt{4n\lambda R} \qquad \ldots\ldots\ldots\ldots\ldots(1)$$

Where, λ = wavelength of the light used
R = Radius of curvature of plano convex lens
n = ring number

Squaring both the sides of equation (1), we get

$$D_n^2 = 4n\lambda R \qquad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Similarly The diameter of $(m+n)^{th}$ Newton's dark ring is given by

$$D_{m+n} = \sqrt{4(m+n)\lambda R} \qquad \ldots\ldots\ldots(3)$$

And
$$D_{m+n}^2 = 4(m+n)\lambda R \qquad \ldots\ldots\ldots(4)$$

Now subtract equation (3) from equation (4) we get

$$D_{m+n}^2 - D_n^2 = 4m\lambda R \qquad \ldots\ldots\ldots\ldots(5)$$

$$\mathbf{R = \frac{D_{m+n}^2 - D_n^2}{4m\lambda}} \qquad \ldots\ldots\ldots\ldots\ldots(6)$$

Where, wavelength of sodium light $\lambda = 5893\dot{A}$.

Procedure:

If a point source is used only then we require a convex lens otherwise while using an extended source, convex lens L1 is not required. Before starting the experiment the glass plates G1 and G2 and the plano-convex lens L2 should be thoroughly cleaned. The centre of lens L2 is well illuminated by adjusting the inclination of glass plate G1 at 45° as shown in figure 1 (Left).

Focus the eyepiece on the cross-wire and move the microscope in the vertical plane by means of rack and pin on arrangements till the rings are quite distinct. Adjustments are to be done till satisfactory fringe system of perfect circular shape with a dark spot at the centre is obtained. The microscope is focused to get clear dark and bright fringes in the field of view as shown in figure 1 (right). Clamp the microscope in the vertical side.

First, the microscope is adjusted so that the centre of the cross wires coincides with the central dark spot of the fringe system. The microscope is then moved slowly either towards left or right of the centre. While the microscope is moved, the number of dark rings is counted say, up to 18. At the 18^{th} dark ring the microscope is stopped and its motion is reversed. It is brought back to the position of 16^{th} ring. The vertical cross wire is adjusted such that it will be tangential to the 16^{th} dark ring. In this position the reading of the microscope is noted. The microscope is then moved to the 14^{th} dark ring such that the vertical cross wire is again tangential to the ring. The reading of the microscope is noted. The above process is continued till 6^{th} dark ring is reached. After taking the reading for the 6th ring the microscope is moved in the same direction on to the opposite side of the centre. The microscope is moved till the 6th dark ring on the opposite side is reached. The reading is taken as before for the 6th dark ring. The measurements are continued on the opposite side till 16th dark ring is reached. The observations are noted in table.

OBSERVATION:

Value of one division of the main scale=…….. cm.
No of division on the vernier scale=……….
Least count of the travelling microscope = ………. cm.

(A) Table for determination of $D^2_{m+n} - D^2_n$:

S. No.	**Ring No. n**	**Reading of travelling microscope**								**$D_n = x_1 \sim x_2$ (c.m.)**	**D^2_n (c.m.)^2**	**$D^2_{m+n} - D^2_n$ (c.m.)^2 (m=4)**	**Mean $D^2_{m+n} - D^2_n$ (c.m.)^2**
		Left hand side				**Right hand side**							
		M.S.R. (c.m.)	**V.C.**	**V.S.R. (c.m.)**	**X_1= M.S.R. +V.S.R. (c.m.)**	**M.S.R. (c.m.)**	**V.C.**	**V.S.R. (c.m.)**	**X_2= M.S.R. +V.S.R. (c.m.)**				
1	**6th**												
2	**8 th**												
3	**10 th**												
4	**12 th**												
5	**14 th**												
6	**16 th**												

Calculations:

We have $$\mathbf{R} = \frac{\mathbf{D^2_{m+n} - D^2_n}}{\mathbf{4m\lambda}}$$

Here, **Mean** $(D^2_{m+n} - D^2_n)$ = … … … … … … … … …(c.m.)^2

m = 4 and λ = 5893Å.

so

R= ……………………cm.

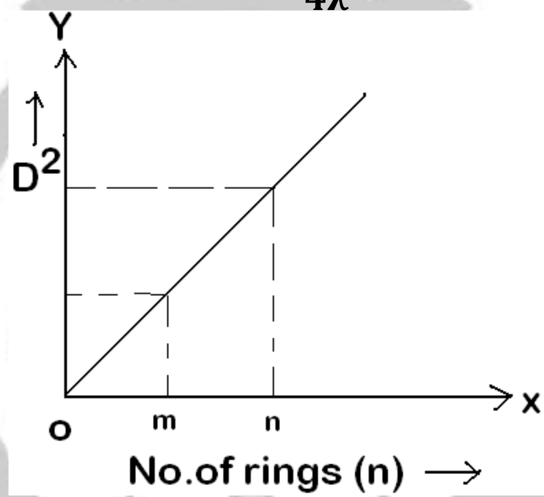
Standard value = 100 cm.

$$\%\text{error} = \frac{\text{standard value} - \text{calculated value}}{\text{standard value}} \times 100\% = \ldots\ldots\ldots\ldots\ldots\ldots\%$$

Graphical calculation :

Plot a graph between $D_n^2\ (\text{cm.})^2$ vs ring no. (n) by taking D_n^2 on y-axis and ring no. n on x-axis. The graph will be straight line passing through origin. Find slope of the graph and calculate R using the formula

$$\mathbf{R = \frac{slope}{4\lambda}}$$



Result/Conclusion:

The radius of curvature of the supplied Plano convex lens was found to be ……………cm. with error of ……………….%.

By graph R=…………………cm.

Precautions:

(1) Glass plates and lens should be cleaned thoroughly.
(2) The plano-convex lens should be of large radius of curvature.
(3) The sources of light used should be an extended one.
(4) The range of the microscope should be properly adjusted before measuring the diameters.
(5) Crosswire should be focused on a dark ring tangentially.
(6) The centre of the ring system should be a dark spot.
(7) The microscope is always moved in the same direction to avoid back lash error.
(8) Radius of curvature should be measured accurately.
(9) Since the first few rings near the center are deformed, they must be avoided while taking readings for the rings.

(10) Care must be taken not to disturb the lens and glass plate combination in any way during the experiment.

Questions:

1. In the Newton's ring experiment, how does interference occur?
2. Where have the fringes formed?
3. Why are the fringes circular?
4. Are all rings equispaced?
5. Why is an extended source used in this experiment?
6. What will happen if a point source or an illuminated slit is used instead of the extended source?
7. In place of lens, if a wedge shaped film formed by two glass plates is supplied to you, will you be able to observe Newton's ring? Why?
8. How is the central spot in your experiment, bright or dark? Why?
9. Instead of reflected rays, if you look at transmitted rays, what do you expect to observe?
10. What happens with the central spot when a liquid of refractive index greater than that of the lens and less that that of the glass plate is introduced between the lens and the glass plate?
11. Is it possible to determine the refractive index of the liquid by this experiment?
12. What would happen to the ring if the space between lens and the plate is filled with a liquid of refractive indexs?
13. What do you expect to see in the microscope if you use a white light source?
14. What is the difference between biprism fringes and Newton's ring fringes?
15. On which factors does the diameter of a ring depend?
16. What would happen if a glass plate is replaced by a plane mirror?
17. Why should a lens of large radius of curvature be used in this experiment?
18. Is it desirable to measure the radius of curvature of the given lens by a spherometer in the usual way?
19. What do you understand by (a) fringes of equal thickness (b) fringes of equal inclination and (c) fringes of equal chromatic order.
20. How does the sodium source, which you are using in your experiment

Experiment No. 3

Aim:

To determine the value of Young's modulus of the material of the supplied wire by using Searl's apparatus.

Apparatus Required :

Searl's apparatus, Screw gauge, meter scale, slotted weight, wire.

Theory :

Any solid material undergoes some elastic deformation if we apply a small external force on it. Whenever, engineers design bridges or buildings and structural implants for body, it is useful to know the limits of elastic deformation for endurance.

Young's modulus is a measure of the stiffness of a solid material. It is calculated only for small amounts of elongation or compression which are reversible and do not cause permanent deformation when the external applied force is removed.

Young's modulus is a characteristic property of the material and is independent of its dimensions i.e., its length, diameter etc. However, its value depends on ambient temperature and pressure.

Consider a wire of length L and diameter d. Let its length L increases by an amount l when the wire is pulled by a longitudinal external force F. Young's modulus of the material of the wire is given by,

$$\mathbf{Y} = \frac{\text{Longitudinal stress}}{\text{Longitudinal strain}} = \frac{F/A}{l/L} = \frac{FL}{Al} = \frac{mgL}{\frac{\pi d^2}{4}\,l} = \frac{\mathbf{4gL}}{\boldsymbol{\pi}\mathbf{d^2}}\left(\frac{\mathbf{m}}{\mathbf{l}}\right)$$

Here,

F = mg and $A = \frac{\pi d^2}{4}$

The units of Young's modulus are the same as that of stress (note that strain is dimensionless) which is same as the units of pressure i.e., **N/m^2 or $dyne/cm^2$**. Graphically, Young's modulus is generally determined from the slope of stress-strain curve.

Searl's Apparatus:

It consists of two wires (control or reference wire and test wire) of equal lengths and are attached to a rigid support (see figure). Both control and test wires are connected to a horizontal bar at the other ends. A spirit level is mounted on this horizontal bar. Now, this bar is hinged to the control wire. If we increase the weight on the side of test wire, it gets extended and causes the spirit level to tilt by a small amount. We can adjust any tilt of the spirit level by turning the screw of a micrometer, which is positioned on the test wire side. We restore it to the horizontal position to take the desired readings.

In a variation of Searle's apparatus, the control wire supports a vernier scale which will measure the extension of the test wire. The force on the test wire can be varied using the slotted masses. The micrometer is same as screw gauge. It has a main scale (shown vertically in the figure) and a circular scale (shown horizontally in the figure). When the screw is rotated to make the spirit level horizontal, the readings of the main scale and circular scale change. These readings are used to find the elongation l of the test wire.

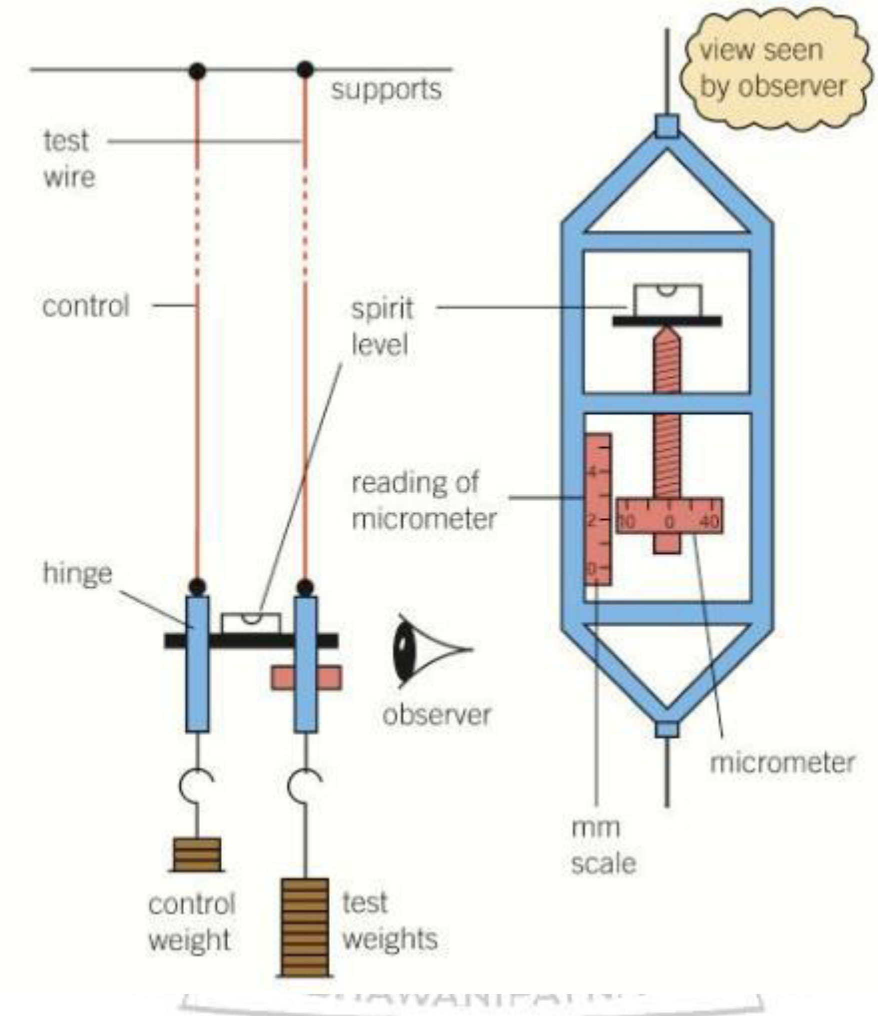


Figure : searl’s apparatus

Procedure :

1. Measure the initial length L of the wire by using a meter scale.

2. Measure the diameter d of the wire by using a screw gauge. The diameter should be measured at several different points along the wire and at mutually perpendicular directions at each place of the wire. Take mean value of these reading to get the average diameter.

3. Adjust the spirit level so that it is in the horizontal position by turning the micrometer. Record the micrometer reading to use it as the reference reading.

4. Load the test wire with a further weight. The spirit level tilts due to elongation of the test wire.

5. Adjust the micrometer screw to restore the spirit level into the horizontal position and record the micrometer reading.

6. Repeat above steps by increasing load on the test wire from the minimum value to the maximum value (loading) and in another set, measure the elongation by decreasing the test weight from the maximum value to the minimum value (unloading), in same number of steps.

7. Find elongation for equal step weights.

8. Plot the graph between elongation and weight loaded; it should be a straight line passing through origin. Determine the value of the slope and then calculate Y.

Observations:

Initial Length of wire L = …………………..cm.

Table-1 For measurement of diameter (d) of the wire.

Pitch of screw gauge = …………………..mm. = ……………………..cm.
Least count of screw gauge = …………………..mm = …………………..cm.

S.No.	**Pitch (P) (cm.)**	**Least. Count (L.C.) (cm.)**	**Initial C.S.R. (I)**	**No. of turns (N)**	**Final C.S.R. (F)**	**D= I~F**	**P.S.R. = P×N (cm.)**	**C.S.R. = D×L.C.**	**Total= P.S.R. + C.S.R.**	**Mean diameter (cm.)**
1										
2										
3										
4										
5										
6										

Table-2 For load and extension

Least count of micrometer srew = ……………………mm. = …………………cm.

S. No.	Additi-onal load (m) in (gm.)	Micrometer reading (load increasing)		$X_1=R_1-R_2$	Micrometer reading (load decreasing)		$X_2=R'_1-R'_2$	$D = \left(\frac{x_1+x_2}{2}\right) \times L.C.$	Elogation (l) in (cm.)
		C.S.R. at the begning of the step (R_1)	C.S.R. at the end of the step (R_2)		C.S.R. at the begning of the step (R'_1)	C.S.R. at the end of the step (R'_2)			
1	0								
2	500								
3	1000								
4	1500								
5	2000								
6	2500								
7	3000								

Calculations:

From table 1, d = …………………………cm.

From table 2, by plotting the graph between Elogation (l) in cm. vs load m (gm.), taking elogation on y-axis and load on x-axis we get a straight line passing trough origin. From graph find

$$\frac{m}{l} = \frac{1}{slope} = \dots\dots\dots\dots\dots\dots\dots \ gm./cm.$$

Initial length of wire L = ………………………cm.

Acceleration due to gravity, g = 980 cm./sec^2

Calculate the value of young's modulusby using the formula

$$Y = \frac{4gL}{\pi d^2}\left(\frac{m}{l}\right) \quad = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{dyne/cm.}^2$$

Standard value of young's modulus for material(……………………..) of wire = ……………………………….dyne/cm.^{2}

Calculate %error by using the formula

$$\%\text{error} = \frac{\text{standard value} - \text{calculated value}}{\text{standard value}} \times 100\% \ = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots..\%$$

Result/Conclusion:

The young's modulus of the material (…………….) of the supplied wire is found to be ……………………………..dyne/cm.^{2}

Precautions:

1. The control (or reference) wire and the test wire are must be of the same material.
2. The wires used in the experiment are identical, long and thin. The long and thin wires gives larger elongation and hence better measurement accuracy.
3. The wires should be taut otherwise length L can not be measured correctly. The control weight or dead weight is used to make the wires taut.
4. When a set of readings are taken, the micrometer screw must be rotated in the same direction to avoid back-lash error.
5. After adding a load or removing a load, wait for some time before taking the next reading this will help the wire to elongate or contract fully.

Experiment No. 4

Aim:

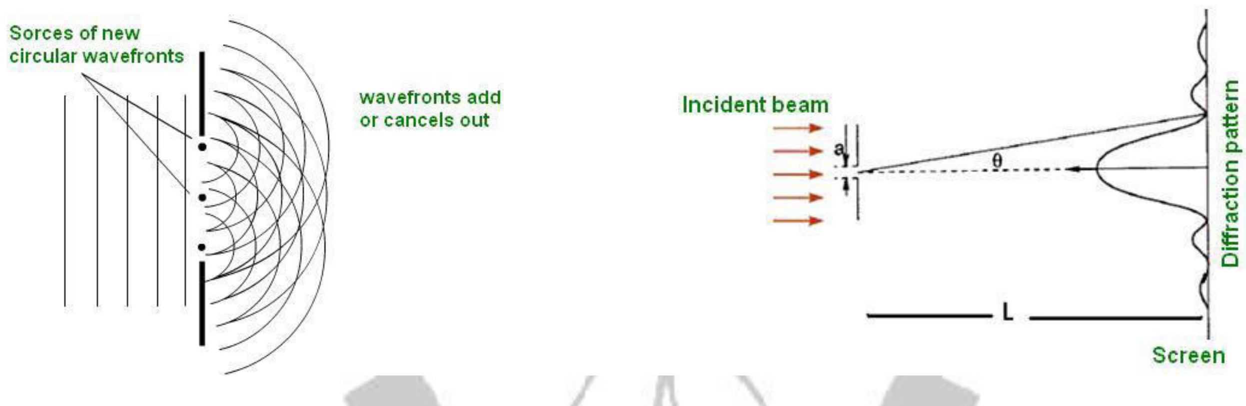
To determine the grating element of the supplied plane diffraction grating using monochromatic source of light.

Apparatus required:

Spectrometer, source of monochromatic light (sodium vapour lamp), magnifying lens with light.

Theory:

When a wave train strikes an obstacle, the light ray will bend at the corners and edges of it, which causes the spreading of light waves into the geometrical shadow of the obstacle. This phenomenon is termed as diffraction.



Diffraction grating is an optical component having a periodic structure consists of several identical parallel and equidistance slits which can split and diffract light at several beams travelling in different directions. This depends on the spacing of two consecutive slit on the grating and the wavelength of the incident light.

At normal incidence,

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

Where, a = slit width

b = width of opaque region between teo consecutive slits

θ_n = Angle of diffraction for n^{th} order fringe

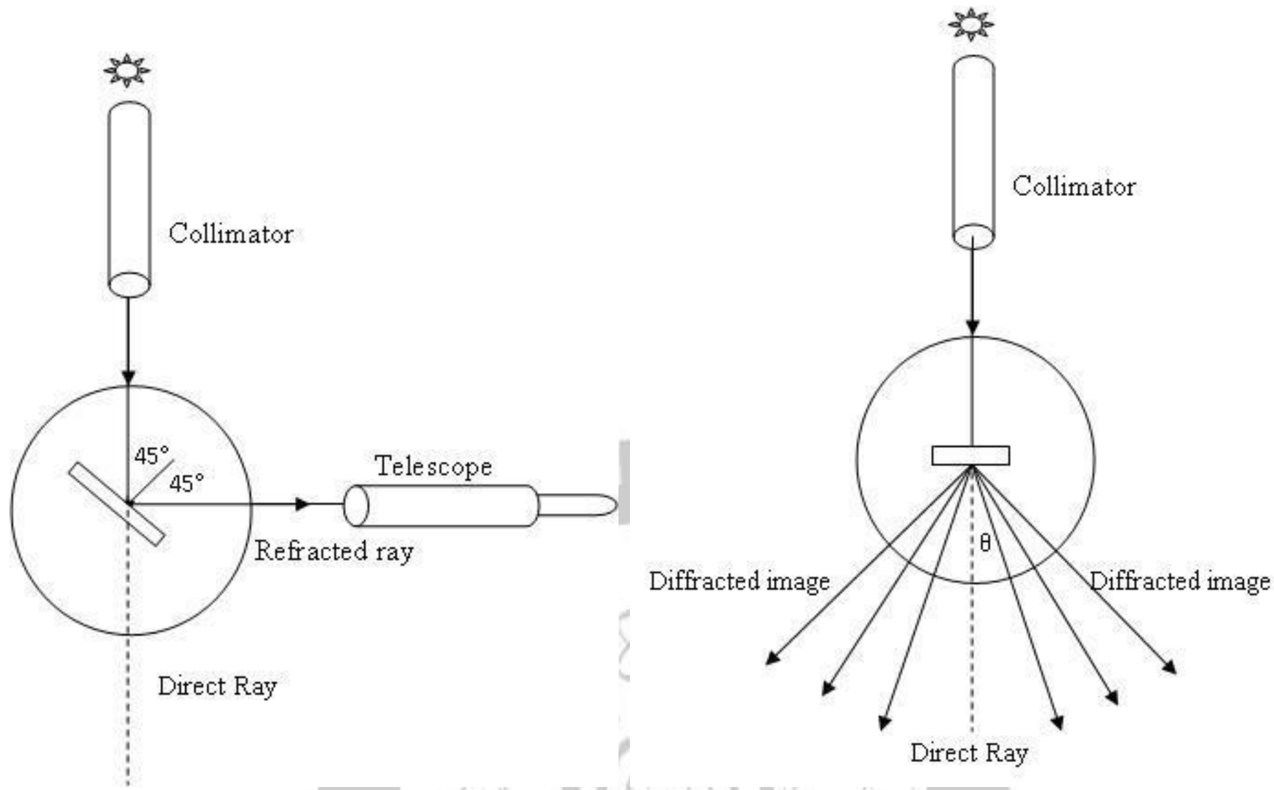
λ = wavelength of light used

n = order of grating spectrum

Grating element = (a+b)= space between two consecutive slit

= slit width +width of opaque region between teo consecutive slits

$$\boldsymbol{Grating\ element = (a+b) = \frac{n\lambda}{\sin\theta_n}}\ \textbf{(c.m.)}$$



Ray diagram of apparatus

Procedure:

The preliminary adjustments of the spectrometer are made. The grating is set for normal incidence. The slit is illuminated by sodium vapour lamp. The telescope is brought in a line with the collimator and the direct image of the slit is made to coincide with the vertical cross wire. The readings of one vernier are noted. The vernier table is firmly clamped. Now, the telescope is rotated exactly through 90° and is fixed in this position. The grating is mounted vertically on the prism table with its ruled surface facing the collimator. The vernier table is released and is slowly rotated till the reflected image coincides with the vertical cross wire. The leveling screws are adjusted so that the image is at the centre of the field of view of the telescope. The prism table is fixed and after making fine adjustments with the tangential screw, the readings of the vernier are noted. Now, the angle of incidence is 45°. The vernier table is then released and rotated exactly through 45° in the proper direction so that the surface of the grating becomes normal to the incident light. The vernier table is firmly clamped in this position.

The telescope is then released and is brought to observe the direct image. On the either side of the direct image, the diffraction spectra are seen.The telescope is turned slowly towards the left so that the vertical cross wire coincides with the mid of yellow lines of the first order. The readings of the vernier are taken. The vertical cross wire is then made to coincide with the second order lines on the left and the vernier readings are taken in each case. The telescope is then moved to the right and the reading of different order lines is similarly taken. The difference between the readings on the left and right on the same vernier is determined for each order line. The mean value of this difference gives 2θ-twice the angle of diffraction.

Thus the angle of diffraction θ for each spectral line is determined. The wavelength of the sodium light line is 5893 x10^{-10}m. The grating element is calculated for each order and then take the mean.

Observations:

Least count of spectrometer = …………………………………

Order of fringe	**Vernier no.**	**Spectrometer reading Left hand side**				**Spectrometer reading Right hand side**				**$2\theta_n = x_1 \sim x_2$**	**$\theta_n = {2\theta_n}/{2}$**	**mean θ_n**
		M.S.R.	**V.C.**	**V.S.R. =V.C.× L.C.**	**Total (x_1)**	**M.S.R.**	**V.C.**	**V.S.R. =V.C.× L.C.**	**Total (x_2)**			
1^{st} n = 1	**I**											
	II											
2^{nd} n = 2	**I**											
	II											

Calculations :

We have

$$\textbf{Grating element} = (a+b) = \frac{n\lambda}{\sin\theta_n} \text{ (c.m.)}$$

For 1 st order

n = 1
θ_1 = ……………………..
λ = 5893 × 10^{-8} c.m.
$(a+b)_1$ = ………………………………………. c.m.

For 2 nd order

n = 2
θ_2 = ……………………..
λ = 5893 × 10^{-8} c.m.
$(a+b)_2$ = ………………………………………. c.m.

$$\textbf{Mean } (a+b) = \frac{(a+b)_1 + (a+b)_2}{2}$$

= …………………………………………..c.m.

Standard value of grating element for supplied grating = 1.6933×10^{-4} c.m.

Calculate %error by using the formula

$$\%error = \frac{standard\ value - calculated\ value}{standard\ value} \times 100\%$$ =……………………..%

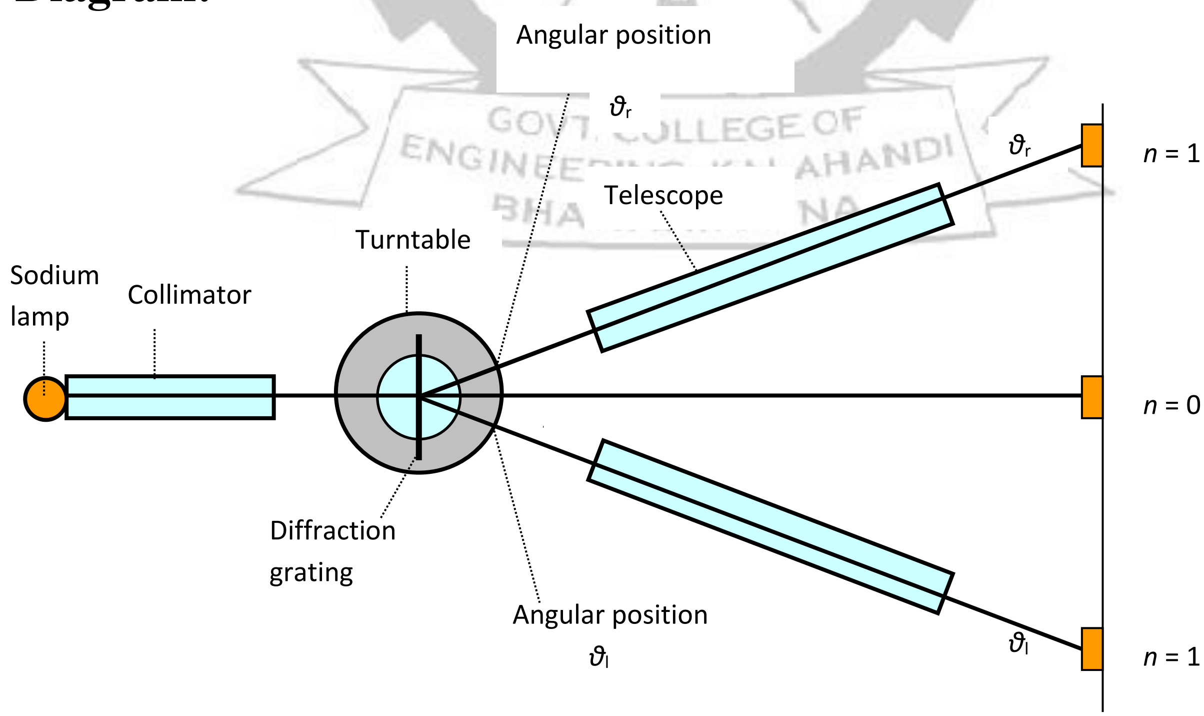
Result/Conclusion:

The grating element of the supplied plane diffraction grating is found to be ………………………………. c.m. with an error of ………………………%.

Precautions:

1. Make sure diffraction grating is standing vertically
2. Ensure turntable is horizontal/flat by using the levlling screws
3. Check that the vernier callipers are set at 0 degrees before proceeding
4. Adjust the eyepiece until the crossthreads are clearly in focus
5. Adjust the slit so that a narrow beam can be seen through the crossthreads
6. Check that the central ray is shining directly through the centre of the crossthreads.
7. Set collimeter so that only parallel rays come through

Diagram:



Experiment No. 5

Aim:

To study Hall's effect and determine the Hall's coefficient and concentration of the charge carrier of the supplied specimen.

Apparatus Required:

Two solenoids, Power supply for electromagnet, constant current source, digital gauss meter, Hall probe, four brobe, a piece of semiconductor, Hall effect apparatus (which consist of Constant Current Generator (CCG), milli voltmeter and milli ammeter etc.).

Theory:

If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

Consider a rectangular conductor of thickness ***t*** kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current ***I*** flow through the sample. If ***w*** is the width of the sample and ***t*** is the thickness. There for current density is given by

$$J_x = I/wt \qquad (1)$$

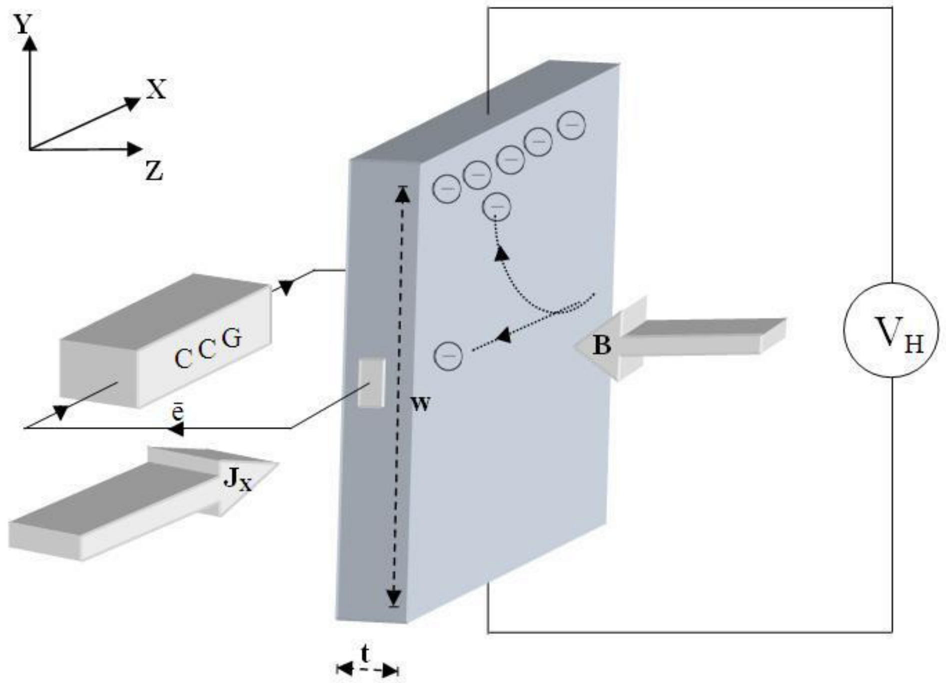


Fig.1 Schematic representation of Hall Effect in a conductor.

CCG – Constant Current Generator,
JX – current density,
ē – electron,
B – applied magnetic field,
t – thickness,
w – width
VH – Hall voltage

If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field $\mathbf{E_y}$ in the sample. This develop a potential difference along y-axis is known as Hall voltage V_H and this effect is called Hall Effect.

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field B=0, the voltage difference will be zero.

We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In both cases, under the application of magnetic field the magnetic Lorentz force, $F_m = q\ (v\ \times B)$ causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter.

In steady state condition, the magnetic force is balanced by the electric force. Mathematically we can express it as

$$eE = evB \qquad (2)$$

Where 'e' the electric charge, 'E' the hall electric field developed, 'B' the applied magnetic field and 'v' is the drift velocity of charge carriers.

And the current 'I' can be expressed as,

$$I = neAv \qquad (3)$$

Where 'n' is the number density of electrons in the conductor of length l, breadth 'w' and thickness't'.

Using (1) and (2) the Hall voltage V_H can be written as, [∵A = w x t]

$$V_H = Ew = vBw = \frac{IB}{net}$$

$$V_H = R_H \frac{IB}{t} \qquad (4)$$

by rearranging equation (4) we get

$$R_H = \frac{V_H}{I} \times \frac{t}{B} \qquad (5)$$

Where R_H is called the Hall coefficient.

$$R_H = 1/ne \qquad (6)$$

Description of apparatus:

This experimental set-up consists of 3 main instrumental parts.

1) **Digital Gaussmeter with Hall probe :-**

Hall probe cable is to be plugged-in to the socket of the digital gaussmeter and the power should be given to the gaussmeter. This probe also operates basing on the principle of Hall effect. A small current sent through the Hall probe develops a small Hall voltage when it is placed in a magnetic field and the Hall voltage is amplified by an amplifier whose output is calibrated in Gauss which directly gives the magnetic induction (B) value in the gaussmeter.

2) **Electromagnet with constant current supply :-**

Two insulated Copper wires are wound on two soft iron bars whose faces are facing each other. When a D.C. current (in amperes) from a constant current source is sent through the coils, the faces of the iron bars acts as the two poles of a magnet (electromagnet) creating a magnetic field in between them. The gap between poles can be varied , in general, the gap should be 1 cm.

3) Hall effect board with Hall probe semi-conductor specimen mounted on sun mica PCB :-

A specithen of rectangular semi-conductor slab in which Hall effect is to be studied is fixed to a printed circuit board (PCB) with the help of 4 supporting terminals. Out of 4 terminals, 2 terminals are along the length and these (Middle & green) terminals are connected to the current source of the Hall effect board. The other 2 terminals are along the width and these (Red) terminals are connected to the Voltmeter of the Hall effect board. The Hall effect board has 2 uses. A) To pass current (IX) through the specimen & to measure that current. B) To measure the Hall voltage (VH) developed across the specimen. To meet these two purposes a two mode switch is arranged to the digital meter of the board. First mode is to measure the current (IX), sent through the specimen and the second mode is to measure the Hall voltage (VH) developed across the specimen.

Procedure:

- Connect 'Constant current source' to the solenoids.
- Four probe is connected to the Gauss meter and placed at the middle of the two solenoids.
- Switch ON the Gauss meter and Constant current source.
- Vary the current through the solenoid from 1A to 5A with the interval of 0.5A, and note the corresponding Gauss meter readings…………
- Switch OFF the Gauss meter and constant current source and turn the knob of constant current source towards minimum current.
- Fix the Hall probe on a wooden stand. Connect green wires to Constant Current Generator and connect red wires to milli voltmeter in the Hall Effect apparatus
- Replace the Four probe with Hall probe and place the sample material at the middle of the two solenoids.
- Switch ON the constant current source and CCG.
- Carefully increase the current I from CCG and measure the corresponding Hall voltage V_H. Repeat this step for different magnetic field B.
- Thickness t of the sample is measured using screw gauge.
- Hence calculate the Hall coefficient R_H using the equation 5.
- Then calculate the carrier concentration n. using equation 6.

Observations:

Thickness of Specimen 't' = ________________________ m
Magnetic Flux Density 'B' = _____________ Gauss = ______________ X 10^{-4} Tesla

Observation Table:

S.No.	I (mA)	V_H (mV)	(V_H/I) (Ω)	Mean (V_H/I) (Ω)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Calculations:

The Hall's coefficient of specimen is given by

$$R_H = \frac{V_H}{I} \times \frac{t}{B} \quad (m^3C^{-1}) \quad \frac{V_H}{I} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \Omega$$

B =…………………………..Tesla
t = …………………………...m

Now

R_H = ………………………………………… m^3C^{-1}

$$n = \frac{1}{R_H\, e} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ no. of carriers / } m^3$$

Result/Conclusion :

The value of Hall's coefficient is found to be ………………………mC^{-1} and the concentration of charge carrier is found to be ………………………….no. of carriers / m^3.

Precautions:

1) Electromagnet power supply should be connected to a 3 pin main socket having good earth connection.
2) Switch "ON" or "OFF" the power supply at zero current position.
3) Adjust the distance between the poles of the magnet nearly 1 cm, then only the gaussmeter shows correct reading.

Experiment : 6

Aim:

To determine the surface tension of a liquid (water) by capillary rise method.

Apparatus required:

A clean and dry capillary tube, a glass beaker containing water, adjustable wooden stand, a tipped pointer, clamps and stand, a traveling microscope and reading lens.

Formula used:

The surface tension of a liquid is given by the formula.

$$T = r\left(h + \frac{r}{3}\right)\frac{\rho g}{2} \qquad N/m$$

Where, r = radius of the capillary tube at the liquid meniscus

h = height of the liquid in the capillary tube above the free surface of liquid in the beaker

ρ = density of water (ρ = 1.00 × 10^3 Kg/m^3 for water)

Theory:

When glass is dipped into a liquid like water, it becomes wet. When a clean fine bore glass capillary is dipped into such a liquid it is found to rise in it, until the top of the column of water is at a vertical height 'h' above the free surface of the liquid outside the capillary. The reason for this rise is the surface tension, which is due to the attractive forces between the molecules of the liquid. Such forces called cohesive forces try to make the surface of the liquid as small as possible. This is why a drop of liquid is of spherical shape.

Since the surface tension tries to reduce the surface of a liquid we can define it as follows. If an imaginary line of unit length is drawn on the surface of a liquid, then the force on one side of the line in a direction, which is perpendicular to the line and tangential to the surface, is called SURFACE TENSION.

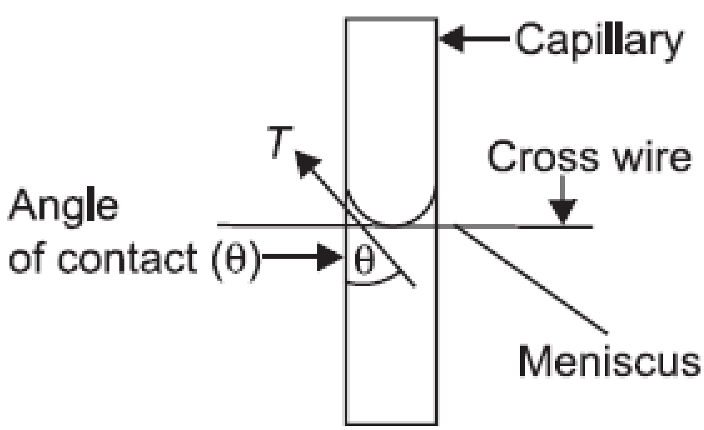


Fig. 1 Magnified view of the meniscus in the capillary.

When the liquid is in contact with the glass then on the line of contact the cohesive forces (or surface tension) try to pull the liquid molecules towards the liquid surface and the adhesive forces *i.e.* the forces between the molecules of the glass and the liquid try to pull the liquid molecules towards the glass surface. Equilibrium results when the two forces balance each other. Such equilibrium arises after the water has risen in the capillary to a height of 'h'. This column has weight equal to *mg* where *m* is the mass of the water in the column. This balances the upward force due to the surface tension which can be calculated as follows:

The length of the line of contact in the capillary between the surface of the water and the glass is $2\pi r$ where 'r' is the radius of the capillary. As seen from Fig.1, the surface tension *T* acts in the direction shown and θ is called the angle of contact. The upward component of T is given by $T\ cos\ \theta$ and therefore, recalling that *T* is the force per unit length, we get the total upward force equal to $2\pi rTcos\theta$. This must balance the weight *mg* and we have

$$mg = 2\pi rT\ cos\ \theta$$

For water-glass contact, $\theta = 0°$ and so $cos\ \theta = 1$

Therefore, $$mg = 2\pi rT \qquad \text{...(1)}$$

Now $$m = rV \qquad \text{...(2)}$$

Where r is the density of the liquid and *V* is the Volume of the column of water

Since radius of the capillary is '*r*'

$$V = \pi r^2 h + volume\ in\ meniscus \text{ (See Fig. 1).}$$

And

The volume of liquid in the meniscus =

volume of cylinder radius '*r*' & height '*r*' – volume of hemisphere of radius 'r'

i.e. Volume in meniscus $= \pi r^3 - \left(\frac{2}{3}\right)\pi r^3 = \frac{1}{3}\pi r^3$

Therefore, $$V = \pi r^2 h + \frac{1}{3}\pi r^3 = \pi r^2\left(h + \frac{r}{3}\right) \qquad \text{...(3)}$$

Substituting the value of *V* from Eq. (3) in Eq. (2) we obtain

$$m = \rho\pi r^2\left(h + \frac{r}{3}\right)$$

and so, Eq. (1) becomes

$$2\pi rT = \rho\pi r^2\left(h + \frac{r}{3}\right)g$$

or

$$\boxed{T = r\left(h + \frac{r}{3}\right)\frac{\rho g}{2}}$$

For water in C.G.S. units, $\rho = 1$ and we finally obtain the formula for a glass capillary dipping in water to be

$$\boxed{T = r\left(h + \frac{r}{3}\right)\frac{g}{2}}$$

in C.G.S. units, *i.e.* dynes/c.m. at ....°c

Where r = radius of the capillary tube at the liquid meniscus, h = height of the liquid inthe capillary tube above the free surface of liquid in the beaker.

Procedure:

To set up the apparatus :

- Place the adjustable height stand on the table and make its base horizontal by leveling the screws.
- Fix the capillary tube and the pointer in a cork, and clamp it in a rigid stand so that the capillary tubes and the pointer become vertical.
- Adjust the height of the vertical stand, so that the capillary tubes dip in the water in an open beaker.
- Adjust the position of the pointer, such that its tip just touches the water surface.

To find the capillary rise :

- Find the least count of the travelling microscope for the horizontal and the vertical scale.
- Make the axis of the microscope horizontal.
- Adjust the height of the microscope using the height adjusting screw.
- Bring the microscope in front of the capillary tube and clamp it when the capillary rise becomes visible.
- Make the horizontal cross wire just touch the central part of the concave meniscus.
- Note the reading of the position of the microscope on the vertical scale.
- Now, carefully remove the beaker containing water
- Move the microscope horizontally and bring it in front of the pointer.
- Lower the microscope and make the horizontal cross wire touch the tip of the pointer.
- Corresponding vertical scale readings are noted.
- The difference in the two readings (i.e., height of water meniscus and height of the tip of pointer) will give the capillary rise of the given liquid.
- We can repeat the experiment by changing the height of the wooden stand.

To find the internal diameter of the capillary tube :

- Place the capillary tube horizontally on the adjustable stand.
- Focus the microscope on the end dipped in water.
- Make the horizontal cross- wire touch the inner circle at A (fig i). Note microscope reading on the vertical scale.
- Raise the microscope to make the horizontal cross wire touch the circle at B (fig ii). Note the vertical scale reading.
- The difference between the two readings will give the vertical internal diameter (AB) of the tube.
- Move the microscope on the horizontal scale and make the vertical cross wire touch the inner circle at C (fig iii). Note microscope reading on the horizontal scale.
- Move the microscope to the right to make the vertical cross wire touch the circle at D (fig iv). Note the horizontal scale reading.

- The difference between the two readings will give the horizontal internal diameter (CD) of the tube.

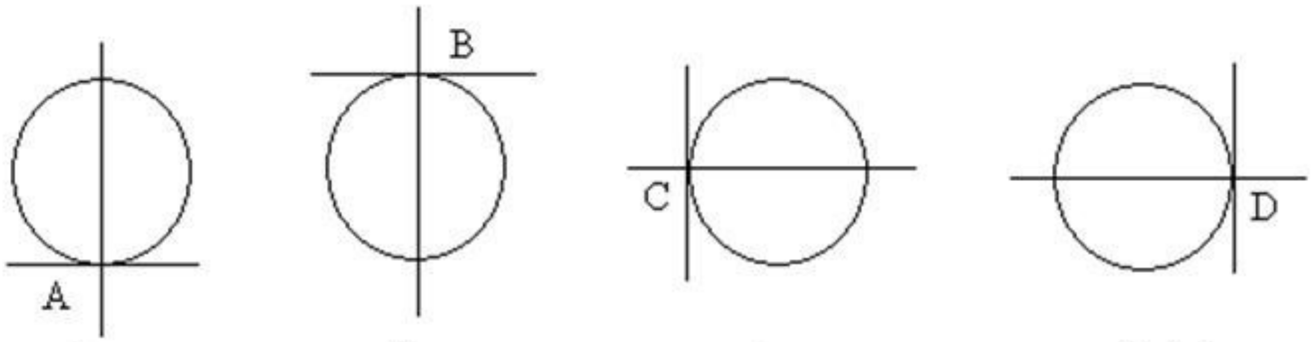


fig (i) fig (ii) fig (iii) fig (iv)

- We can calculate the diameter of the tube by calculating the mean of the vertical and horizontal internal diameters. Half of the diameter will give the radius of the capillary tube.

Observations:

Room temperature = ……………………°C

Least count of the traveling microscope = ……………………….mm
=……………………….c.m.

Table1- To find the capillary rise

S. No	Reading at the water meniscus			Reading at the tip of pointer			Height, h = h_1-h_2 (cm)	Mean h (cm)
	M.S.R. (cm)	V.S.R. (div.)	Total = MSR+(VSR×LC) h_1 (cm)	M.S.R. (cm)	V.S.R. (div.)	Total = MSR+(VSR×LC) h_2 (cm)		
1								
2								
3								

Table2- To find the internal diameter of the capillary tube

S. No	Microscope reading for one position			Microscope reading for other position			Internal diameter, d= x_1-x_2 (cm)	Mean d (cm)
	M.S.R. (cm)	V.S.R. (div.)	Total = MSR+(VSR×LC) x_1 (cm)	M.S.R. (cm)	V.S.R. (div.)	Total = MSR+(VSR×LC) x_2 (cm)		
1 Position A or B								
2 Position C or D								

Calculations:

The surface tension of water in C.G.S. unit is given by the formula

$$T = r\left(h + \frac{r}{3}\right)\frac{g}{2} \quad \text{dyne/c.m.}$$

Acceleration due to gravity g = ………………… c.m./sec^2

From table1

h = …………………………..c.m.

From table2

r = …………………………..c.m.

Surface tension of water T = ...………dyne/c.m.

= ……………………..N/m

Standard value of surface tension of water at temperature ……….°C =…………..

Calculate the %error by using the formula

$$\%error = \frac{standard\ value - calculated\ value}{standard\ value} \times 100\%$$

=………………………%

Result/Conclusion:

Surface tension of water at temperature …………….. °C is found to be …………………dynes/cm = ………………. N/m with error …………………………….%

Precautions:

1. The water surface and the capillary must be clean since the surface tension is affected by contamination.
2. Capillary tube must be vertical.
3. Capillary tube should be clean and dry.
4. Capillary tube should be of uniform bore.
5. Since the capillary may be conical in shape, so it would be better to break the capillary at the site of the meniscus and find the diameter at that point. However, this is not permitted in our laboratory.
6. The diameter of the tube must be measured very accurately in two perpendicular directions at the point upto which liquid rises.

Experiment No. 7

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 Required:

Two parallel knife edges on which the beam is placed, a hook to suspend weightseith a neddle at top, a meter scale, travelling microscope, 500gm weights, 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.

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

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 = depression of the beam in the middle, d = thickness of the beam.

Theory:

Young's modulus is named after Thomas Young, 19th century, British scientist. In solid mechanics, Young's modulus is defines as the ratio of the longitudinal stress over longitudinal strain, in the range of elasticity the Hook's law holds (stress is directly proportional to strain). It is a measure of stiffness of elastic material.

The arrangement of a beam supported at its both the ends and loaded in the middle is the most convenient method of measurements. A long beam AB of uniform cross-section is supported symmetrically on two knife edges K_1 and K_2 in the same horizontal plane and parallel to each other at a distance l apart. When the beam is loaded at its middle point c by a weight W, this generates two reactions equal to $W/2$ each, acting vertically upwards at the two knife-edges. The beam is bent in the manner as shown in figure. The maximum depression is produced in the middle of the beam where it is loaded.

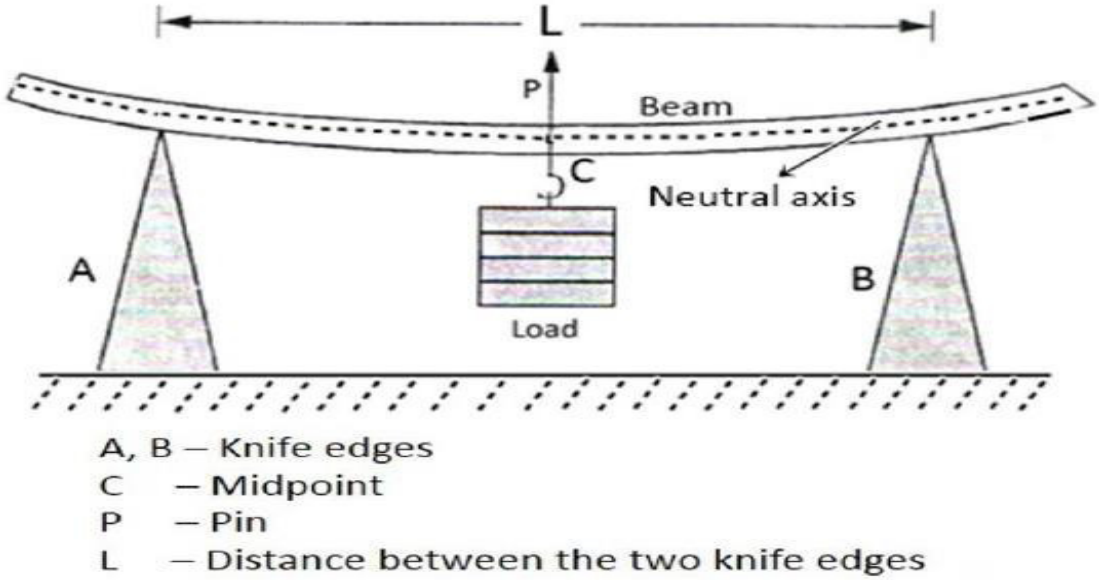


Fig. Young's modulus - Non-uniform bending

By consideration of symmetry it is clear that the tangent to the beam at C will be horizontal. Hence the beam can be divided into two portions AC and CB by a transverse plane through the middle point of the beam. Each portion can be regarded as a cantilever of length $l/2$, fixed horizontally at point C and carrying a load $W/2$ in the upward direction at the other end (i.e., these are inverted cantilevers). The elevation of the ends A and B above middle point C is equal to the depression of the point C.
The depression at the middle point is thus obtained as

$$\delta = \frac{\frac{W}{2} \times \left(\frac{l}{2}\right)^3}{3YI} = \frac{Wl^3}{48YI}$$

since W = Mg

$$\delta = \frac{Mgl^3}{48YI}$$

For a rectangular beam of breadth b and thickness d

Moment of Inertia $I = \frac{bd^3}{12}$

Hence depression $\delta = \frac{Mgl^3}{4Ybd^3}$

From these expressions, knowing the dimensions of the beam and the depression at the middle point by a known weight, the value of Young's modulus Y, for the material of the beam can be calculated.

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.

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

(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 travelling microscope.

(7) Suspend the hanger with a needle attached to it, on the mid-point of the beam. Now focus the microscope on needle tip such that horizontal line of cross wire tangent to needle tip and note its reading. This gives zero mass depression.

(8) Now load 500 gm on hanger. At this position, Further focus the microscope on needle tip such that horizontal line of cross wire tangent to needle tip and note its reading. This gives depression for 500gm.

(9) Increase the mass on hanger till 3000gm in interval of 500gm and note the microscope reading when horizontal line of cross wire tangent to needle tip.This will give you the depressions at different masses.

(10) Note the same reading of depression, for M=3000gm in case of decreasing load.

(11) Now remove the 500gm mass from hanger and again focus the microscope on needle tip such that horizontal line of cross wire tangent to needle tip and note its reading. This provides you the value of depression for 2500gm mass at load decreasing case.

(12) Similarly decrease the load up to zero mass in steps of 500gm and note the microscope reading when horizontal line of cross wire tangent to needle tip. This will give you the depressions at different masses in case of load decreasing.

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

(14) Now calculate the difference of mean microscope 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 among 1st& 4th, 2nd&5th and 3rd and 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 slop. The slop 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:

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

Table1 - for thickness (d) of beam:

Least count of screw gauge= ……………………….mm =…………………..……cm

S.No.	Pitch (P) (cm.)	Least. Count (L.C.) (cm.)	Initial C.S.R. (I)	No. of turns (N)	Final C.S.R. (F)	D= I~F	P.S.R. = P×N (cm.)	C.S.R. = D×L.C.	Total= P.S.R. + C.S.R.	Mean thickness d (cm.)
1										
2										
3										

Table2 - for breadth (b) of beam:

Least count of Vernier calipers = ……………………cm
Zero error in Vernier calipers=………………………cm

S.No.	M.S.R. (cm.)	V.S.	V.S.R.= V.S. × L.C. (cm.)	Total = M.S.R.+V.S.R. (cm.)	Mean un-corected breadth T (cm.)	corrected breadth (b=T± zero error) (cm.)
1						
2						
3						

Table3 - for mass and depression:

Least count of travelling microscope = ……………………cm

S. No.	Additi-onal load (m) in (gm.)	Reading of travelling microscope								Mean $y = \frac{(y1+y2)}{2}$ (c.m.)	Depression δ (cm.)
		For load increasing				For load decreasing					
		M.S.R. (c.m.)	V.C.	V.S.R. (c.m.)	y_1= M.S.R. +V.S.R. (c.m.)	M.S.R. (c.m.)	V.C.	V.S.R. (c.m.)	y_2= M.S.R. +V.S.R. (c.m.)		
1	0									A	$\delta_1 = A - A$
2	500									B	$\delta_2 = B - A$
3	1000									C	$\delta_3 = C - A$
4	1500									D	$\delta_4 = D - A$
5	2000									E	$\delta_5 = E - A$
6	2500									F	$\delta_6 = F - A$
7	3000									G	$\delta_7 = G - A$

Calculations:

From table 1, Thickness d = …………………………cm.

From table 2, Breadth b = ……………………………cm.

From table 3, by plotting the graph between Depression (δ) in cm. vs load m (gm.), taking depression on y-axis and load on x-axis we get a straight line passing through the origin. From graph find

$$\frac{m}{\delta} = \frac{1}{\text{slope}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{gm.}/\text{cm.}$$

Length of the Beam between the two knife edges L = ………………………cm.
Acceleration due to gravity, g = ……………………..cm./sec^2

Calculate the value of young's modulus by using the formula

$$Y = \frac{gl^3}{4bd^3}\frac{M}{\delta} = \text{……………………………………dyne/cm.}^2$$

Standard value of young's modulus for material(……………………..) of beam = ……………………………….dyne/cm.^{2}

Calculate %error by using the formula

$$\%\text{error} = \frac{\text{standard value} - \text{calculated value}}{\text{standard value}} \times 100\% = \text{……………………..\%}$$

Result/Conclusion:

The young's modulus of the material (…………….) of the supplied Beam is found to be ……………………………..dyne/cm.^{2} with error of ………………% .

Precautions:

1. The knife edges should be rigid and fixed on rigid support.
2. The knife edges should be at 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 backless error, the circular scale of screw gauge and spherometer should be moved in one direction.
6. After adding a load or removing a load, wait for some time before taking the next reading this will help the wire to elongate or contract fully.

Experiment No. 8

Aim:

To determine the modulus of rigidity of the material of a given rod by static method using horizontal pattern of Barton's apparatus.

Apparatus Required:

Horizontal pattern of the BARTON's apparatus , half kilogram slotted weights with hanger , Thread , Meter scale and Screw gauge.

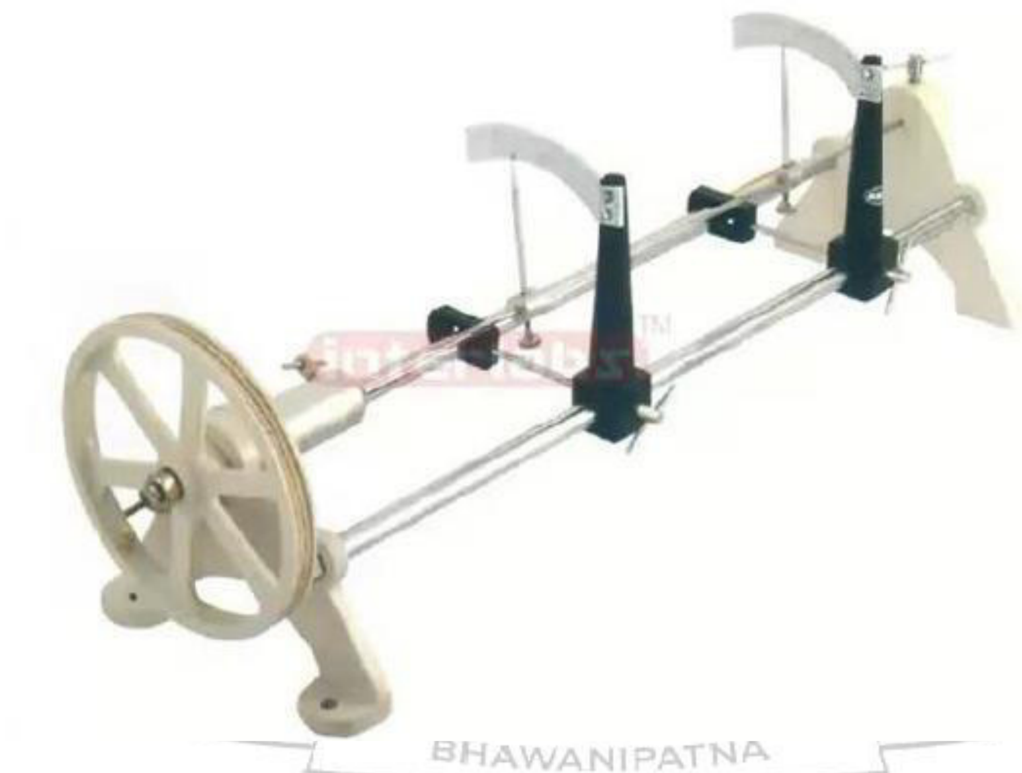


Fig.1 Barton's Horizontal arrangement apparatus

Working Formula:

The modulus of rigidity

$$\boldsymbol{\eta = \frac{180\ MgD\ (l_2 - l_1)}{\pi^2\ r^4\ (\theta_2 - \theta_1)}}$$

Where

M = Load suspended

g = acceleration due to gravity (g =980 cm/sec^2)

D = Diameter of the pulley.

r = Radius of the experimental rod.

θ_1 = The angle of twist produced at pointer No.1

θ_2 = The angle of twist produced at pointer No.2

$(l_2 - l_1)$ = The length of the rod between the two pointers

Description of the apparatus:

The horizontal pattern of Barton's apparatus is shown in fig.1. The experimental rod AB is rigidly clamped at the end A. The other end is attached to the centre of a pulley B (of large diameter). Pulley can rotate about the axis of the rod. The pulley is provided with a hook to whom a thread is tied. This thread is wound over the pulley and its free end is attached with a hanger or pan. There are two pointers which can be clamped anywhere on the experimental rod and they move over the circular scales as shown in fig.1 when a load is applied.

Theory:

When mass M is suspended in the hanger, then Mg will be the weight in the hanger. So, moment of this force about the axis of rotation (axis of experimental wire)

$$= Mg \times \frac{D}{2}$$

where D is diameter of the pulley.

If θ is the twist produced in the rod of radius r at a distance l from the fixed end then restoring couple setup in the wire

$$= \frac{\pi\theta\eta r^4 \times \pi}{2l \times 180°}$$

In equilibrium, external couple = Restoring couple

$$\frac{mgD}{2} = \frac{\pi\theta\eta r^4 \times \pi}{2l \times 180°} \quad \text{or} \quad \eta = \frac{180\, MgDl}{\pi^2\, r^4\, \theta}$$

To remove the error due to uncertainity in the position of the clamped end of the rod, note down the twist θ_1 and θ_2 for two lengths l_1 and l_2, then we have

$$\eta\theta_1 = \frac{180\, MgDl_1}{\pi^2\, r^4} \quad \text{and} \quad \eta\theta_2 = \frac{180\, MgDl_2}{\pi^2\, r^4}$$

$$\boldsymbol{\eta = \frac{180\ MgD\ (l_2 - l_1)}{\pi^2\ r^4\ (\theta_2 - \theta_1)}}$$

Procedure:

1. Find the least count of srew gauge. Measure the diameter of the experimental rod at different points using the screw gauge. Find mean diameter and then radius of the rod.
2. Find out the circumference $(2\pi r)$ of the Pulley by wrapping the rope once around the pulley and measure the length of the rope by a centimeter scale. Then calculate diameter of pulley.
3. Clamp the pointers at different places and measure the distance $(l_2 - l_1)$ between them using meter scale.
4. Put the hanger on the pulley and fix the pointer attached to the circular scale at the zero position.
5. Put a load of 0.5 kg on the hanger and observe the readings of the two circular scales $(\theta_1 and \theta_2)$ accordingly and measure corresponding angle of twist $(\theta_2 - \theta_1)$ of the rod.
6. Increase the load in steps of 0.5 kg on the hanger up to 3.0 kg and observe the differences of readings $(\theta_2 - \theta_1)$ between two circular scales.
7. Now repeat steps 5 and 6 by decreasing the load in steps of 0.5 kg from 3.0 kg to zero load.
8. Take mean of two and find out mean $(\theta_2 - \theta_1)$ for each load.

9. Plot the graph between load M vs angular twist of rod mean $(\theta_2 - \theta_1)$, by taking load M on x-axis and twist on y-axis.. The graph will be straight line passing through the origin. Find the slope of the graph and calculate M/$(\theta_2 - \theta_1)$ by using the slope of the graph.
10. Calculate modulus of rigidity of material of the rod using the formula

$$\boldsymbol{\eta = \frac{180\ MgD\ (l_2 - l_1)}{\pi^2\ r^4\ (\theta_2 - \theta_1)} = \frac{180\ gD\,(l_2 - l_1)}{\pi^2\ r^4}\ \frac{M}{(\theta_2 - \theta_1)}}$$

Observations:

- Circumference of the pulley C = ……………… cm.
- Length of the rod between the two pointers $(l_2 - l_1)$ = ……………. cm.

Table1- For radius of the Rod:

Least count of screw gauge L.C. = …………… mm. = …………….. cm.

S.No.	**Pitch (P) (cm.)**	**Least. Count (L.C.) (cm.)**	**Initial C.S.R. (I)**	**No. of turns (N)**	**Final C.S.R. (F)**	**D= I~ F**	**P.S.R. = P×N (cm.)**	**C.S.R. = D×L.C.**	**Total= P.S.R. + C.S.R.**	**Mean diameter D (cm.)**
1										
2										
3										

Table2- For twist of the Rod due to application of the load:

S.No.	**Load to the hanger M (gm)**	**Twist for load increasing**			**Twist for load decreasing**			**Angle of twist**
		Reading of first pointer θ_1	**Reading of second pointer θ_1**	**twist $(\theta_2 - \theta_1)$**	**Reading of first pointer θ_1'**	**Reading of second pointer θ_1'**	**twist $(\theta_2' - \theta_1')$**	***Mean* $(\theta_2 - \theta_1)$**
1	**0**							
2	**500**							
3	**1000**							
4	**1500**							
5	**2000**							
6	**2500**							
7	**3000**							

Calculations:

The modulus of rigidity of Rod

$$\eta = \frac{180 \;\; gD\ (l_2 - l_1)}{\pi^2 \;\; r^4} \; \frac{M}{(\theta_2 - \theta_1)}$$

Circumference of pulley = $2\pi R = \pi D$ =……………… cm.

Diameter of pulley, D = $\frac{circumference}{\pi}$ = ………………… = ……….. cm.

Acceleration due to gravity, g =………………….cm./sec^2

From table1, Diameter of the Rod, d = …………….cm.
Radius of the Rod, r = d/2 = ………………cm.

From table2, by plotting the graph between angle of twist Mean $(\theta_2 - \theta_1)$ vs load M (gm.), taking angle of twist on y-axis and load on x-axis we get a straight line passing through the origin. From graph find

$$\frac{M}{(\theta_2 - \theta_1)} = \frac{1}{\text{slope}} = \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{gm./degree}$$

The modulus of rigidity of Rod η =…………………………………….. dyne/cm^2

Standard value of modulus of ridgidity for material(……………………..) of rod = ……………………………….dyne/cm.^{2}

Calculate %error by using the formula

$$\%\text{error} = \frac{\text{standard value} - \text{calculated value}}{\text{standard value}} \times 100\% = \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\%$$

Result/Conclusion:

The modulus of rigidity of the material (…………….) of the supplied Rod is found to be ……………………………..dyne/cm.^{2} with error of ………………% .

Precutions:

1. The base of the instrument should be levelled by levelling screws provided with the base.
2. The pulley should be frictionless.
3. The thread wound round the cylinder should be flexible thin and strong.
4. Load should be increased or decreased gradually and gently.

5. The load should never exceed the maximum permissible value.
6. The radius of the rod (which appears in fourth power in the formula) should be measured very carefully.
7. The pointer must be clamped very tightly, otherwise an error in the reading may arise.

Experiment No. 9

Aim:

To plot the characteristics curve of PN junction diode in Forward & Reverse bias.

Apparatus Required:

P-N junction Diode, resistor, variable DC power supply (0-30volt), milli-ammetre (0-100mA), micro-ammeter (0-100μA), voltmeter(0-20volt), Rheostat and connecting wire.

Circuit Diagram:

FORWARD BIAS:

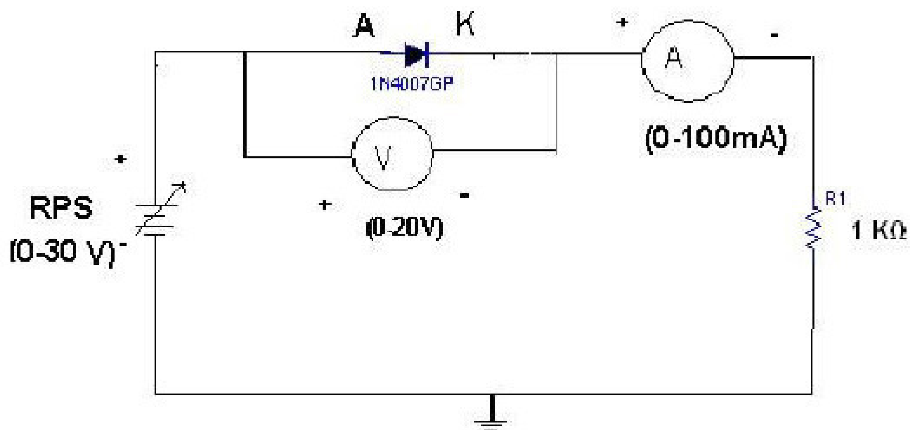


Fig. (a)

REVERSE BIAS:

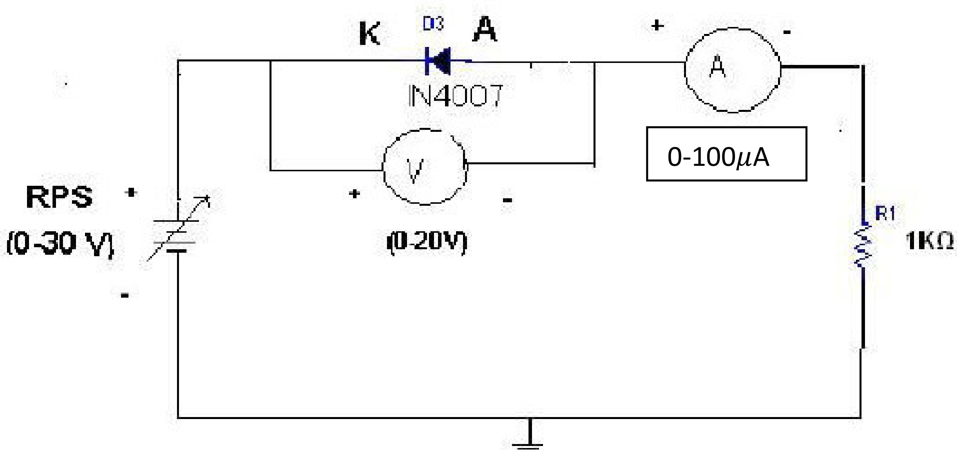


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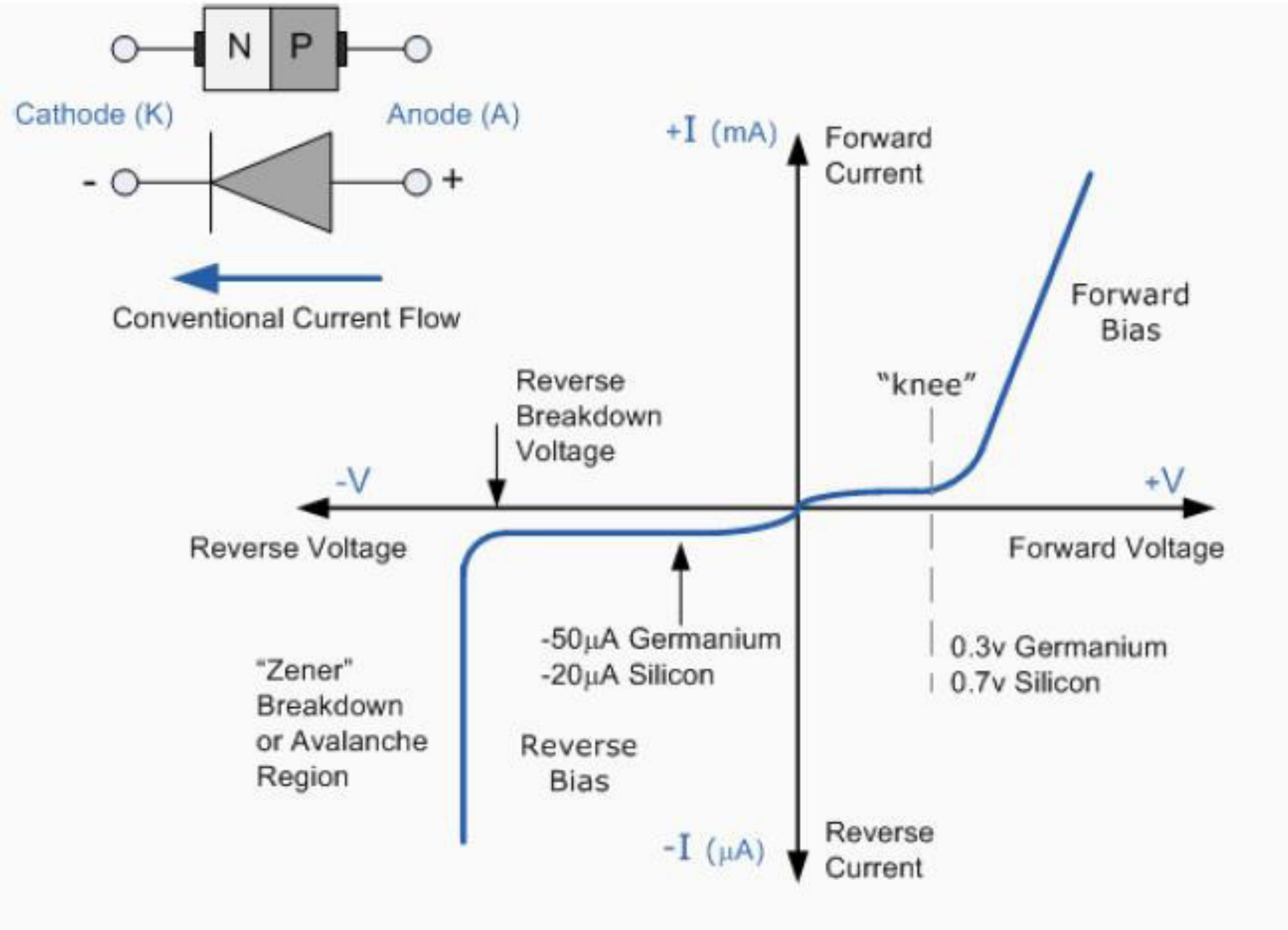
Fig. (b)



The Basic Diode Symbol and Static V-I Characteristics.

Theory:

This is a two terminal device consisting of a P-N junction formed either in Ge or Si crystal. A P-N junction is illustrated in fig. shows P-type and N-type semiconductor pieces before they are joined. P-type material has a high concentration of holes and N-type material has a high concentration of free electrons and hence there is a tendency of holes to diffuse over to N side and electrons to P side.The process is known as diffusion.

V-I Characteristics of P-N Junction: - Fig.shows the circuit arrangement for drawing the volt-ampere characteristics of a P-N junction diode. When no external voltage is applied the circuit current is zero. The characteristics are studied under the following two heads:

(i) Forward bias (ii) Reverse bias

(i)Forward bias:- For the forward bias of a P-N junction, P-type is connected to the positive terminal while the N-type is connected to the negative terminal of a battery. The potential at P-N junction can be varied with the help of potential divider. At some forward voltage (0.3 V for Ge and 0.7V for Si) the potential barrier is altogether eliminated and current starts flowing. This voltage is known as threshold voltage(Vth) or cut in voltage or knee voltage .It is practically same as barrier voltage VB. For V<Vth, the current flow is negligible. As the forward applied voltage increases beyond threshold voltage, the forward current rises exponentially.

(ii)Reverse bias: - For the reverse bias of p-n junction, P-type is connected to the negative terminal while N-type is connected to the positive terminal of a battery.
Under normal reverse voltage, a very little reverse current flows through a P-N junction. But when the reverse voltage is increased, a point is reached when the junction break down with sudden rise in reverse current. The critical value of the voltage is known as break down (VBR). The break down voltage is defined as the reverse voltage at which P-N junction breakdown with sudden rise in reverse current.

Procedure:

(A) For forward bias characteristics:

1. Make the connections for forward bias as shown in fig (a). Using milli-ammetre and a voltmeter check your connections.

2. Adjust the position of the variable contact of the rheostat (or the potentiometer) so that the voltmeter reads zero. Now increase the voltage in small steps of about 0.1 volt each and note the reading of voltmeter and the corresponding reading of milli-ammetre.

3. Plot a graph between forward voltage V_F and forward current I_F by taking V_F along x-Axis and I_F along y-axis.

4. Draw a tangent on V_F - I_F curve and find its slope. Reciprocal of slope gives the Forward resistance of the diode. Also find knee voltage.

(B) For reverse bias characteristics.

5. Complete the electric circuit as shown in fig (b). Using micro-ammeter and voltmeter check the connections.

6. Starting with zero voltage increase the reverse voltage in steps of 1 - 2 volts reach and note the reading of voltmeter as well as the corresponding readings of micro-ammeter.

7. Plot a graph between reverse voltage V_R and I_R taking V_R along x-axis and I_R along y-axis.

Observations:

Least count of voltmeter = ………………..volt
Least count of milliammetre =………………..mA
Least count of microammetre = …………………μA

Table1 - For V-I characteristics

S.No.	Reading for Farward Bias		Reading for Reverse Bias	
	Voltage V_F (volt)	Current I_F (mA)	Voltage V_R (volt)	Current I_R (μA)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
11				
12				
13				
14				
15				

Result:

The V-I characteristics of junction diode in forward and reverse bias condition has been be plotted on the graph.

Precautions:

1. Connections in forward and reverse bias arrangement should be thoroughly checked and voltmeters and milli or micro ammeters of appropriate range should be used.
2. Voltages applied should not be so high and should be within safety limit of given diode.
3. The current drawn from semiconductor diode in forward bias should not exceed its current carrying capacity. A suitable resistance of about 100 ohm may be applied in series of the diode circuit.
4. For determining resistance, so use only the middle smooth portions of the characteristic curves

Experiment No. 10

Aim:

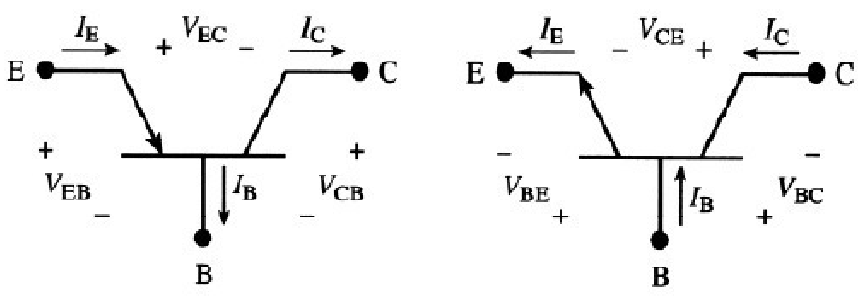
To plot the Transistor input and output characteristics in Common Emitter Mode.

Apparatus Required:

BJT (BC-547B), Bread board, resistor (1KΩ, 100KΩ), connecting wires, Ammeters (0-10mA, 0-100μ A), DC power supply (0-30V) and multimeter.

Theory:

The transistor is a two junction, three terminal semiconductor device which has three regions namely the emitter region, the base region, and the collector region. There are two types of transistors. An **npn** transistor has an n type emitter, a p type base and an n type collector while a **pnp** transistor has a p type emitter, an n type base and a p type collector. The emitter is heavily doped, base region is thin and lightly doped and collector is moderately doped and is the largest. The current conduction in transistors takes place due to both charge carriers- that is electrons and holes and hence they are named Bipolar Junction Transistors (BJT).



(a) *pnp* (b) *npn*

Two of the most important applications for the transistor are (1) as an amplifier in analog electronic systems, and (2) as a switch in digital systems.

Basic Concepts The operation of the BJT is based on the principles of the pn junction. In the npn BJT, electrons are injected from the forward-biased emitter into the thin base region where, as minority carriers, they diffuse toward the reverse-biased collector. Some of these electrons recombine with holes in the base region, thus producing a small base current, I_B. The remaining electrons reach the collector where they provide the main source of carriers for the collector current, I_C. Thus, if there are no electrons injected from the emitter, there will be (almost) no collector current and, therefore, the emitter current controls the collector current. Combining currents, the total emitter current is given as $I_E = I_B + I_C$. For normal **pnp** operation, the polarity of both voltage sources must be reversed.

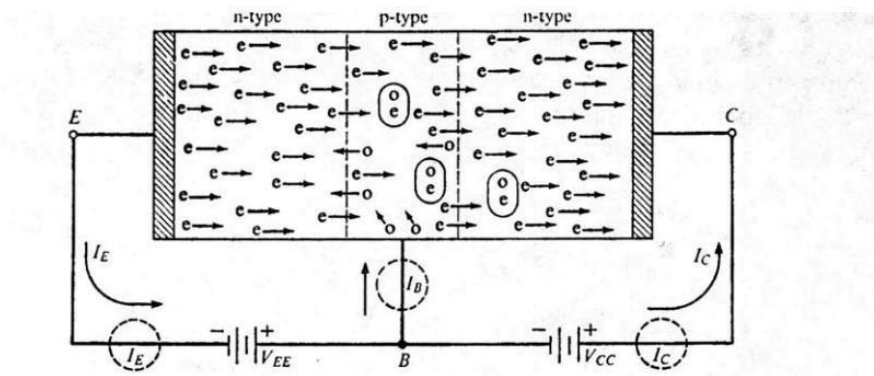
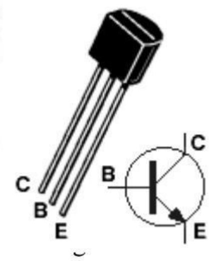


Figure : Representation of npn transistor in operation with forward biased emitter-base junction and reverse biased collector-base junction (e = electrons, 0 = holes, and oe = recombination of holes and electrons).



BJTs are used to amplify current, using a small base current to control a large current between the collector and the emitter. This amplification is so important that one of the most noted parameters of gain, β (or h_{FE}), which is the ratio of collector current to base current.

When the BJT is used with the base and emitter terminals as the input and the collector and emitter terminals as the output, the current gain as well as the voltage gain is large. It is for this reason that this common-emitter (CE) configuration is the most useful connection for the BJT in electronic systems

Characteristics curves:

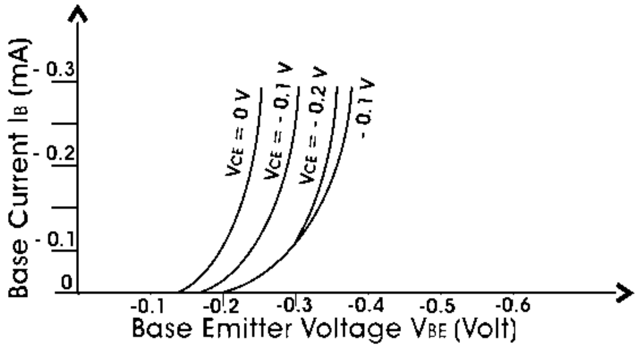
The most important characteristics of transistor in any configuration are input and output characteristics.

A. Input Characteristics: -

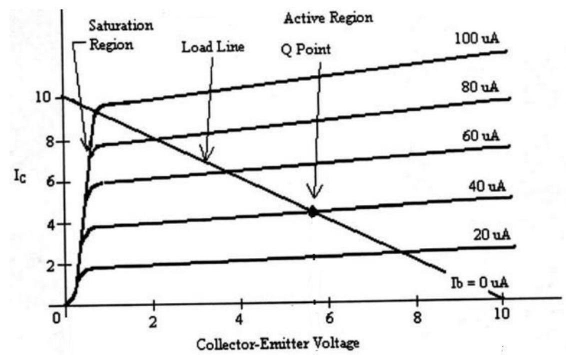
It is the curve between input current I_B and input voltage V_{BE} constant collector emitter voltage V_{CE}. The input characteristic resembles a forward biased diode curve. After cut in voltage the I_B increases rapidly with small increase in V_{BE}. It means that dynamic input resistance is small in CE configuration. It is the ratio of change in V_{BE} to the resulting change in base current at constant collector emitter voltage. It is given by $\Delta V_{BE} / \Delta I_B$.

B. Output Characteristics: -

This characteristic shows relation between collector current I_C and collector voltage for various values of base current. The change in collector emitter voltage causes small change in the collector current for the constant base current, which defines the dynamic resistance and is given as $\Delta V_{CE} / \Delta I_C$ at constant I_B. The output characteristic of common emitter configuration consists of three regions: Active, Saturation and Cut-off.



Input characteristic(CE mode)



Output characteristics(CE mode)

Circuit diagram:

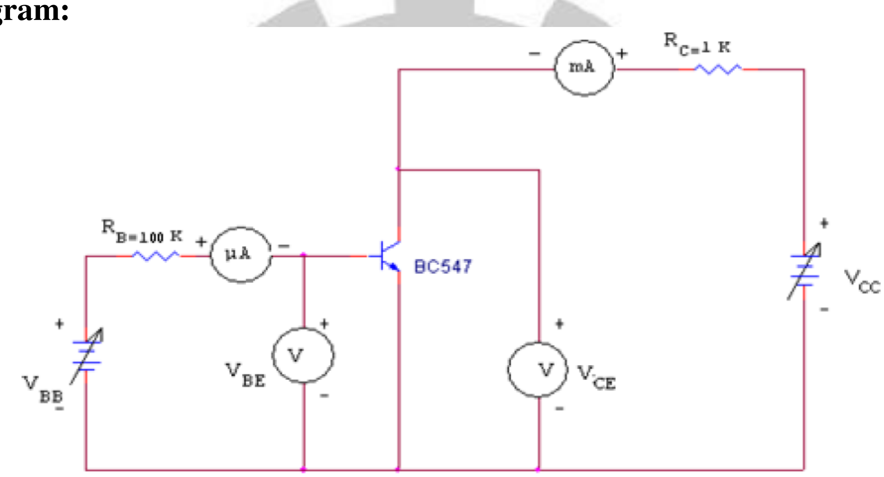


Fig. diagram of common emitter configuration

Procedure: -

Input Characteristics:

1. Using suitable patch cords make connections as per shown in fig. For NPN transistor.
2. Keep the knobs of both 0 – 10 V DC supplies to fully anticlockwise position.
3. Switch on the power to the training board.
4. Set the collector voltage to a certain value say 1 V.
5. Vary the base voltage V_B in 15 mV (20 mV) steps and observe the corresponding base current by keeping the current meter in 200 μA ranges.
6. Take the observations as per table 1 and plot the readings on a graph sheet. Take V_B on the X-axis and I_B on the Y-axis.
7. Evaluate dynamic input resistance which is the ratio of change in V_{BE} to the resulting change in base current at constant collector emitter voltage. It is given by $\Delta V_{BE} / \Delta I_B$.
8. The reciprocal of the slope of the linear part of the characteristic gives the dynamic input resistance of the transistor.

Output Characteristics:

1. Using suitable batch cords make connections as per shown in fig. For NPN transistor.
2. Keep the knobs of both 0 – 10 V DC supplies to fully anticlockwise position.
3. Switch on the power to the training board.
4. Set the base current to a certain value say 25 μA with the help of 0 – 10 V DC supply of the input circuit.
5. Now vary the collector voltage from 0 – 10 V in steps say 1 V and note down the corresponding values of the collector current I_C as per table 2.
6. Repeat the collector voltage and collector current for different settings of the base current.
7. Plot the of collector voltage along X-axis and collector current along Y-axis.
8. The change in collector emitter voltage causes small change in the collector current for the constant base current, which defines the dynamic output resistance and is given as ΔV_{CE} / ΔI_C at constant I_B or the output conductance is given $\Delta I_C/\Delta V_{CE}$ with the I_B at a constant current.
9. Find output conductance from the slope of the linear portion of the characteristic curves and also find small-signal current gain which is calculated by $\beta = \Delta I_C/\Delta I_B$ with the V_{CE} at a constant voltage.

Observations:

Least count of voltmeter V_{BE} = …………… volt
Least count of voltmeter V_{CE} = …………… volt
Least count of milli-ammeter = …………… mA
Least count of micro-ammeter = …………… μA

Table1 – For Input characteristics

S.No.	**V_C = ……..volt**		**V_C = ……..volt**		**V_C = ……..volt**	
	V_B (volt)	**I_B (μA)**	**V_B (volt)**	**I_B (μA)**	**V_B (volt)**	**I_B (μA)**
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Table2 – Output characteristics

S.No.	I_B = …..…. μA		I_B = …..…. μA		I_B = …..…. μA	
	V_C (volt)	I_C (mA)	V_C (volt)	I_C (μA)	V_C (volt)	I_C (μA)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						

Calculations:

1. **Small-Signal Current Gain:**
   $\beta = \Delta I_C / \Delta I_B$ with the V_{CE} at a constant voltage.
   = …………
2. **Dynamic input resistance:**
   It is given by $\Delta V_{BE} / \Delta I_B$ at constant V_{CE}
   R_d = …………..
3. **Dynamic output resistance:**
   It is given as $\Delta V_{CE} / \Delta I_C$ at constant I_B
   R_O = …………..

Result:

Input and Output characteristics of a Transistor in Common Emitter Configuration are Plotted. As shown in graph their pattern is similar to standard characteristics.

1. **Small-Signal Current Gain: ………………**
2. Dynamic input resistance: ………………..

3. Dynamic output resistance: ………………

Precautions:

1. While performing the experiment do not exceed the ratings of the transistor. This may lead to damage the transistor.
2. Connect voltmeter and ammeter in correct polarities as shown in the circuit diagram.
3. Do not switch ON the power supply unless you have checked the circuit connections as per the circuit diagram.
4. Make sure while selecting the emitter, base and collector terminals of the transistor.