b) To determine the moment of inertia of the given fly wheel without measuring time interval.

Apparatus:

Flywheel, thread, weights, meter scale, Vernier Callipers.

An interesting and unconventional method of determining the moment of inertia of a fly wheel is not to use the stopwatch at all . the steps are as follows.

i) A thread is wound on the axle of the flywheel N_1 times and a mass M is attached to the free end of the thread. The mass M is now released and it starts descending, as the thread gets unwound. The counter reading is noted, before releasing the mass M. Let the reading be C_1.

ii) The mass M falls on the ground, when the thread is completely unwound. The flywheel continues to rotate, till it ultimately stops due to friction. Let the final counter reading be C_2.

The difference $|C_2 - C_1|$ is equal to the total number of rotations made by the fly wheel. As before we denote by N_2, the number of rotations made by the flywheel after the thread has been completely unwound. Thus

$$N_1 + N_2 = |C_2 - C_1|$$

This equation can be used to determine N_2.

Observations:

S. No.	Mass attached M (gm)	N_1	Counter reading C_1	Counter reading C_2	N_2
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					

Calculation:

Energy conservation implies that

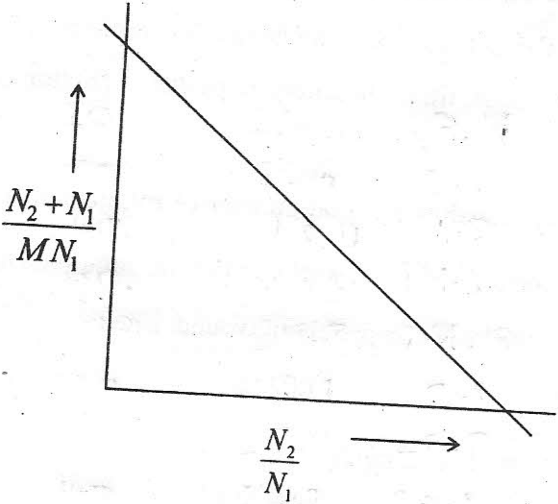
$$Mg\,(2\pi\, rN_{1)} = \frac{1}{2}I\omega^2 + \frac{1}{2}Mr^2\omega^2 + N_1\,\xi$$

also $\frac{1}{2}I\omega^2 = N_2\,\xi$

Eliminating ω^2 from the above two equations, one gets

$$\frac{N_1 + N_2}{M N_1} = \frac{2\pi rg}{\xi} - \frac{r^2}{I} \cdot \frac{N_2}{N_1}$$

This suggests the following straight line graph:



Magnitude of slope $= \frac{r^2}{I}$

and Intercept $\frac{2\pi rg}{\xi}$

Hence I and ξ can be calculated.

8.7. To determine the frequency of an electrically maintained tuning fork by Melde's method.

Apparatus:
Tuning fork, Melde's arrangement, thread, pan, slotted weights.

(a)- Transverse arrangement

Fix a thread to one of the prongs of the fork, with the help of a screw supplied for this purpose. Stretch the thread in a line with the prong of the fork and pass is over a ball bearing pully clamped to a stand. At its other end tie a small pan for the purpose of putting weights.

Place suitable weights in the pan. Adjust the gap between the platinum contacts and make the fork vibrate. The vibrations of the prong are at right angles to the line of stretched thread. The arrangement is shown in the figure Fig 8.13. Note the number of loops and measure the length of thread. The number of loops can be changed by changing the weight in the pan and the distance between the pulley and the tuning fork.

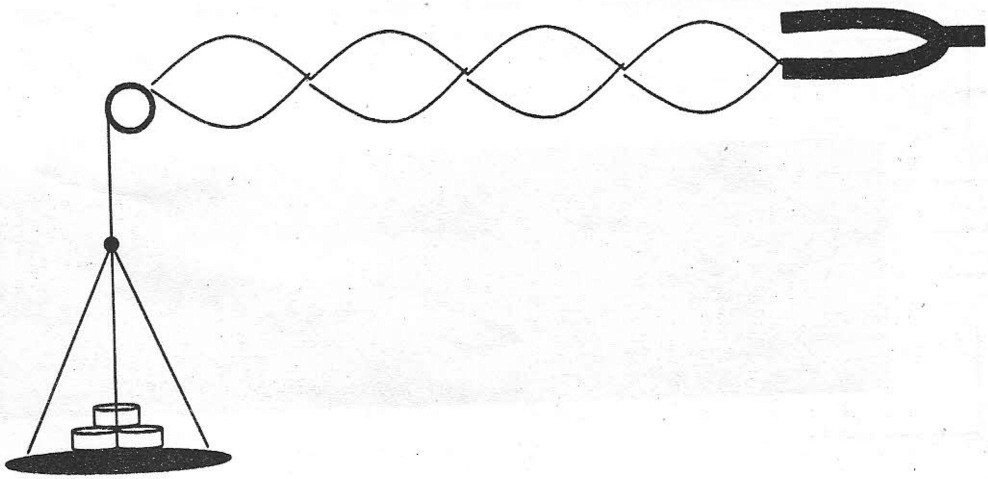


Figure 8.13

The frequency of the fork is given by

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

where l is the length of one loop,

$T = mg$; Tension

μ = mass of the thread per unit length

Observation Table:

S.No.	$T = mg$	Number of loops p	Total length of thread L	$l = \frac{L}{p}$	$f = \frac{1}{2l}\sqrt{\frac{T}{m}}$
1.					
2.					
3.					
4.					
5.					

(b) Longitudinal arrangement

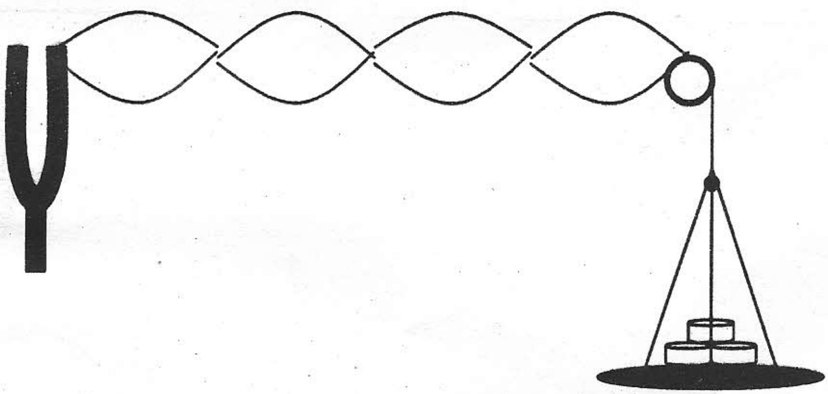


Figure 8.14

Tie one end of the thread to one of the prongs of the fork, with the help of a screw fixed to the prong of the fork. Stretch the thread in a line with the prong of the fork and pass it over a ball bearing pully clamped to a stand. At its end tie a small pan for the purpose of putting weights.

Place suitable weights in the pan. Adjust the gap between the platinum contacts and make the fork vibrate.. The vibration of the prongs are parallel to the line of stretched thread.

The frequency of the fork is given by

$$f = \frac{1}{l}\sqrt{\frac{T}{\mu}}$$

where l is the length of one loop,

$T = mg$ =Tension

μ = mass of the thread per unit length gm/cm.

Observation Table:

S.No.	$T = mg$	Number of loops p	Total length of thread L	$l = \frac{L}{p}$	$f = \frac{1}{l}\sqrt{\frac{T}{m}}$
1.					
2.					
3.					
4.					
5.					

9.3. To determine the wavelength of sodium light by Newton's rings method.

Apparatus:

Sodium lamp assembly, two plane glass plates, wooden stand, plano convex lens, traveling microscope.

Very carefully clean the surface of the convex lens of a large focal length and place it on the clean plate of glass. Switch on the sodium lamp and wait till it attains full brilliancy. Use a short focus lens suitably mounted on a stand to allow the rays to fall on the glass plate inclined at 45^0 to the vertical. The lens should be placed with respect to the source of light that the emergent pencil of light is approximately parallel. The glass plate sends this pencil of light vertically downwards and thus the angle of reflection into the air film is practically zero. The rays of light are partly reflected at the two surfaces bounding the air film and give rise to the interference bands in the form of concentric circular rings. These rings are localized fringes, being formed in the air film.

Having obtained the bright rings, set microscope properly so that the point of intersection of the two perpendicular cross wires lies on the center of the central dark ring.

Calculate the diameter of each ring by taking the difference of the readings of the same ring on the left hand side (LHS) and on the right hand side (RHS). Calculate the value of squares of the diameters of these rings and evaluate the expression $D_{n+p}^2 - D_n^2$. Then get the mean value of $D_{n+p}^2 - D_n^2$ for a known value of p (p is any number greater than 1)

The wavelength of the sodium light ; $\lambda = \dfrac{D_{n+p}^2 - D_n^2}{4pR}$ (9.11)

where R is the radius of curvature of the lens

Observation table:

Ring No.	Microscope Readings		Diameter	$(L_1-L_2)^2$	$D_{n+p}^2 - D_n^2$
	R.H.S. L_1 (cm)	L.H.S. L_2 (cm)	$L_1 - L_2$ (cm)		
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
144.					
15.					
16.					
17.					
18.					
19.					
20.					

9.4 To determine the refractive index of the material of a prism for the given wavelengths of light.

Apparatus:

Prism spectrometer, Prism, Mercury lamp assembly.

First of all the prism is placed on the prism table and then adjusted approximately for minimum deviation position. The spectrum is now seen through the telescope. The prism table is rotated slightly away from this position towards collimator and the telescope is brought in view. The collimater is well focused on the spectrum. Again rotate the prism table on the other side of minimum deviation position, i.e. towards telescope and focus the telescope for the best image of the spectrum. The process of focusing the collimator and telescope is continued till slight rotation of the prism table does not make the image to go out of focus. This means that both collimator and telescope are now individually set for parallel rays.

Now mount the prism on the table such that its center coincides with the main axis of the instrument. The refractive index of the material is given by

$$\mu = \frac{\sin\left(\frac{A+\delta_{min}}{2}\right)}{\sin\frac{A}{2}} \tag{9.12}$$

where A is the angle of prism and δ_{min} is the angle of minimum deviation for the ray of given wavelength.

Angular measurement in spectrometer

The main scale is a full circle divided into 360×2 divisions. Hence each small division on the main scale represents half a degree. A vernier scale is available which is aligned with the main scale and the vernier scale has 30 divisions on it. These 30 divisions coincide with 29 divisions of the main scale.

Hence vernier constant = 1 main scale division – 1 vernier scale division

$$= \frac{1}{2}\deg ree - \frac{29}{30}\times\frac{1}{2}\deg ree$$

$$= \frac{1}{60} \text{degree}$$

$$= 1 \text{ minute}$$

The reading of a particular angular position is taken by combining the main scale reading and vernier scale reading

Example 1: Let main scale reading $= 36^0$

Vernier divisions = 20

then total reading $= 36^0 20'$

$$= \left(36 + \frac{20}{60}\right) \text{degree}$$

$$= 36.33^0$$

Example 2: Let main scale reading $= 63.5^0$

Vernier divisions = 15

then total reading $= 63.5^0 + 15 \text{ minute}$

$$= 63^0 45'$$

$$= \left(63 + \frac{45}{60}\right) \text{degree}$$

$$= 63.75^0$$

Observation table:

a) Measurement of the angle of prism

S.No.	Vernier	Reflection from face AB	Reflection from face AC	Difference	Average 2A
1.					
2.	V_1				
3.					
1.					
2.	V_2				
3.					

Angle of prism =..........

b) Measurement of the angle of deviation

S.No.	Vernier	Dispersed Image	Direct Image	Difference	Average δ_{min}
1.					
2.	V_1				
3.					
1.					
2.	V_2				
3.					

The refractive index of the material of the prism for a particular colour (a particular wavelength) =..........

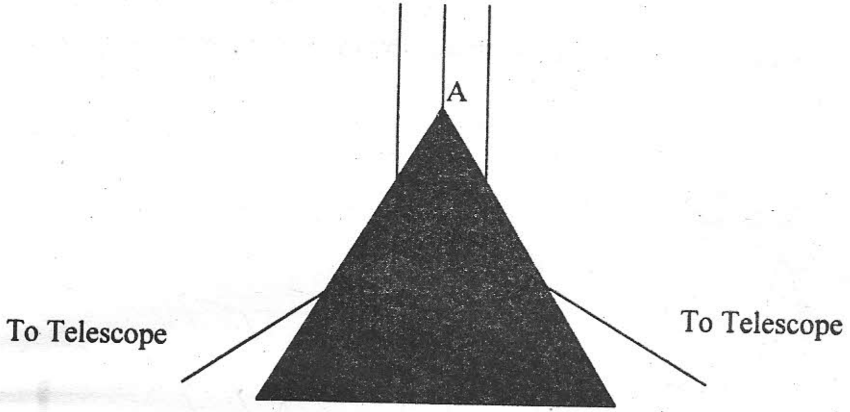


Fig. 9.6

Note: The calculation of refractive index should be done individually for light of different colours.

9.5 Plane polarization of light.

The plane polarization of light may be studied by the simple arrangement as shown in Fig 9.7

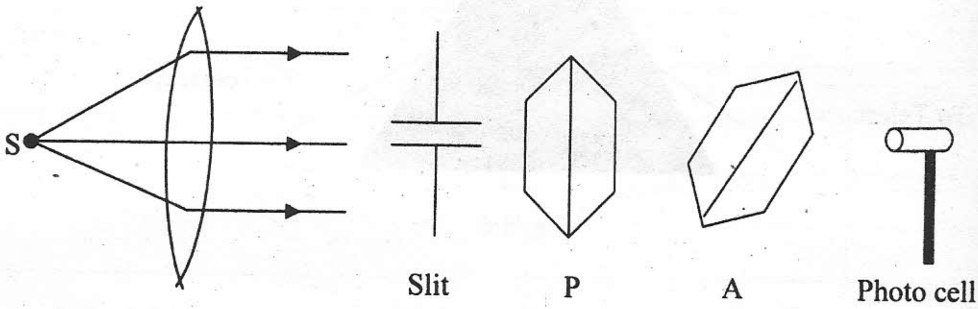


Figure 9.7 Study of plane polarization of light.

A dark room is required for this exercise. The light falling on the slit is a parallel beam of unpolarized light. The polarizer produces plane polarized light. The analyzer is also a "polarizer" but its role will be to "analyse" the beam falling on it. The beam after passing through analyzer A is collected by the photocell. The photocell is connected to a micrometer which measures the generated current.

If the angle between the optic axes of the polarizer and analyzer is ϑ, the intensity received at the photocell is given by

$$I(\vartheta) = I_0 \cos^2 \vartheta \qquad (9.13)$$

Apparatus:

Sodium lamp assembly, polarisers, photo cell, micrometer.

Observations:

S.No.	ϑ	Current in the photocell (I)	$\cos^2\vartheta$
1.			
2.			
3.			
4.			
5.			

A graph of the current as a function of $\cos^2\vartheta$ will be a straight line. This would verify Eqn. (9.13)

10.2. Measurement of the diameter of a thin wire using the phenomenon of diffraction

Apparatus:
He-Ne laser, thin wire, screen , stand.

When a wire is illuminated by a laser beam, a diffraction pattern is observed on the screen. If d is the diameter of the wire, diffraction is being observed at a distance D from the screen, and x is the width of central maxima then

$$d = \frac{D\lambda}{x} \tag{10.1}$$

where λ is the wavelength of laser light.

Illuminate the wire with He-Ne laser beam (keep this distance about half meter) as shown in Fig. 10.2 and observe the diffraction pattern on the graph paper pasted on screen. Measure the distance D of the screen from the wire and the width of the central maximum (x). Now apply the equation given above and find out the diameter of the wire. The wavelength of He-Ne laser is 632.8 nm.

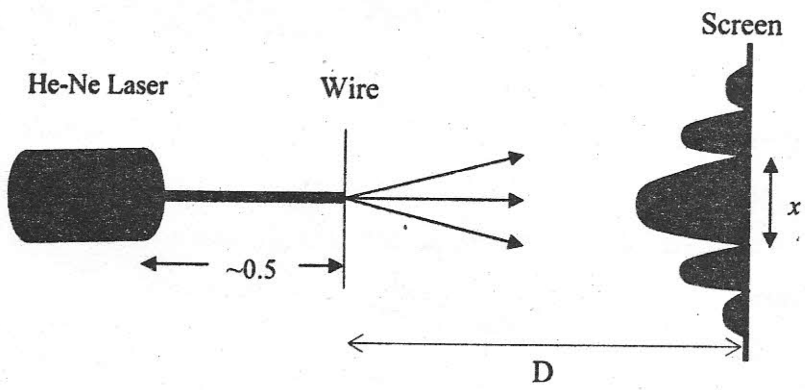


Figure 10.2

Observations:

S.No.	Distance of screen from wire D (cm)	Width of central maxima x cm)	$d = \frac{D\lambda}{x}$
1.			
2.			
3.			
4.			
5.			
6.			
7.			
8.			
9.			
10.			

10.3 To measure the divergence of a laser beam.

Apparatus:

He-Ne laser, screen , stand.

Divergence is defined as the spread of the laser beam i.e. how much angle is subtended by the laser spot at the point of origin. It is measured in radians. The divergence of the laser beam is extremely small as compared to the conventional light sources. The typical divergence of He-Ne laser is of the order of 1 milliradian. We setup three equations to obtain the values of the divergence angle. For this purpose W (spot radius) is measured at some arbitrary plane distant Z, Z+D, Z+2D from a reference plane. We have,

$$W_1^2 = W_0^2 + \vartheta_0^2 Z^2 \qquad (10.2)$$

$$W_2^2 = W_0^2 + \vartheta_0^2 (Z+D)^2 \qquad (10.3)$$

$$W_3^2 = W_0^2 + \vartheta_0^2 (Z+2D)^2 \qquad (10.4)$$

From these equations we obtain,

$$2\vartheta_0^2 D^2 = W_3^2 - 2W_2^2 + W_1^2$$

or,

$$\vartheta_0 = \frac{W_3^2 - 2W_2^2 + W_1^2}{\sqrt{2}D} \qquad (10.5)$$

Measure the beam spot sizes at three different planes at Z, $Z+D$, $Z+2D$ respectively as shown in Fig. 10.3. The separation D is measured with a meter scale or measuring tape. The divergence angle is then calculated using Equation (10.5). The procedure may be repeated by measuring spot sizes at additional planes and then averaging the values.

Observations :

S.No.	Distance (cm)	Spot radius W (cm)	ϑ_0 (milliradian)
1.	Z = 100		
2.	$Z+D$ =		
3.	$Z+2D$ =		

$D = 100$ cm

Calculate the divergence from the above formula. Calculate the relative % error if the expected divergence angle is known.

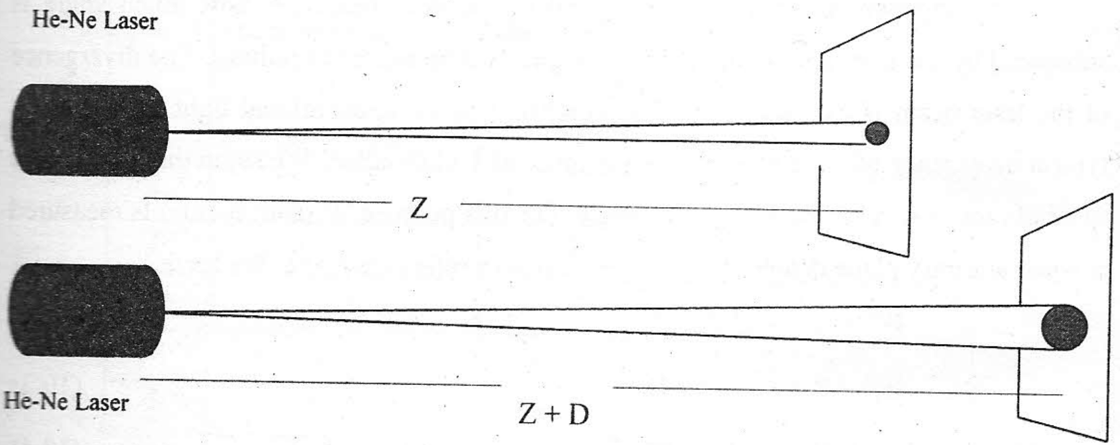


Figure 10.3

11.2. PN Junction

Semiconductors have the unusual property that addition of suitable "impurities" in proper amount changes their current conduction behaviour drastically. In a semiconductor, current is carried by both electrons and holes. With reference to Fig. 11.2, an electron when "excited" from the valence band to the conduction band leaves behind a vacancy or a "hole" in the valence band. When this semiconductor sample is placed in the electric field, both electrons and holes" moves in response to the electric field. The movement of both of these entities contributes to the current in the sample. The holes moves in the direction of electric field applied while electrons move opposite to the electric field.

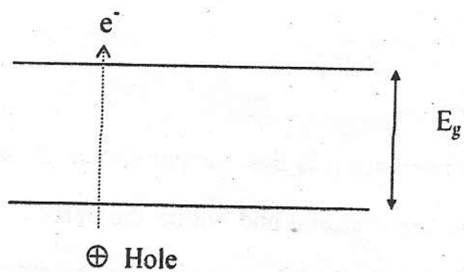


Figure 11.2 Energy band gap in a semiconductor.

In a pure semiconductor, the number of conduction electrons and the number of holes are equal; thermal excitation always produces exactly one hole for each electron excited to the conduction band. However an "impurity" added to the semiconductor may change this situation. By adding a small amount of a fifth group element to a formerly pure Ge or Si sample; the number of conduction electrons may be made larger than the number of holes. This "impure" sample is called a *n* type material.

$$n_e > n_h \qquad \text{(n-type)}$$

Similarly an impurity of third group element added to a pure semiconductor produced a *p* type sample.

$$n_h > n_e \qquad \text{(p-type)}$$

A junction of two such materials is called PN junction. It has the unusual property of effectively conducting the electric current in only one direction. This is the simplest device of its kind. A given PN junction may be studied by plotting its V-I characteristics i.e. by investigation of how the current through the junction varies when the potential difference across it is changed.

11.3 PNP and NPN arrangements

The next simplest arrangements combine three such samples either as NPN or as PNP. Many more variables are now available and therefore this device, called the transistor, is capable of much more involved behavior; as compared with the simpler PN junction. The strategy of studying it however remains the same i.e. one plots the characteristics of the device in the various possible configurations. The semiconductor devices have the useful property that they are rugged, can be of very minute size and consume very little power.

11.4 (a) - Determination of reverse saturation current I_0 and material constant η of a PN-junction.

Apparatus

PN junction setup with current and voltage displays.

The current I in a PN junction is given by

$$I = I_0(e^{qV/\eta kT} - 1) \tag{11.3}$$

where q = electronic charge (1.6×10^{-19})

η = material constant $\eta_{Ge} = 1; \eta_{Si} = 2$

k = Boltzman constant (1.38×10^{-23} J/K)

T = Temperature in Kelvin

V = Junction voltage in volts

I_0 = Reverse saturation current

The reverse saturation current is usually too small to be measured directly. An indirect graphical method is to calculate the natural lograthim of Equation (11.3) for $e^{qV/\eta kT} >> 1$. Thus

$$\ln I = \ln I_0 + \left(\frac{q}{\eta kT}\right)V \tag{11.4}$$

When V and *ln*I are plotted on a graph, a straight line is obtained. This line intersects the horizontal axis at $\ln I_0$ and its slope may be calculated to compute η

$$\eta = \frac{q}{kT}\cdot\frac{\Delta V}{\Delta(\ln I)} \tag{11.5}$$

The diode to be tested is connected to the terminals with the polarity as indicated. Readings are now recorded from the two display sets of voltage and current respectively.

Observations:

Temperature= ……

S.No.	Potential difference V (volts)	Current I (mA)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
22.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

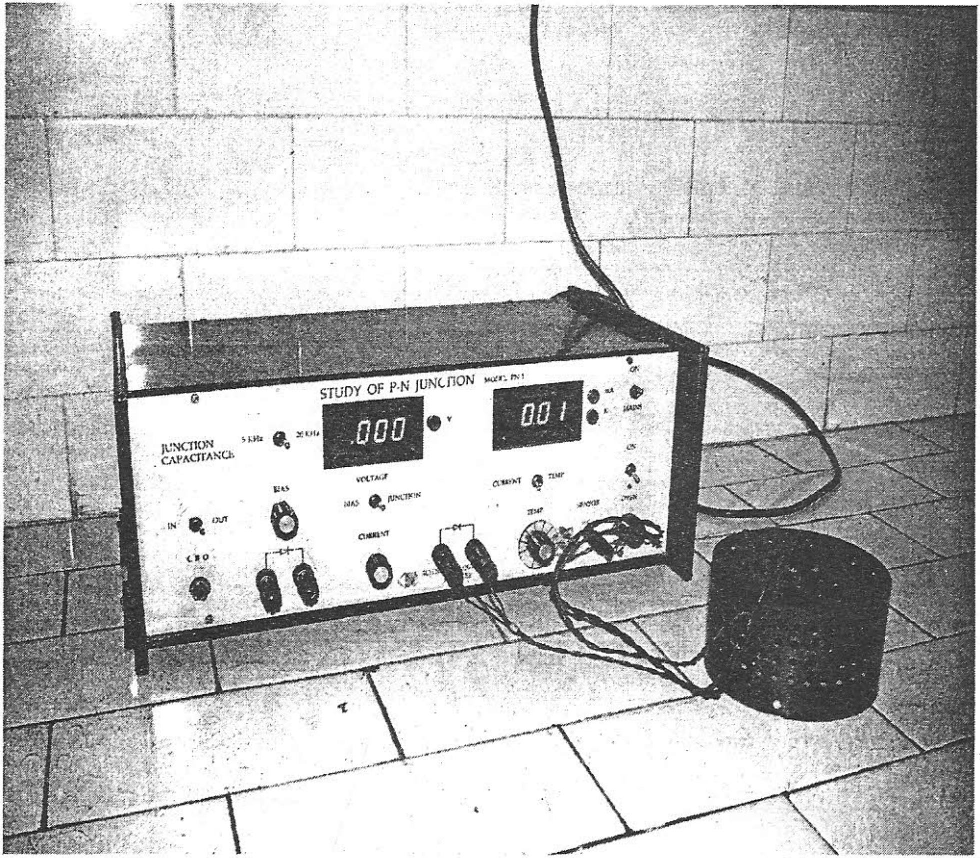


Figure 11.3 PN-junction setup.

(b) Determination of temperature coefficient of junction voltage and energy band gap.

Apparatus:

PN - junction setup with displays for current, voltage and temperature, oven.

With the connections as in (a), the Oven and sensor leads are inserted in the respective sockets. The diode is put in the Oven and its forward current is set to a low value (say 1 mA) to avoid heating. The display-1 is now switched to TEMP, to read the oven temperature.

The Oven temperature can now be varied from room temperature to about 360K in suitable steps and the junction voltage may be recorded. Keeping the current constant the temperature controlled oven requires about 5 minutes to stabilize at every new setting.

Observations:

Current= ......mA

S.No.	Temperature T (K)	Potential difference V (volts)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		

The reverse saturation current is given by

$$I_0 = AT^m \, e^{-V_0 / \eta V_T} \qquad (11.6)$$

where V_0 is the energy band gap.

and $V_T = KT/q$ (11.7)

Then

$$I_0 = AT^m e^{-qV_0/\eta kT} \qquad (11.8)$$

Combining the above with Equation (11.3), we get

$$I \cong A\,T^m\, e^{(q/\eta kT)(V-V_0)} \quad \text{(neglecting 1 as compared to } e^{qV/\eta kT}\text{)}$$

Hence, $I\,T^{-m}\, e^{-qV/\eta kT} = A\, e^{-qV_0/\eta kT}$

Or, $\ln I - m\ln T - (qV/\eta k)(1/T) = \ln A - (qV_0/\eta k)(1/T)$

Or $m\ln T + (qV/\eta k)(1/T) = \ln(I/A) + (qV_0/\eta k)(1/T)$ (11.9)

Denote, $[m\ln T + (qV/\eta k)(1/T)]$ as y then plot variation of y as a function of $\frac{1}{T}$

(It will be a straight line as shown in figure below). ($m = 1.5$ for Si)

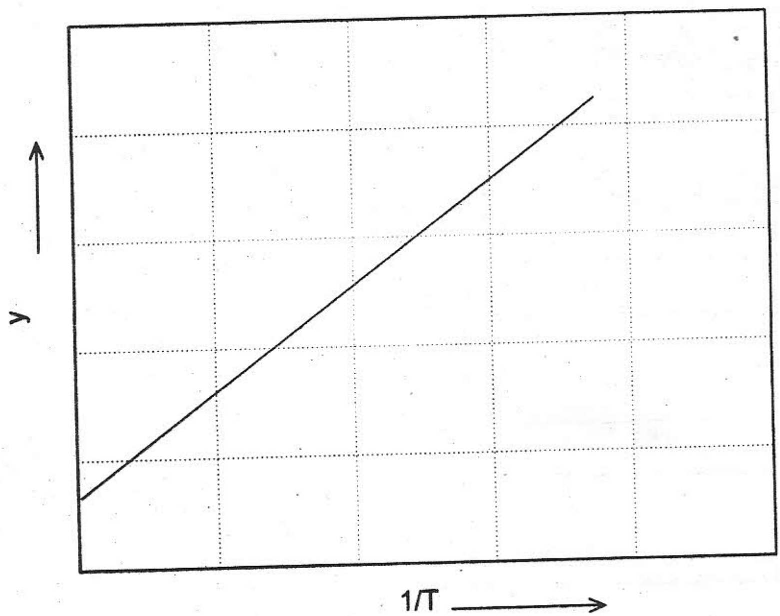


Figure 11.4

Slope of graph : $qV_0/\eta k$

Intercept : $\ln(I/A)$; calculate A.

(c) Calculation of temperature coefficient

Calculation of temperature coefficient:

Differentiating Eqn.(11.9) with respect to T (treating V as temperature dependent)

$$m/T + (q/\eta k)\left[(-V/T^2) + (1/T)(dV/dT)\right] = (-qV_0/\eta k)(1/T^2)$$

or $$(q/\eta k)\left[(1/T)(dV/dT)\right] = (q/\eta k)[(V - V_0)/T^2] - (m/T)$$

or $$dV/dT = \left[(V - V_0)/T\right] - [m\eta k/q] \qquad (11.10)$$

Hence , the temperature coefficient (dV/dT) has a weak dependance on the temperature. Use this equation to plot a graph showing the variation of (dV/dT) with the temperature T.

11.8 Study of Hall Effect.

Apparatus

Hall effect setup, gaussmeter, power supply, sensor and sample.

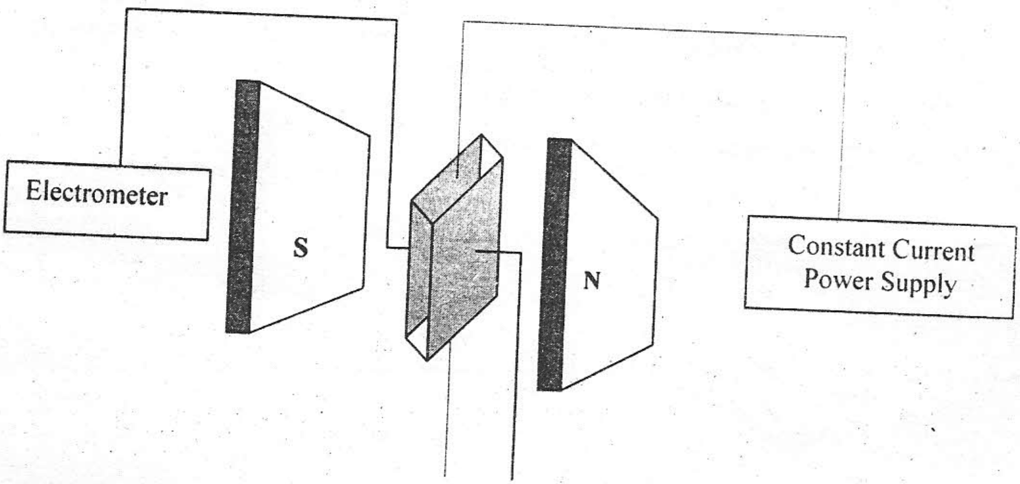


Figure 11.10 Study of Hall Effect.

1. Connect the widthwise contacts of the Hall probe to the terminals marked "voltage" and lengthwise contacts to terminals marked "current" (as shown in Fig. 11.11).
2. Switch "ON" the Hall Effect setup and adjust the current (say few mA).
3. Switch over the display to voltage side. There may be some voltage reading even outside the magnetic field. This is due to the imperfect alignment of the four contacts of the Hall probe and is generally known as the "Zero field potential". This error should be subtracted from the Hall voltage reading.
4. Now place the probe in the magnetic field as shown in Fig 11.10 and switch on the electromagnet power supply and adjust the current to any desired value. Rotate the Hall probe till it become perpendicular to magnetic field. Hall Voltage will be maximum in this adjustment.

5. Measure Hall Voltage for both the directions of the current and magnetic field. (i.e. four observations for a particular value of current and magnetic field)
6. Measure the Hall Voltage as a function of current keeping the magnetic field constant. Plot a graph.
7. Measure the Hall voltage as a function of magnetic field keeping a suitable value of current as constant. Plot a graph.
8. Measure the magnetic field by Gauss meter.

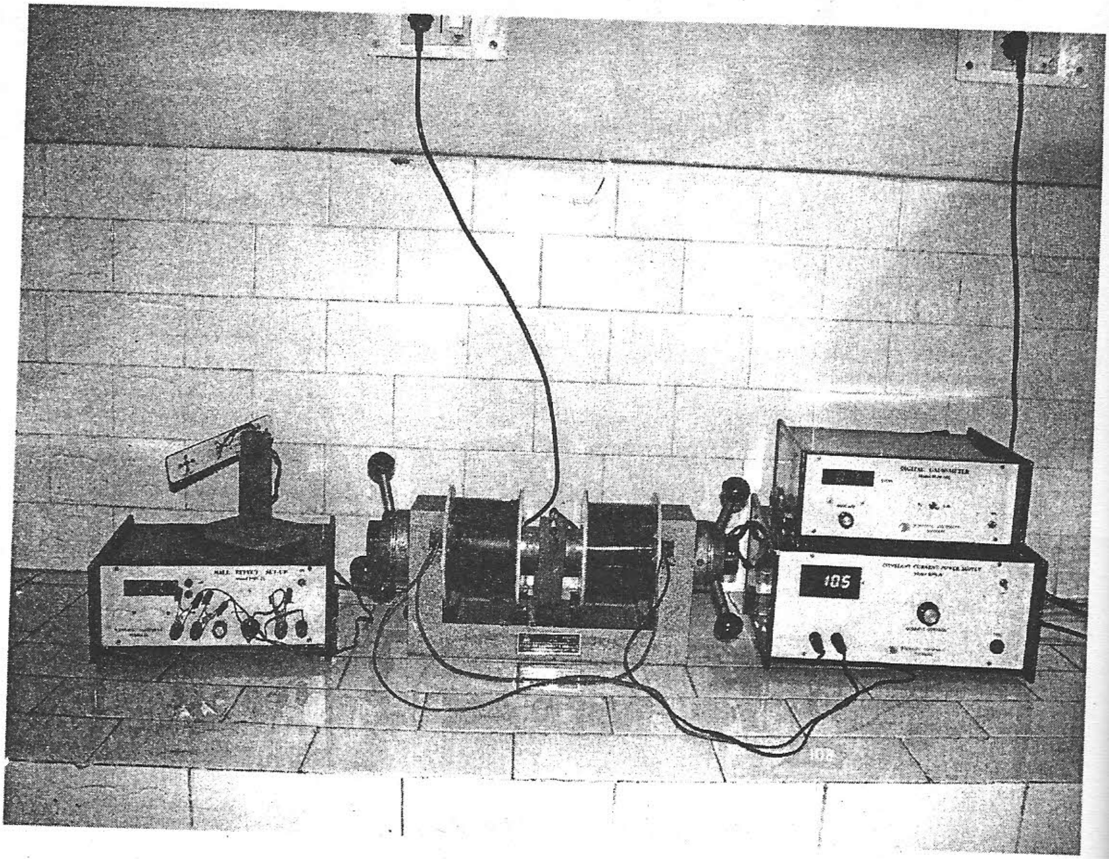


Figure 11.11 Hall effect setup.

Observations

(a) Calibration of magnetic field

S.No.	Current I (A)	Magnetic field B (gauss)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

(b) $i_H = constant$, variation of V_H with B

S.No.	Voltage V_H (V)	Magnetic field B (gauss)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

(c) $B = constant$; variation of Hall current i_H with Hall voltage V_H

S.No.	Voltage V_H (V)	Current i_H (A)
1.		
2.		
3.		
4.		
5.		
6.		
7.		
8.		
9.		
10.		
11.		
12.		
13.		
14.		
15.		
16.		
17.		
18.		
19.		
20.		

Calculations

From the graph of Hall voltage as a function of magnetic field, calculate Hall coefficient.

Use $R_H = \left(\frac{V_H}{I}\right)\left(\frac{Z}{B}\right)$ (11.22)

where V_H is Hall voltage and B is magnetic field and $Z = 5\times10^{-4}\,\text{m}$ (thickness of the usual sample)

Calculate charge density from the relation (11.21)