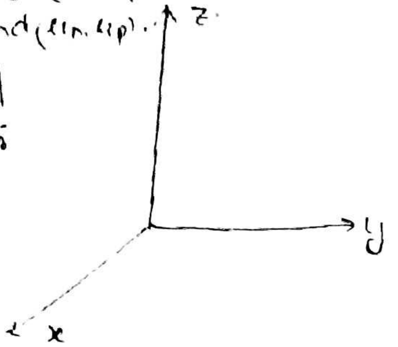
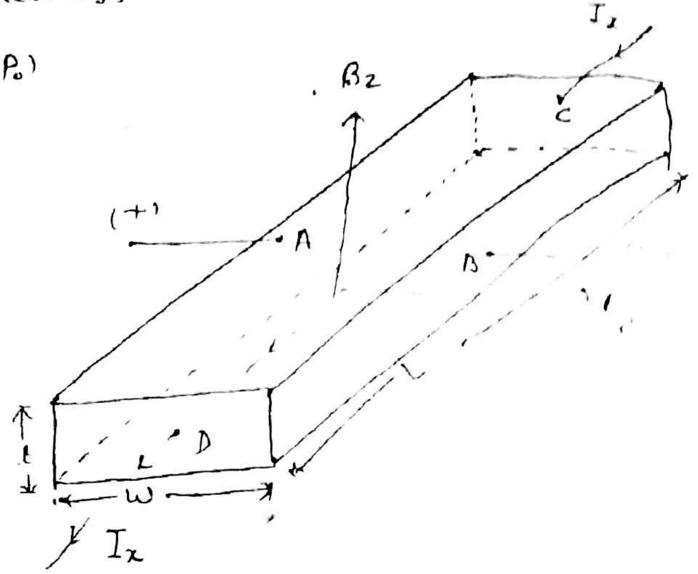
* Hall Effect :- By using Hall effect we can

Concentration of charge carrier. (n_0, P_0)
conductivity (σ_n, σ_p)
mobility and (μ_n, μ_p)
also type of
Semiconductor
material





Consider a p type ABCD bar, of thickness t, width w and length L.
Total force on a single hole due to electric and magnetic field.

$$F = q\,(E + v \times B)$$

But in y-direction force is -

$$F_y = q\,(E_y - v_x B_z) \quad \text{------ (i)}$$

Holes moves in the x direction with velocity v_x so, current I_x is flows.

Each hole experience a force $-q v_x B_z$ in in -y direction so, for maintaining this force. (applying $F_y = 0$)

$$q E_y = q v_x B_z$$

$$E_y = v_x B_z \quad \text{------------ (ii)}$$

While $E_y = \dfrac{V_{AB}}{w}$

$$\therefore \frac{V_{AB}}{w} = v_x B_z$$

$$\therefore \boxed{V_{AB} = v_x B_z \cdot w}$$

Where V_{AB} called Hall voltage.

* Now for Type of Semiconductor :-

Consider the current density equation

$$J = v_x\,(-q n)$$

$$J_x = \frac{E_y}{B_z} \times q P_0 \quad \{\text{-for ...}$$

$$\therefore E_y = \frac{J_x}{q P_0} \cdot B_z \quad \text{------------ (iii)}$$

where qP_0 is constant and consider as.

$$\frac{1}{qP_0} = \text{Constant} = R_H$$

$$R_H = \frac{1}{qP_0}$$

Hence equation (iii) becomes-

$$E_y = \frac{J_x}{qP_0} \cdot B_z$$

$$\therefore P_0 = \frac{J_x \times B_z}{q E_y} = \frac{I_x/wt \times B_z}{q \; V_{AB}/w}$$

$$P_0 = \frac{\frac{I_x \times B_z}{wt}}{\frac{q \, A \, V_{AB}}{w}} = \frac{I_x \times B_z}{q V_{AB} t}$$

$$\boxed{P_0 = \frac{I_x \times B_z}{q V_{AB} t}}$$

» For conductivity:- The resistivity.

$$\therefore R = \frac{\rho L}{A} \Rightarrow \rho = \frac{RA}{L}$$

$$\rho = \frac{V_{CD}}{I_x} \cdot \frac{Wt}{L} \qquad \left\{ \because R = \frac{V_{CD}}{I_x} \right.$$

$$\boxed{\rho = \frac{V_{CD}}{I_x} \cdot \frac{Wt}{L}}$$

$$\sigma_p = 1/\rho$$

» Now for mobility:- $\sigma = q \mu_p P_0$

$$\therefore \mu_p = \frac{\sigma}{qP_0} = \frac{1/\rho}{\frac{1}{R_H}}$$

$$\boxed{\mu_p = \frac{R_H}{\rho}}$$

Problem: Consider a semiconductor bar with $w = 0.1\,mm$, $t = 10\,\mu m$ and $L = 5\,mm$. For $B = 10\,kG$ in the z direction ($1\,kG = 10^{-5}\,wb/cm^2$) and a current of $1\,mA$, we have $V_{AB} = -2\,mV$, $V_{CD} = 100\,mV$. Find the type of S/c, majority carrier concentration and mobility of majority carriers.

Solution: Given $B = 10\,kg = 10\,kG$, KG - Kilo Gauss.

$= 10 \times 10^{-5}\,wb/cm^2 = 10^{-4}\,wb/cm^2$

From the sign of V_{AB}, we can see that the majority carriers are electrons. Hence type of semiconductor is n type.

$$n_o = \frac{I_x B_z}{q\,t(-V_{AB})} = \frac{1 \times 10^{-3}\,Amp \times 10^{-4}\,wb/cm^2}{1.6 \times 10^{-19} \times 10 \times 10^{-4}\,cm \times 2 \times 10^{-3}}$$

$$= 3.125 \times 10^{17}/cm^3$$

$$\rho = \frac{V_{CD}}{I_x} \cdot \frac{wt}{L} = \frac{100 \times 10^{-3} \times 1 \times 10^{-4} \times 10 \times 10^{-6}}{1 \times 10^{-3} \times 5 \times 10^{-3}}$$

$$= 2 \times 10^{-3}\,\Omega cm$$

$$= .002\,\Omega cm$$

$$\mu_n = \frac{1}{\rho\, q\, n_o} = \frac{1}{0.002 \times 1.6 \times 10^{-19} \times 3.125 \times 10^{17}}$$

$$= 10000\,cm^2/Volt\text{-}sec$$

$n_o = 3.125 \times 10^{17}/cm^3$

$\rho = 0.002\,\Omega cm$

$\mu_n = 10000\,cm^2/Volt\text{-}sec$

Answer

$\boxed{\text{Type or Sign of } V_{AB} \text{ gave type of semiconductor}}$

Problem: A sample of Si is dopped with 10^{17} Phoshphorous atoms/cm³. What would you expect resistivity. What is Hall voltage you expect to major it's sample. Given.

Thickness $= 100\,\mu m$

$I_x = 1\,mA$

determining above values in the following sequence
$\sigma,\ \rho,\ R_H\ \&\ V_H$

$$\sigma = +q\,\mu_n n_0$$
$$= 1.6\times10^{-19}\times 700\times10^{17}$$
$$= 1.6\times7\times\cancel{10^{-19}}\times\cancel{10^{19}} = 11.2\ (\Omega\text{-cm})^{-1}$$

$$\therefore \rho = \frac{1}{11.2} = 0.089\ \Omega\text{cm}.$$

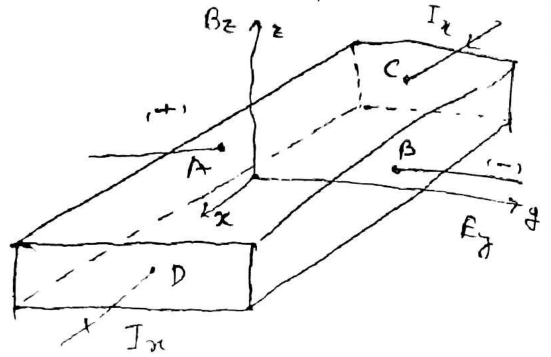
$$\therefore R_H = \frac{1}{-q n_0} = \frac{1}{-1.6\times10^{-19}\times10^{17}}$$
$$= -62.5\ \text{cm}^3/\text{coulomb}.$$

$$\&\quad V_{AB} = \frac{I_x B_z R_H}{t}$$
$$= \frac{1\times10^{-3}\times1\times10^{-5}\ \text{wb/cm}^2\times -62.5\ \text{cm}^3/\text{C}}{100\times10^{-4}\ \text{cm}}$$
$$= \frac{-62.5\times10^{-8}}{10^{-2}}$$
$$= -62.5\times10^{-6}\ \text{volt}.$$

$\therefore V_{AB} = 62.5$ microvolt.

$$\left.\begin{aligned} \sigma &= 11.2\ (\Omega\text{cm})^{-1} \\ \rho &= 0.089\ (\Omega\text{cm}) \\ R_H &= -62.5\ \text{cm}^3/\text{coulomb} \\ V_{AB} &= 62.5\ \mu\text{volt} \end{aligned}\right\}\ \text{Ans}$$

Assignment: Illustrate Hall effect for n-type semiconductor bar and determine Hall effect R_H, Hall voltage V_{AB}, and measurement of n_o, μ_n, σ_n and ρ_n



Total force on single electron due to electric field and magnetic field -

$$F = -q(E + v B) \quad ----(i)$$

But the Force in y-direction can be given by -

$$F_y = -q(E_y - v_x B_z) \quad ------ (ii)$$

for maintaining the force acting on electron :-

$$-q E_y = q v_x B_z$$

$$E_y = -v_x B_z$$

$$\because E_y = \frac{V_{AB}}{w}$$

$$\therefore \boxed{V_{AB} = -v_x B_z w}$$

V_{AB} called Hall voltage with - sign

Now for type of Semiconductor :- Consider current density equation -

$$J = v_x(-q n_o)$$

$$J_x = -\frac{E_y}{B_z} \times q n_o$$

$$\therefore E_y = -\frac{J_x}{q n_o} \times B_z \quad (iii)$$

where $-q n_o$ is constant and consider as below.

$$-\frac{1}{q n_o} = R_H$$

Hence equation (iii) becomes -

$$E_y = -\frac{J_x}{q n_o} \cdot B_z$$

$$n_o = -\frac{J_x}{q E_y} \cdot B_z$$

$$n_o = -\frac{I_x / w t}{q V_{AB}/w} \times B_z$$

$$\therefore \boxed{n_o = \frac{I_x \times B_z}{q V_{AB} \cdot t}}$$

for Conductivity :-

$$R = \rho \frac{L}{A}$$

$$\rho = \frac{RA}{L} = \frac{V_{CD}/I_x \times w t}{l}$$

$$\boxed{\rho = \frac{V_{CD}}{I_x} \cdot \frac{w t}{L}}$$

Hence conductivity.

$$\boxed{\sigma_n = \frac{1}{\rho} = \frac{I_x \cdot L}{V_{CD}\, w t}}$$

and mobility. $\mu_n = \frac{R_n}{\rho}$

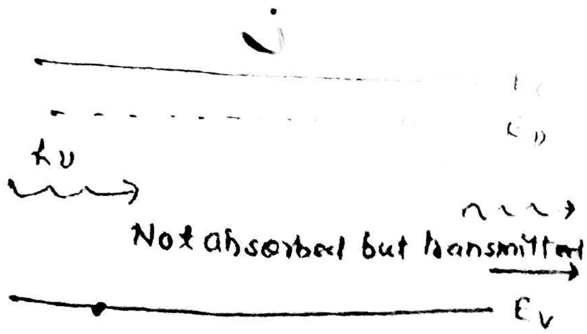
Note : 1. Excess Carriers :- The charge carriers generated other than EHP are called excess carries. All the semiconductors are operated by creating excess carriers. Firstly the excess carriers are generated and then injected.

There are a number of ways to creating excess carriers —

→ Applying Biasing. &

→ Bombardment of photons

The photons are absorbed only the Energy ~~$E_g > h\nu$~~. $h\nu \geq E_g$.
The photons of energy $h\nu < E_g$ are not absorbed. But they are transmitted.

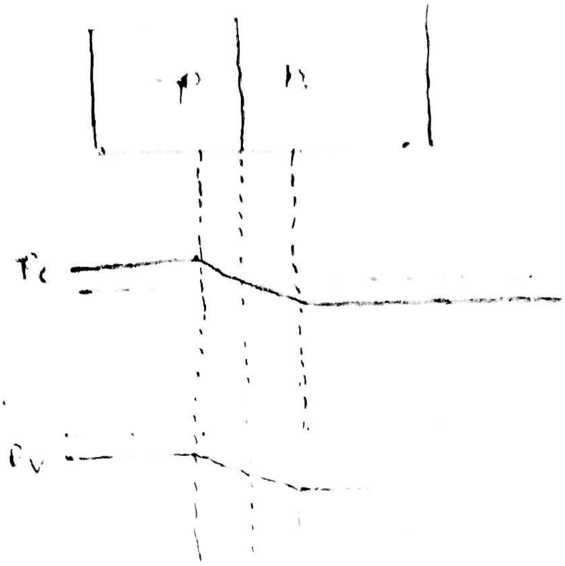


[2]:-

* **Notes**:- E_f means probability being 50% occupied at 42.
equilibrium

Fermi levels are at same.
Equilibrium means No
biasing is applied.

But when we applied the
biasing then biasing then
E_f of both both semiconductor
(N-Type and P Type are aligned).



When excess electrons and Holes are generated in the semi-conductor then there is corresponding increase in the conductivity.
If excess carriers are created from optical excitation then resulting increase in conductivity is called photoconductivity.
The photoconductivity in the terms of carriers life-time can be given as below -

$$\boxed{\sigma = q\, g_{op} [\tau_n \mu_n + \tau_p \mu_p]}$$

where, σ = Photo conductivity
g_{op} = Optical Generation rate.
τ_n = electrons life time.
τ_p = Life time for holes

2 :-

-: Excess Carriers in the Semiconductor :-

The charge carriers generated other than EHP are called excess carriers. All the semiconductor devices are operated by creating excess carriers. Firstly the excess carriers are generated an then injected. There are a number of way for creating excess carriers-

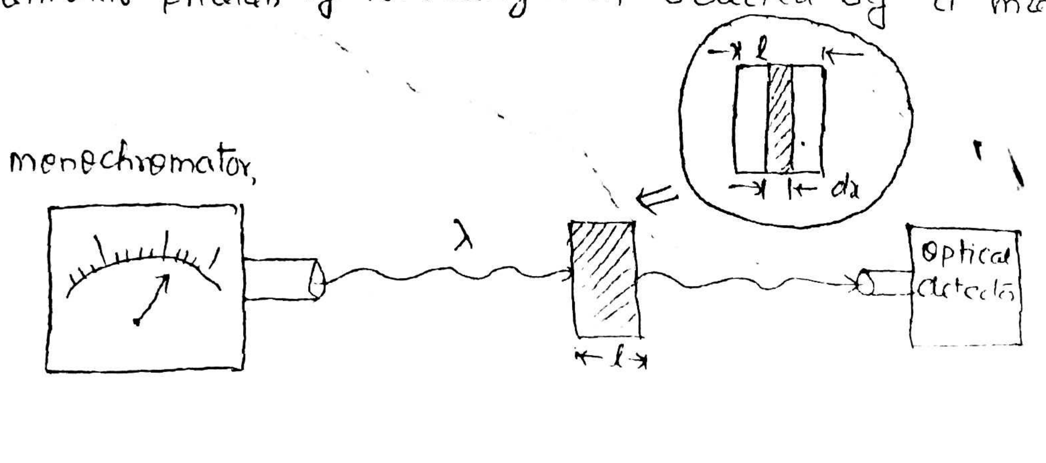
» Applying Biasing and,

» Bombardment of photons.

The photons are absorbed if Eg $h\nu \geq E_g$. If a photon of energy $h\nu < E_g$ is unable to excite an electron from valence band to conduction band.

** **Optical Absorption :-** The measuring of energy band Gap of semiconductor material is done by absorption of incident photons on the material. In this experiment photon of selected wavelength are direct at the sample. The photon with energy $h\nu > E_g$ are absorbed while photon's energy $h\nu < E_g$ are transmitted.

Let a photon beam of Intensity I_0 (photons / cm² - sec) directed at the sample of thickness l. The beam contains photon of wavelength λ, selected by a monochromator.



$\frac{hc}{\lambda} > E_g \longrightarrow$ Absorption.

$\frac{hc}{\lambda} < E_g \longrightarrow$ Transmission

$$-\frac{dI(x)}{dx} = \alpha I(x)$$

$$-\frac{dI_0}{dx} \propto I(x)$$

$$-\frac{dI_0}{dx} = \alpha I(x) \quad \text{------} \quad (1)$$

where α is absorption coefficient and it is depends upon material and incident photons. The solution of equation (1) can be given by-

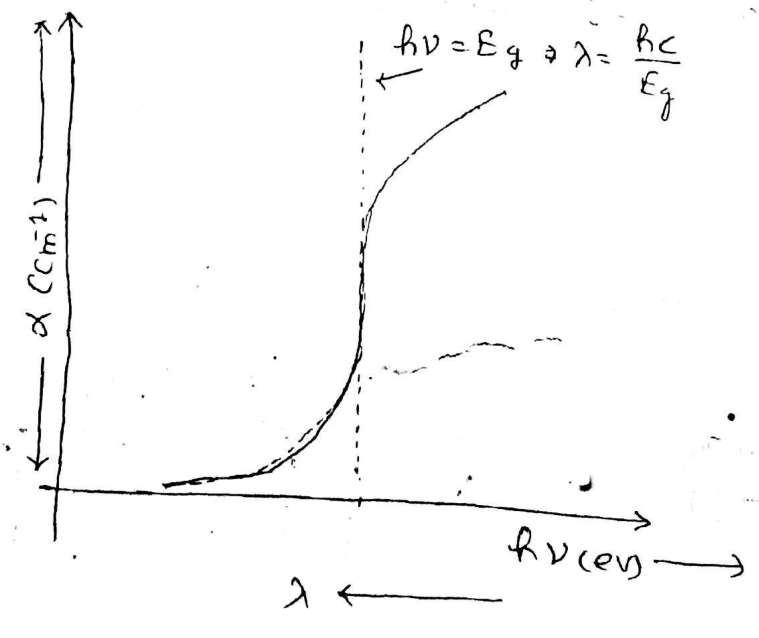
$$I(x) = I_0 e^{-\alpha x}$$

and the intensity of light transmitted through the sample thickness l is-

$$I(l) = I_0 e^{-\alpha l}$$

$$\frac{I(l)}{I_0} = e^{-\alpha l}$$

α depends upon thickness of material, and unit of α is cm^{-1}. A typical plot of α vs wavelength shown in the figure.



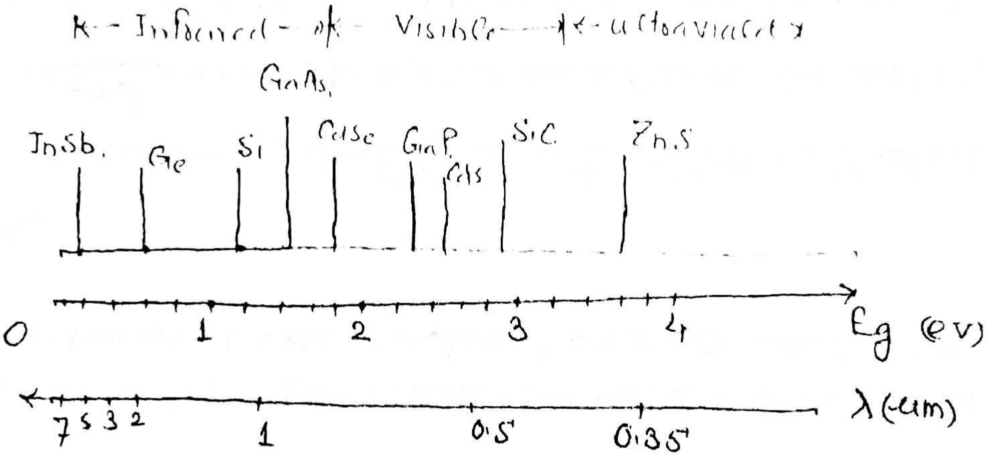
There is negligible absorption at long wavelengths (small $h\nu$), and considerable absorption of photons with energy larger than E_g.

$$E = h\nu$$
$$= \frac{hc}{\lambda}$$
$$E = 1.24/\lambda$$

where E in electron volts, λ in micrometers (μm)

Energy band Gap of some common semiconductor material relative to the visible, infrared, and ultraviolet portion of spectrum.

→ Spectrum ←



Energy Band Gap of some common Semiconductor with relative to → the Optical Spectrum ←

* **Luminescence** :- when carriers are excited by using external energy then they go to higher energy level from which they fall to their equilibrium state and emitted light. The general property of light emission is called "luminescence". Mostly compound Semiconductor material with direct band gap are give this phenomenon. The luminescence is subdivided into following three types -