1.Determination of Hall Coefficient and carrier type for a Semi-conducting Material

Aim

To determine the hall coefficient of the given n type or p-type semiconductor

Apparatus Required

Hall probe (n type or p type), Hall effect setup, Electromagnet, constant current power supply, gauss meter etc.,

Formulae

i) Hall coefficient (R_H) $= \dfrac{V_H .t}{IH} \times 10^{8}\ cm^3\ C^{-1}$

where
V_H = Hall voltage (volt)
t = Thickness of the sample (cm)
I = Current (ampere)
H = Magnetic filed (Gauss)

ii) Carrier density (n) $= \dfrac{1}{R_H\, q}\ cm^{-3}$

where
R_H = Hall coefficient ($cm^3\ C^{-1}$)
q = Charge of the electron or hole (C)

iii) Carrier mobility (μ) $= R_H\sigma\ cm^2 V^{-1}\ s^{-1}$

where
R_H = Hall coefficient ($cm^3 C^{-1}$)
σ = Conductivity ($C\ V^{-1}\ s^{-1}\ cm^{-1}$)

Principle

Hall effect: When a current carrying conductor is placed in a transverse magnetic field, a potential difference is developed across the conductor in a direction perpendicular to both the current and the magnetic field.

Measurement of Hall coefficient

Current in the Hall effect setup = ----------mA

Current in the constant current power supply (A)	Magnetic field (H) (Gauss)	Hall Voltage (V_H) (volts)	Hall coefficient (R_H) $cm^3\ C^{-1}$

Observations and Calculations

(1) Thickness of the sample = t = cm

(2) Resistivity of the sample = ρ = $V\ C^{-1}\ s\ cm$

(3) Conductivity of the sample = σ = $CV^{-1} s^{-1}\ cm^{-1}$

(4) The hall coefficient of the sample = $R_H = \frac{V_H . t}{IH} \times 10^8$

= -------------

(5) The carrier density of the sample = $n = \frac{1}{R_H q}$

= -------------

(6) The carrier mobility of the sample = $R_H \sigma$

= ---------------

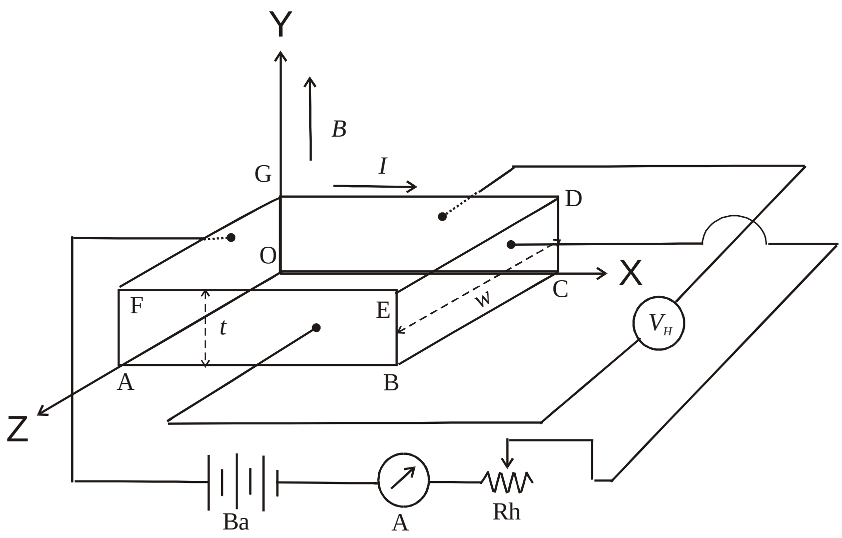


Fig. 1.1. Hall Effect Setup

Procedure

1. Connect the widthwise contacts of the hall probe to the terminals marked as 'voltage' (i.e. potential difference should be measured along the width) and lengthwise contacts to the terminals marked (i.e. current should be measured along the length) as shown in fig.
2. Switch on the Hall Effect setup and adjust the current say 0.2 mA.
3. Switch over the display in the Hall Effect setup to the voltage side.
4. Now place the probe in the magnetic field as shown in fig and switch on the electromagnetic power supply and adjust the current to any desired value. Rotate the Hall probe until it become perpendicular to magnetic field. Hall voltage will be maximum in this adjustment.
5. Measure the hall voltage and tabulate the readings.
6. Measure the Hall voltage for different magnetic fields and tabulate the readings.
7. Measure the magnetic field using Gauss meter
8. From the data, calculate the Hall coefficient, carrier mobility and current density.

Result

1. The Hall coefficient of the given semi conducting material =
2. The carrier density =
3. The carrier mobility =

2. Band Gap Determination using Post Office Box

Aim

To find the band gap of the material of the given thermistor using post office box.

Apparatus Required

Thermistor, thermometer, post office box, power supply, galvanometer, insulating coil and glass beakers.

Principle and formulae

(1) Wheatstone's Principle for balancing a network $\frac{P}{Q} = \frac{R}{S}$

Of the four resistances, if three resistances are known and one is unknown, the unknown resistance can be calculated.

(2) The band gap for semiconductors is given by,

$$Eg = 2k\left(\frac{2.303 \log_e R_T}{1/T}\right)$$

where k = Boltzmann constant = 1.38×10^{-23} J/K

R_T = Resistance at T K

Procedure

1. The connections are given as in the Fig. 6.1(a).1. Ten ohm resistances are taken in P and Q.
2. Then the resistance in R is adjusted by pressing the tap key, until the deflection in the galvanometer crosses zero reading of the galvanometer, say from left to right.
3. After finding an approximate resistance for this, two resistances in R, which differ by 1 ohm, are to be found out such that the deflections in the galvanometer for these resistances will be on either side of zero reading of galvanometer.
4. We know $R_T = \frac{Q}{P} \times R = \frac{10}{10} \times R_1 \; or \; (R_1 + 1)$.This means that the resistance of the thermistor lies between R_1 and (R_1+1). Then keeping the resistance in Q the same, the resistance in P is changed to 100 ohm.
5. Again two resistances, which differ by one ohm are found out such that the deflections in the galvanometer are on the either side of zero. Therefore the actual resistance of thermistor will be between $\frac{R_2}{10}$ and $\frac{R_2 + 1}{10}$.

To find the resistance of the thermistor at different temperatures

Temp. of thermistor $T = t+273$	$\frac{1}{T}$	Resistance in P	Resistance in Q	Resistance in R	Resistance of the thermistor $R_T = \frac{P}{Q} \times R$	$2.303 \log_{10} R_T$
K	K^{-1}	ohm	ohm	Ohm	ohm	ohm

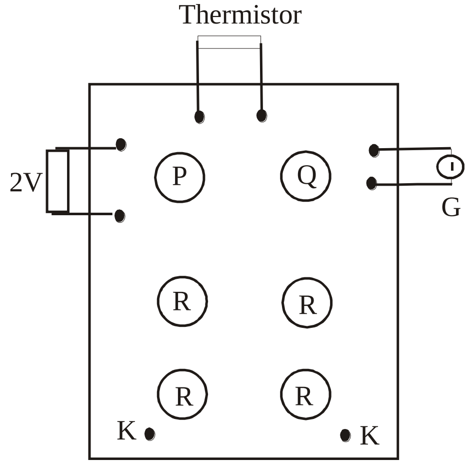


Fig. 2.1. Post Office Box - Circuit diagram

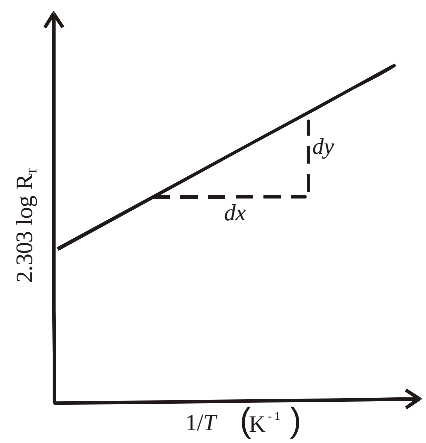


Fig. 2.2. Model Graph

Observation

From graph, slope = (dy / dx) = ……

Calculation

Band gap, $E_g = 2k(dy / dx)$ **=…..**

6. Then the resistance in P is made 1000 ohms keeping same 10 ohms in Q. Again, two resistances R and (R+1) are found out such that the deflection in galvanometer changes its direction. Then the correct resistance.

$$= R_T = \frac{10}{1000}(R) \text{ (or)}$$

$$= R+1 = 0.01R \text{ (or) } 0.01(R+1)$$

7. Thus, the resistance of the thermistor is found out accurately to two decimals, at room temperature. The lower value may be assumed to be R_T (0.01R).

8. Then the thermistor is heated, by keeping it immersed in insulating oil. For every 10 K rise in temperature, the resistance of the thermistor is found out, (i.e) R_T's are found out. The reading is entered in the tabular column.

Graph

A graph is drawn between $\frac{1}{T}$ in X axis and 2.303 log R_T in Y axis where T is the temperature in K and R_T is the resistance of the thermistor at TK. The graph will be as shown in the Fig.6.1(a).2.

Band gap (Eg)=2k $\times$ slope of the graph = $2k \times (\frac{dy}{dx})$

where K = Boltzman's constant.

Result

The band gap of the material of the thermistor = ...eV.

3.To study V-I Characteristics of a Light Dependent Resistor (LDR)

Aim

To measure the photoconductive nature and the dark resistance of the given light dependent resistor (LDR) and to plot the characteristics of the LDR.

Apparatus Required

LDR, Resistor (1 kΩ), ammeter (0 – 10 mA), voltmeter (0 – 10 V), light source, regulated power supply.

Formula

By ohm's law, $V = IR$ (or) $R = \frac{V}{I}$ ohm

where R is the resistance of the LDR (i.e) the resistance when the LDR is closed. V and I represents the corresponding voltage and current respectively.

Principle

The photoconductive device is based on the decrease in the resistance of certain semiconductor materials when they are exposed to both infrared and visible radiation.

The photoconductivity is the result of carrier excitation due to light absorption and the figure of merit depends on the light absorption efficiency. The increase in conductivity is due to an increase in the number of mobile charge carriers in the material.

Procedure

1. The connections are given in as shown in Fig. 6.3.1.
2. The light source is switched on and made to fall on the LDR.
3. The corresponding voltmeter and ammeter readings are noted.
4. The procedure is repeated by keeping the light source at different distances from the LDR.
5. A graph is plotted between resistance and distance of LDR from the light source.
6. The LDR is closed and the corresponding voltmeter and ammeter readings are noted. The value of the dark resistance can be calculated by Ohm's law.

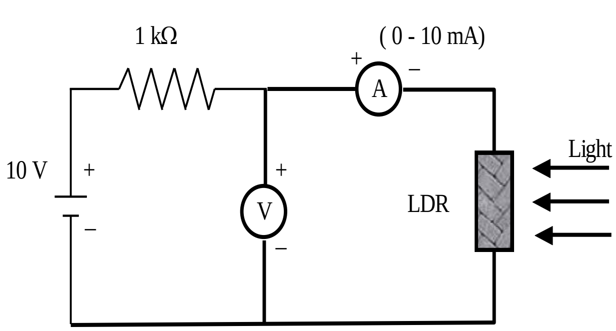


Fig. 3.1. Circuit diagram

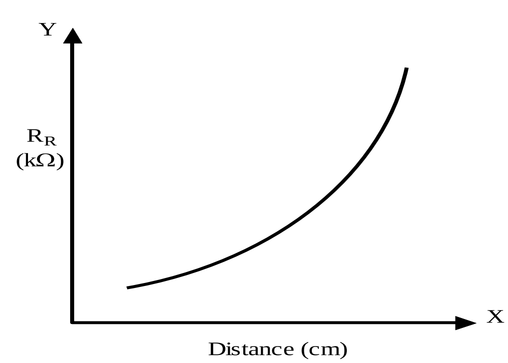


Fig. 3.2. Model graph

Observation

Voltmeter reading when the LDR is closed = …… V

Ammeter reading when the LDR is closed = ……. A

Dark resistance = $R = \frac{V}{I}$ = ……. ohm

To determine the resistances of LDR at different distances

S.No	Distance (cm)	Voltmeter reading (V) volt	Ammeter reading (I) mA	R_R kΩ

Result

1. The characteristics of LDR were studied and plotted.
2. The dark resistance of the given LDR = …….. ohm

4.Resistivity Determination for a Semiconductor Wafer using Four Probe Method

Aim

To determine the energy band gap of a semiconductor (Germanium) using four probe method.

Apparatus Required

Probes arrangement (it should have four probes, coated with zinc at the tips). The probes should be equally spaced and must be in good electrical contact with the sample), Sample (Germanium or silicon crystal chip with non-conducting base), Oven (for the variation of temperature of the crystal from room temperature to about 200°C), A constant current generator (open circuit voltage about 20V, current range 0 to 10mA), Milli-voltmeter (range from 100mV to 3V), Power supply for oven Thermometer.

Formula

The energy band gap, Eg., of semi-conductor is given by

$$E_g = 2k_B \frac{2.3026 \times log_{10}\rho}{1/T} \ in\ eV$$

where k_B is Boltzmann constant equal to 8.6 × 10 $^{-5}$ eV / kelvin , and ρ is the resistivity of the semi-conductor crystal given by

$$\rho = \frac{\rho_0}{f(W/S)} \ where\ \rho_0 = \frac{V}{I} \times 2\pi s \ ; \ \rho = \frac{V}{I}(0.213)$$

Here, s is distance between probes and W is the thickness of semi-conducting crystal. V and I are the voltage and current across and through the crystal chip.

Procedure

1. Connect one pair of probes to direct current source through milliammeter and other pair to millivoltmeter.
2. Switch on the constant current source and adjust current I, to a described value, say 2 mA.
3. Connect the oven power supply and start heating.
4. Measure the inner probe voltage V, for various temperatures.

Graph

Plot a graph in $\left(\frac{10^3}{T}\right)$ and $\log_{10}\rho$ as shown in Fig.6.1(b).2. Find the slope of the curve $\frac{AB}{BC} = \frac{\log_{10}\rho}{10^3/T}$. So the energy band gap of semiconductor (Germanium) is given by

$$E_g = 2k \times \frac{2.3026 \times \log_{10}\rho}{1/T}$$

$$= 2k \times 2.3026 \times \frac{AB}{CD} \times 1000 = 2 \times 8.6 \times 10^{-5} \times 2.3026 \times \frac{AB}{CD} \times 1000 eV = 0.396 \times \frac{AB}{CD} eV$$

To determine the resistivity of the semi-conductor for various temperatures:

Current (I) = …………mA

<table>
<tr><th rowspan="2">S.No.</th><th colspan="2">Temperature</th><th>Voltage (V)</th><th rowspan="2">Resistivity ρ
(ohm. cm)</th><th>10^{-3} / T</th><th rowspan="2">$Log_{10}\rho$</th></tr>
<tr><th>in°C</th><th>in K</th><th>(Volts)</th><th>(K)</th></tr>
<tr><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Observations:

Distance between probes(s) = ……………………..mm

Thickness of the crystal chip (W) = ……………………mm

current (I) = ………………..mA

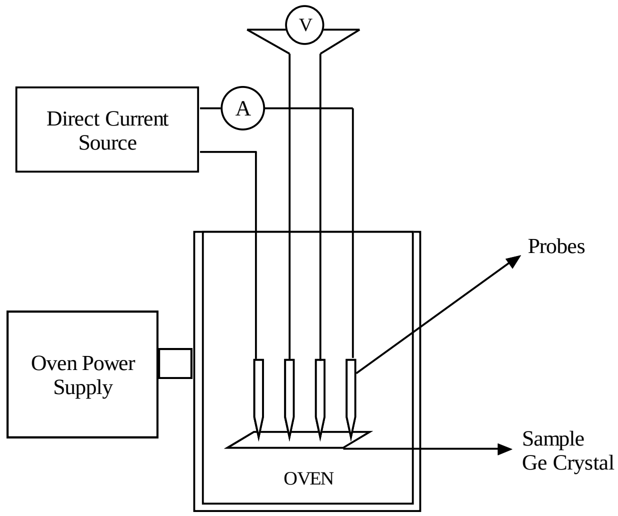


Fig. 4.1. Four Probe Setup

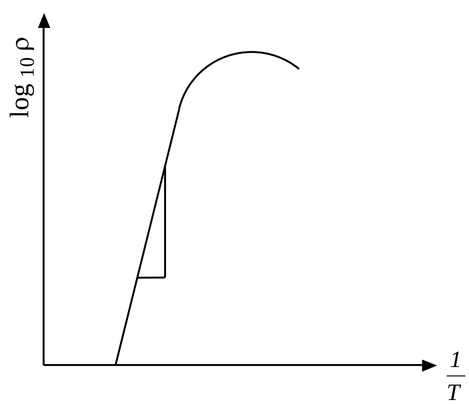


Fig. 4.2. Model Graph

Result

Energy band gap for semiconductor (Germanium) is E_g =….eV

Source of error and precautions

1. The resistivity of the material should be uniform in the area of measurement.
2. The surface on which the probes rest should be flat with no surface leakage.
3. The diameter of the contact between the metallic probes and the semiconductor crystal chip should be small compared to the distance between the probes.

5. Study of v-i and v-r characteristics of a solar cell

Aim

To study the V-I and V-R characteristics of a solar cell.

Apparatus Required

Solar cell, voltmeter,milliammeter, a dial type resistance box, Keys, illuminating lamps, connecting wires etc.

Procedure

A solar cell (photovoltaic cell) essentially consists of a p-n junction diode, in which electrons and holes are generated by the incident photons. When an external circuit is connected through the p-n junction device, a current passes through the circuit. Therefore, the device generates power when the electromagnetic radiation is incident on it.

The schematic representation of a solar cell and the circuit connections are as shown in Fig. 7.1.

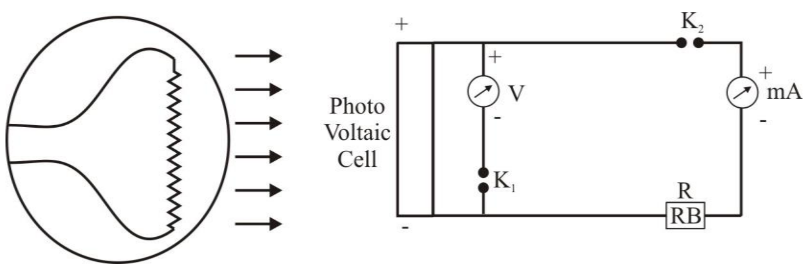


Fig. 5.1. Schematic representation and circuit of Solar Cell

The voltmeter is connected in parallel with the given solar cell through a plug key. A milliammeter and a variable resistor are connected in series to the solar cell through a key as shown in the Fig.6.21.

The solar cell can be irradiated by sun’s radiation. Instead, it can also be irradiated by a filament bulb (60 W or 100 W).

The resistance value is adjusted by a ressitance box and the variation of V-I and V-R are plotted.

Readings are tabulated as follows:

(i) V-I and V-R characteristics

Intensity	Resistance	Voltmeter Reading	Ammeter Reading
Maximum			

V-I and V-R characteristics

Intensity	Resistance	Voltmeter Reading	Ammeter Reading
Minimum			

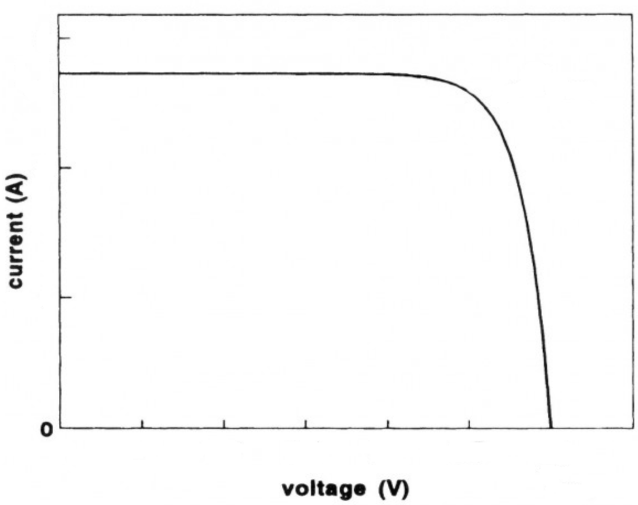


Fig. 5.2. Model Graph for V-I Characteristic

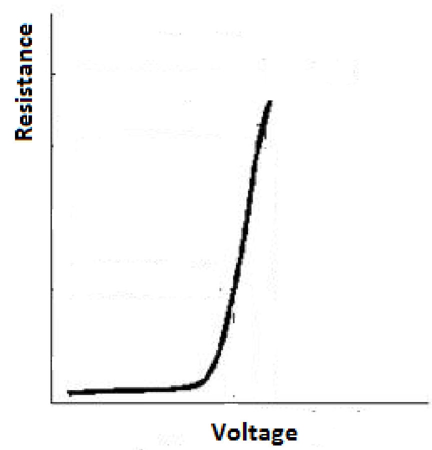


Fig. 5.3. Model Graph for V-R Characteristic

Result:

The V-I and V-R Characteristics of the solar cell is studied.

6. Characteristic of PN junction diode under forward bias

Aim: To plot the characteristics curve of PN junction diode in Forward bias

Apparatus: A diode, DC voltage supplier, Bread board, 100Ω resistor, 2 multimeter for measuring current and voltage and connecting wires

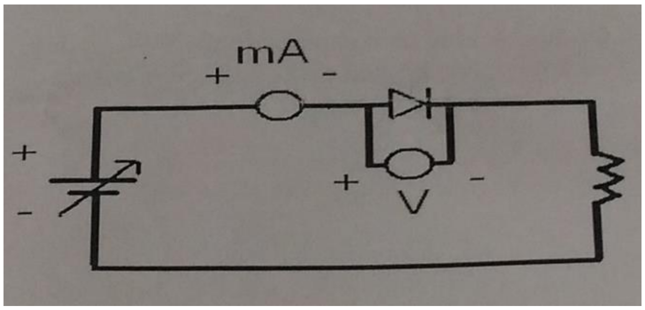


Fig. 6.1. PN Junction Forward Bias

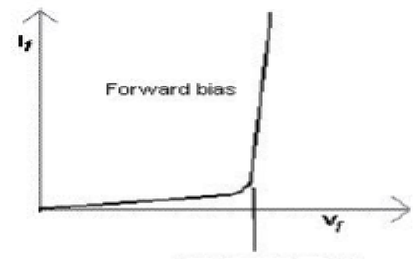


Fig. 6.2. I-V Characteristics

Procedure:

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 V_B. For $V<V_{th}$, the current is negligible. As the forward applied voltage increase beyond threshold voltage, the forward current rises exponentially.

Observation:

S. No	Forward Voltage (V)	Forward Current (µA)

Result: PN junction characteristic is studied and curve is drawn.

7. To Study V-I characteristics of Photo cell

Aim: To study the illumination and V-I characteristic of photocell

Apparatus: Photo cell Apparatus and connecting wires.

Theory: Solid-state device with a photosensitive cathode that emits electrons when illuminated and an anode for collecting the emitted electrons. Illumination excites electrons, which are attracted to the anode, producing current proportional to the intensity of the illumination. In a photovoltaic cell, light is used to produce voltage. In a photoconductive cell, light is used to regulate the flow of current. Photocells are used in control systems, where interrupting a beam of light opens a circuit, actuating a relay that supplies power to a mechanism to bring about a desired operation, such as opening a door or setting off a burglar alarm.

Procedure:

- ILLUMINATION CHARACTERISTICS:
  1. Connect the voltmeter and ammeter as per circuit diagram shown on the apparatus and set RL to minimum position.
  2. A 100 W lamp is arranged over the solar panel such that light falls on it at normal. Initially, the lamp is placed at maximum distance and is switched on.
  3. The voltage and the current is noted.
  4. The intensity of the lamp is varied in steps by changing the distance of lamp. The readings are noted in Observation Table 1.

- ii) CURRENT-VOLTAGE CHARACTERISTICS :
  5. The intensity of the lamp is kept at Medium(I_1).
  6. The voltage and current are switched on.
  7. The load dial is set at 470 ohms. The voltage and current are noted down. The loads is set to 1 k, 2.2 k, 3.3 k, 4.7 k and 10 k ohms and at each setting the voltage and current are recorded. The readings are recorded in Observation Table 2.
  8. The intensity of the lamp is increased (I_2).At this setting, step 7 is repeated.
  9. The intensity of the lamp is set to its maximum (I_3). At this setting step 7 is again repeated.

Observations:

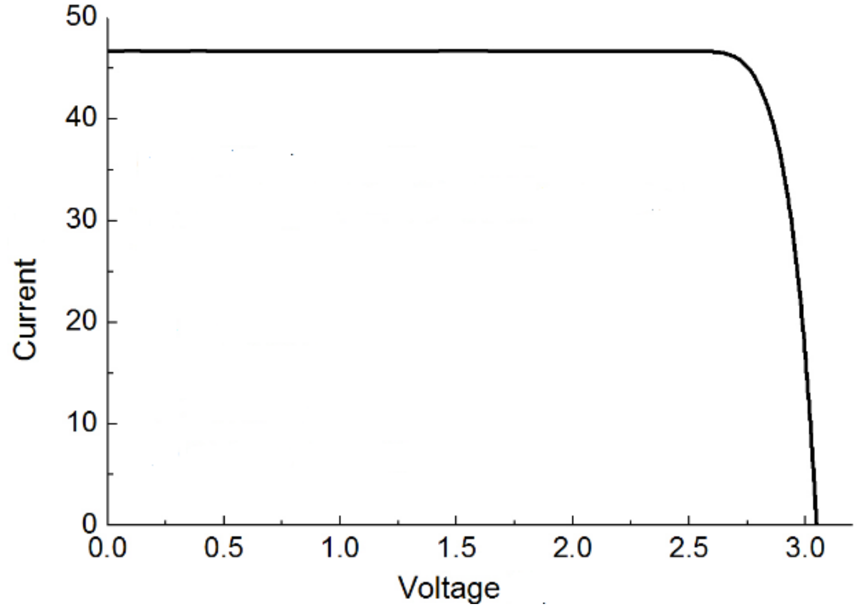
Observation Table 1 - Illumination characteristics

Intensity (distance Cm)	**Voltage**
11 20 29 38	0.5 V 0.4 V 0.3 V 0.2 V

Observation Table 2 - V-I characteristics

R_L (k ohms)	Intensity I_1(at distance......)		Intensity I_2 (at distance......)		Intensity I_3(at distance......)	
	Voltage (Volts)	Current (micro-amps)	Voltage (Volts)	Current (micro-amps)	Voltage (Volts)	Current (micro-amps)
0.47 1 2.2 3.3 4.7 10						

GRAPH: For V-I CHARACTERISTICS, a graph is plotted between the current and voltage.



RESULT: Illumination and V-I characteristics of Photo cell has been studied.

8. Particle size determination using laser

Aim

To determine the size of micro particles using laser.

Apparatus Required

Fine micro particles having nearly same size (say lycopodium powder), a glass plate (say microscopic slide), diode laser, and a screen.

Principle

When laser is passed through a glass plate on which fine particles of nearly uniform size are spread, due to diffraction circular rings are observed. From the measurement of radii of the observed rings, we can calculate the size of the particles. Since for diffraction to occur size of the obstacle must be comparable with wavelength, only for extremely fine particles of micron or still lesser dimension, diffraction pattern can be obtained.

Diffraction is very often referred to as the bending of the waves around an obstacle. When a circular obstacle is illuminated by a coherent collimated beam such as laser light, due to diffraction circular rings are obtained as shown in the figure 3.1 . If “r” is the radius of the first dark ring and “D” is the distance between the obstacle and screen on which the diffraction pattern is obtained, then.

$$\tan\theta = \frac{r}{D}$$

Since θ is very small in this experiment

$$\tan\theta = \theta = \frac{r}{D}$$

According to the theory, the diameter 1a’ of the circular obstacle is given by

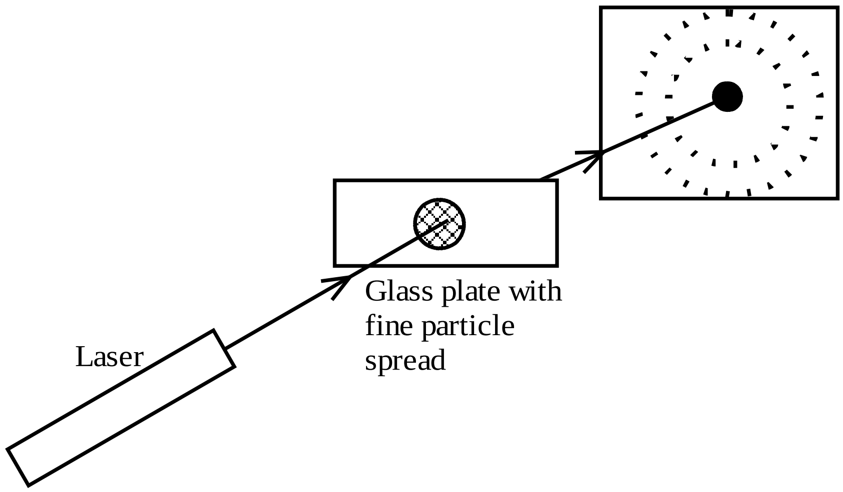
$$2a = \frac{1.22 n\lambda D}{r_n}$$

where

r_n = radius of the n^{th} order dark ring (m)

D = distance between the obstacle and the screen (m)

λ = wavelength of the laser light (Å)



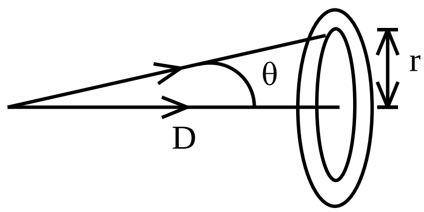


Fig. 8.1. Particle size determination using Laser

Determination of particle size

Sl.No.	**Distance (D)**	**Diffraction order (n)**	**Radius of dark ring (r_n)**	**Particle size (2a)**
Unit	m		m	m
1		1 2		
2		1 2		
3		1 2		
			Mean	

Procedure

1. Fine powder of particles is sprayed/spread on the glass plate.
2. Laser is held horizontally and the glass plate is inserted in its path.

3. Position of the glass plate is adjusted to get maximum contrast rings on the screen which is at a distance more than 0.5 m.

4. A white paper is placed on the screen and the positions of the dark rings are marked. The radii of different order dark rings (r_n) are measured using a scale.

5. The distance between the screen and the glass plate (D) is also measured. Using the given formula, the average diameter of the particles is calculated. $2a = \frac{1.22 n \lambda D}{r_n}$

6. The experiment is repeated for different D values.

Result

The average size of the particles measured using laser = ...μm

9. Study of attenuation and propagation characteristics of optical fiber cable

I . ATTENUATION IN FIBERS

Aim

(i) To determine the attenuation for the given optical fiber.

(ii) To measure the numerical aperture and hence the acceptance angle of the given fiber cables.

Apparatus Required

Fiber optic light source, optic power meter and fiber cables (1m and 5m), Numerical aperture measurement JIG, optical fiber cable with source, screen.

Principle

The propagation of light down dielectric waveguides bears some similarity to the propagation of microwaves down metal waveguides. If a beam of power P_i is launched into one end of an optical fiber and if P_f is the power remaining after a length L km has been traversed , then the attenuation is given by,

$$\text{Attenuation} = \frac{10\log\left(P_i/P_f\right)}{L} \text{ dB / km}$$

Formula

$$\text{Attenuation (dB / km)} = \frac{10\log\left(P_i/P_f\right)}{L}$$

Procedure

1. One end of the one metre fiber cable is connected to source and other end to the optical power metre.
2. Digital power meter is set to 200mV range (- 200 dB) and the power meter is switched on
3. The ac main of the optic source is switched on and the fiber patch cord knob in the source is set at one level (A).
4. The digital power meter reading is noted (P_i)
5. The procedure is repeated for 5m cable (P_f).
6. The experiment is repeated for different source levels.

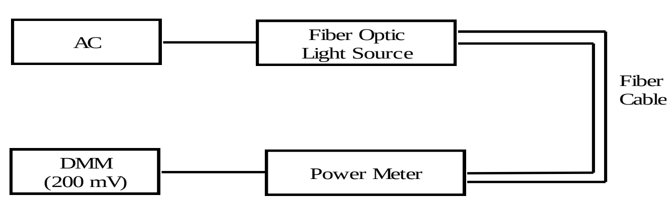


Fig. 9.1. Setup for loss measurement

Determination of Attenuation for optical fiber cables

L = 4 m = 4×10^{-3} km

Source Level	Power output for 1m cable (P_i)	Power output for 5m cable (P_f)	**Attenuation =** $\dfrac{10\log\left(P_i / P_f\right)}{L}$ **dB / km**

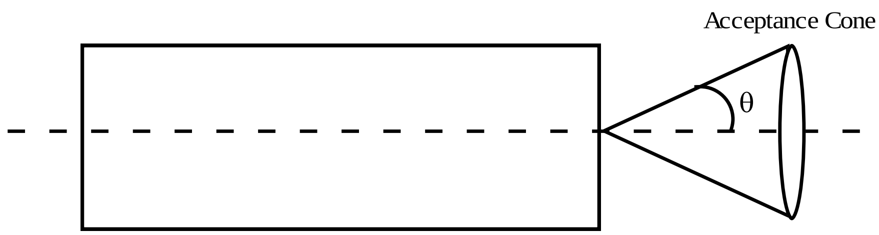


Fig. 9.2. Numerical Aperture

Measurement of Numerical Aperture

Circle	Distance between source and screen (L) (mm)	Diameter of the spot W (mm)	**NA =** $\dfrac{W}{\sqrt{4L^2 + W^2}}$	θ

Result

1. Attenuation at source level A = ----------- (dB/km)
2. Attenuation at source level B = ----------- (dB/km)
3. Attenuation at source level C = ----------- (dB/km)

II. Numerical Aperture

Principle

Numerical aperture refers to the maximum angle at which the light incident on the fiber end is totally internally reflected and transmitted properly along the fiber. The cone formed by the rotation of this angle along the axis of the fiber is the cone of acceptance of the fiber.

Formula

$$\text{Numerical aperture (NA)} = \frac{W}{\sqrt{4L^2 + W^2}} = \sin\theta_{max}$$

Acceptance angle = 2 θ_{max} (deg)

where L = distance of the screen from the fiber end in metre

W =diameter of the spot in metre.

Procedure

1. One end of the 1 metre fiber cable is connected to the source and the other end to the NA jig.
2. The AC mains are plugged. Light must appear at the end of the fiber on the NA jig. The set knob in source is turned clockwise to set to a maximum output.
3. The white screen with the four concentric circles (10, 15, 20 and 25mm diameters) is held vertically at a suitable distance to make the red spot from the emitting fiber coincide with the 10mm circle.
4. The distance of the screen from the fiber end L is recorded and the diameter of the spot W is noted. The diameter of the circle can be accurately measured with the scale. The procedure is repeated for 15mm, 20mm and 25mm diameter circles.
5. The readings are tabulated and the mean numerical aperture and acceptance angle are determined.

Result

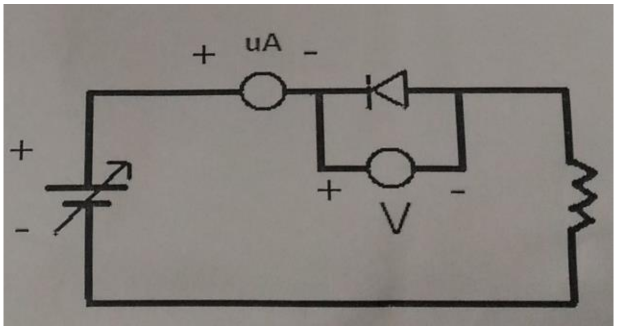
i) The numerical aperture of fiber is measured as........................

ii) The acceptance angle is calculated as................... (deg).

10. Characteristic of PN junction diode under reverse bias

Aim: To plot the characteristics curve of PN junction diode in reverse bias

Apparatus: A diode, DC voltage supplier, Bread board, 100Ω resistor, 2 multimeter for measuring current and voltage and connecting wires.



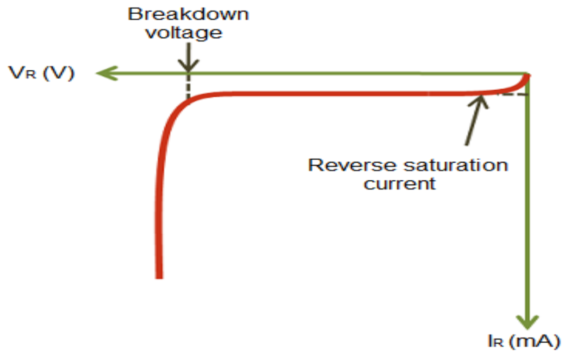


Fig. 10.1. PN Junction Reverse Bias **Fig. 10.2. I-V Characteristics**

Procedure:

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.

Observation:

S. No	Reverse Voltage (V)	Reverse Current (mA)

Result: PN junction characteristic is studied and curve is drawn.

11.Determination of efficiency of solar cell

Aim: To explore solar cells as renewable energy sources and test their efficiency in converting solar radiation to electrical power.

Apparatus:

Solar cell, voltmeter, milliammeter, a dial type resistance box, Keys, illuminating lamps, connecting wires etc.

Formula:

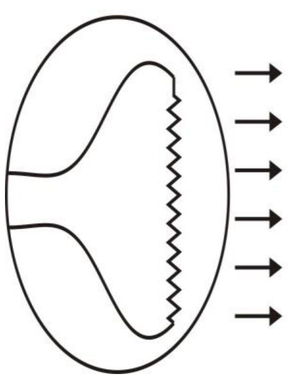
$$\text{Efficiency of solar cell } \eta = [P_{max}/AI_o\ ] \times 100$$

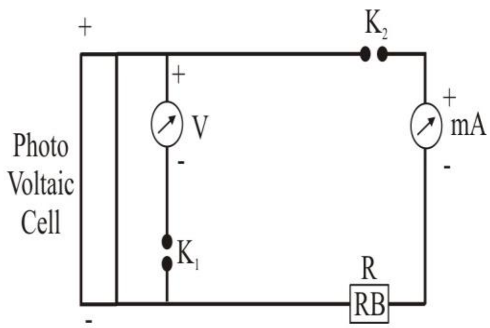
P_{max} = Maximum power = I_{mp} x V_{mp} Watt

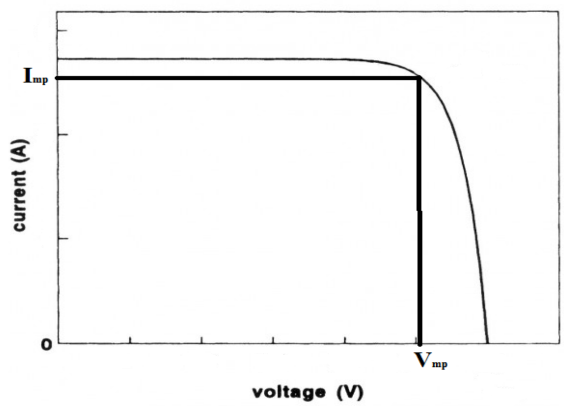
A-Area of the solar panel [7.2 cm x 4.5 cm **Single cell only**]

I_o Intensity of light = Power of the bulb/$4\pi d^2$

d - Distance between solar panel and bulb







Procedure

A solar cell (photovoltaic cell) essentially consists of a p-n junction diode, in which electrons and holes are generated by the incident photons. When an external circuit is connected through the p-n junction device, a current passes through the circuit. Therefore, the device generates power when the electromagnetic radiation is incident on it. The voltmeter is connected in parallel with the given solar cell through a plug key. A milliammeter and a variable resistor are connected in series to the solar cell through a key as shown in the Fig.

The solar cell can be irradiated by sun's radiation. Instead, it can also be irradiated by a filament bulb (75 W). The resistance value is adjusted by a resistance box and the variation of V-I is plotted. From the graph calculate maximum power.

Distance between solar panel and bulb (d) = cm			Distance between solar panel and bulb (d) = cm		
Intensity of light Io = Wm^{-2}			Intensity of light Io = Wm^{-2}		
Resistance (Ohm)	Voltage (V)	Current (mA)	Resistance	Voltage (V)	Current (mA)

Observation:

Maximum power P_{max} = ……….Watt

Area of the solar panel = ………. m^2

Intensity of the light I_o =…………. W/m^2

Efficiency of solar cell $\eta = [P_{max}/AI_o] \times 100$

Result:

Efficiency of solar cell η =…………………….

12. Calculation of Lattice Cell Parameters – X-ray Diffraction

Aim

The calculate the lattice cell parameters from the powder X-ray diffraction data.

Apparatus required

Powder X-ray diffraction diagram

Formula

For a cubic crystal

$$\frac{1}{d^2} = \frac{(h^2 + k^2 + l^2)}{a^2}$$

For a tetragonal crystal

$$\frac{1}{d^2} = \left\{ \frac{(h^2 + k^2)}{a^2} + \frac{l^2}{c^2} \right\}$$

For a orthorhombic crystal

$$\frac{1}{d^2} = \left(\frac{h^2}{a^2} \right) + \left(\frac{k^2}{b^2} \right) + \left(\frac{l^2}{c^2} \right)$$

The lattice parameter and interplanar distance are given for a cubic crystal as,

$$\text{a} = \frac{\lambda}{2 sin\,\theta} \sqrt{h^2 + k^2 + l^2} \ \text{Å}$$

$$\text{d} = \frac{\text{a}}{\sqrt{h^2 + k^2 + l^2}} \ \text{Å}$$

Where, a = Lattice parameter
d = Interplanner distance
λ = Wavelength of the CuKα radiation (1.5405)
h, k, l = Miller integers

Principle

Braggs law is the theoretical basis for X-ray diffraction.

$$(\sin^2 \theta)_{hkl} = (\lambda^2 / 4a^2)\ (h^2 + k^2 + l^2)$$

Each of the Miller indices can take values 0, 1, 2, 3, …. Thus, the factor ($h^2 + k^2 + l^2$) takes the values given in Table 6.7.1.

Value of $h^2 + k^2 + l^2$ for different planes

h, k, l	$h^2 + k^2 + l^2$	***h, k, l***	$h^2 + k^2 + l^2$
100	1	300	9
110	2	310	10
111	3	311	11
200	4	322	12
210	5	320	13
211	6	321	14
220	8	400	16
221	9	410	17

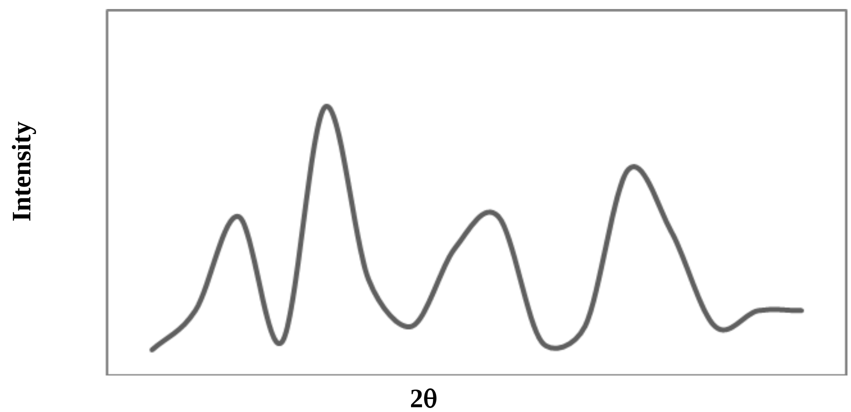


Fig. 12.1. XRD pattern

The problem of indexing lies in fixing the correct value of a by inspection of the $\sin^2\theta$ values.

Procedure:

From the 2θ values on a powder photograph, the θ values are obtained. The $\sin^2\theta$ values are tabulated. From that the values of $1\times\frac{sin^2\theta}{sin^2\theta_{min}}, 2\times\frac{sin^2\theta}{sin^2\theta_{min}}, 3\times\frac{sin^2\theta}{sin^2\theta_{min}}$ are determined and are tabulated. The values of $3\times\frac{sin^2\theta}{sin^2\theta_{min}}$ are rounded to the nearest integer. This gives the value of h^2+k^2+l .From these the values of *h*,*k*,*l* are determined from the Table.6.7.1.

From the *h*,*k*,*l* values, the lattice parameters are calculated using the relation

$$a = \frac{\lambda}{2\sin\theta}\sqrt{h^2+k^2+l^2}\ \text{Å}$$

$$d = \frac{a}{\sqrt{h^2+k^2+l^2}}\ \text{Å}$$

Value of $h^2 + k^2 + l^2$ for different planes

S. No	2θ	$sin^2\theta$	$1 \times \frac{sin^2\theta}{sin^2\theta_{min}}$	$2 \times \frac{sin^2\theta}{sin^2\theta_{min}}$	$3 \times \frac{sin^2\theta}{sin^2\theta_{min}}$	$\boldsymbol{h^2+k^2+l^2}$	***hkl***	**a** Å	**d** Å

Lattice determination

Lattice type	**Rule for reflection to be observed**
Primitive P	None
Body centered I	$hkl : h + k + l = 2n$
Face centered F	$hkl : h, k, l$ either all odd or all even

Depending on the nature of the h,k,l values the lattice type can be determined.

Result:

The lattice parameters are calculated theoretically from the powder x-ray diffraction pattern.