Date

ASSIGNMENT : 2

① Define relaxation time and drift velocity of electron in a semiconductor.

→ The average time between two successive collision is τ. This time is known as relaxation time.

DRIFT VELOCITY :- In absence of external field the random motion of free e^- is equally possible. It is defined as the average velocity attained by a charged particle in a material due to e^- field. The SI unit of drift velocity is m/s.

$$\boxed{V = \frac{I}{neA}}$$

② Define the expression of current density and mobility of charge current flowing carriers for semiconductor

→ CURRENT DENSITY :- It is defined as the amount of electric current flowing per unit cross-section area of a material

$$J = \frac{I}{A} = \frac{NeAV_d}{A} = NeV_d$$

$$J = NeV_d.$$

MOBILITY :- It is defined as the drift velocity of charge carrier per unit electric field.

$$\mu = \frac{V_d}{E_x}$$

$$\therefore E_H \longrightarrow V_d B$$

$$V_d \longrightarrow \mu E_x$$

$$V_d \longrightarrow \frac{E_H}{B}$$

$$\frac{E_H}{B} \longrightarrow \mu E_x$$

$$E_H = \mu E_x B$$

$$E_H = \frac{\mu J_x B}{\sigma}$$

$$\frac{E_H}{B J_x} = \frac{\mu}{\sigma}$$

$$R_H = \frac{\mu}{\sigma}$$

$$\mu = R_H \sigma$$

$$\tan \theta_H = \frac{E_H}{E_x}$$

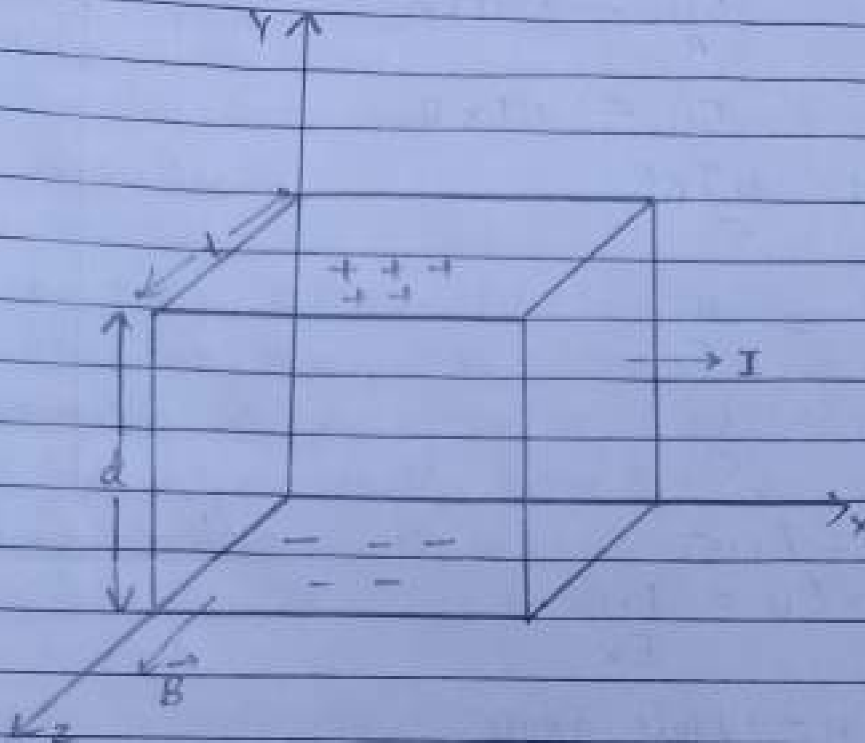
$\theta_H \rightarrow$ Hall angle

$$\mu = \frac{\sigma E_H}{B J_x}$$

$$\mu = \frac{\tan \theta_H}{B}$$

(3) Discuss Hall effect with suitable diagram how can we calculate Hall effect, carrier density and mobility experimentally.

→ **HALL EFFECT:** If a current carrying conductor (or semiconductor) is placed in a magnetic field perpendicular to the direction of current, the magnetic field exerts a transverse force (LORENTZ FORCE) on the moving charge carriers which tends to push them to one sides of the conductor will balance their magnetic influence, producing a measurable voltage is called hall voltage (V_H) and the effect is called Hall effect



CALCULATIONS:-

Lorentz force = $\vec{F_m} = q(\vec{V_d} \times \vec{B})$

$q = -e$, $\vec{V_d} = -\hat{i} V_d$, $B = \hat{k} B$

$= -e(-\hat{i} V_d \times \hat{k} B)$

$= e V_d B (\hat{i} \times \hat{k})$

$= -e V_d B \hat{j}$

Hall effect at equilibrium

$F_H = F_m$

$e E_H = e V_d B$

$E_H = V_d B$ ——— (i)

current density $\boxed{J_x = -ne V_d}$

Hall coefficient

$$R_H = \frac{E_H}{BJ_x} = -\frac{V_d B}{n e V_d B} = -\frac{1}{ne}$$

$$\boxed{E_H = R_H B J_x} \text{ —— (ii)}$$

$$\boxed{R_H = \frac{E_H}{BJ_x} = -\frac{1}{ne}} \text{ —— (iii)}$$

Mobility

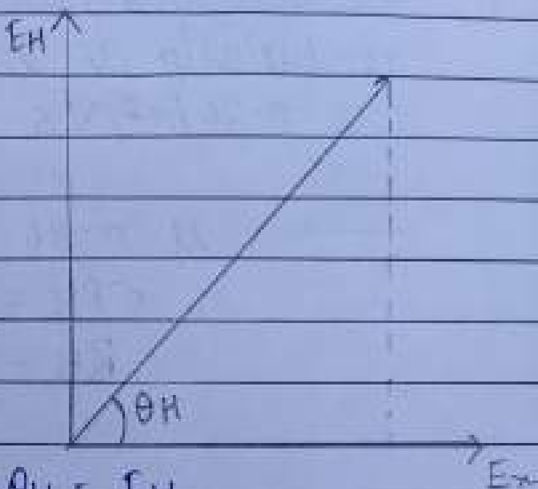
Mobility, $\mu = \frac{V_d}{E_x} \Rightarrow V_d = \mu E_x$

$$E_H = V_d B \Rightarrow E_H = \mu E_x B$$

$$E_H = \frac{\mu J_x B}{\sigma} \quad [J_x = \sigma E_x]$$

$$R_H = \frac{E_H}{BJ_x} = \frac{\mu}{\sigma}$$

$$\boxed{\mu = R_H \sigma}$$



$$\tan\theta_H = \frac{E_H}{E_x}$$

$$\boxed{\mu = \frac{\sigma E_H}{BJ_x}} \quad J_x = \sigma E_x$$

where, θ_H = hall angle

$$\mu = \frac{\sigma E_H}{B\sigma E_x}$$

$$\mu = \frac{E_H}{BE_x}$$

$$\boxed{\mu = \frac{\tan\theta_H}{B}}$$

Date

Determination of hall coefficient

$$E_H = \frac{V_H}{dB}, \quad J_x = \frac{I}{dt}$$

$$R_H = \frac{V_H}{dB} \times \frac{dt}{I} = \frac{V_H t}{BI}$$

(4) Calculate the hall coefficient of a specimen whose electrical conductivity is 2.12 mho/m and charge carrier mobility are $0.36\, m^2/V \cdot s$

$\longrightarrow$ $\mu = 0.36 \qquad \sigma = 2.12$ mho/m

$$\sigma R_H = \mu$$

$$R_H = \frac{\mu}{\sigma} \Rightarrow R_H = \frac{0.36}{2.12}$$

$$= 0.169$$

(5) The hall coefficient (R_H) of a semiconductor is $3.22 \times 10^{-4}\, m^3/C$. If resistivity is $9 \times 10^{-3}\, \Omega m$. Calculate the mobility and the carrier concentration of the carrier ($e = 1.6 \times 10^{-19} C$)

$\longrightarrow$ $R_H = 3.22 \times 10^{-4}\, m^3/C$

$e = 1.6 \times 10^{-19} C$

$n = \frac{1}{R_H e}, \quad \mu = \sigma R_H$

$$\mu = \frac{1}{\rho} R_H$$

n is carrier concentration

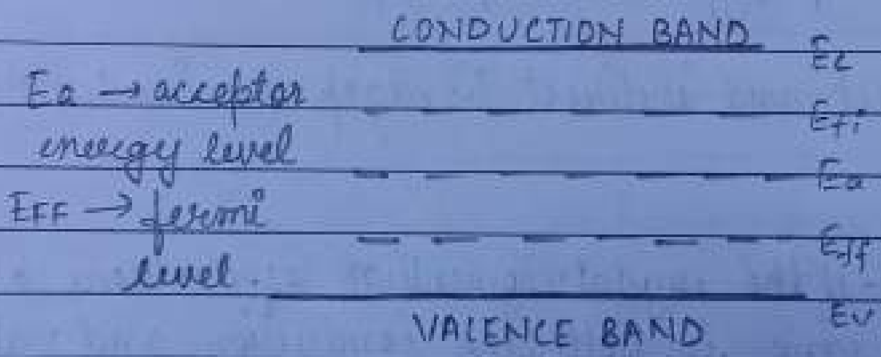
$$n = \frac{1}{3.22\times10^{-4}\times1.6\times10^{-19}} \qquad \mu = \frac{3.22\times10^{-4}}{9\times10^{-3}}$$

$$n = 1.94\times10^{22} \qquad \boxed{\mu = 3.5}$$

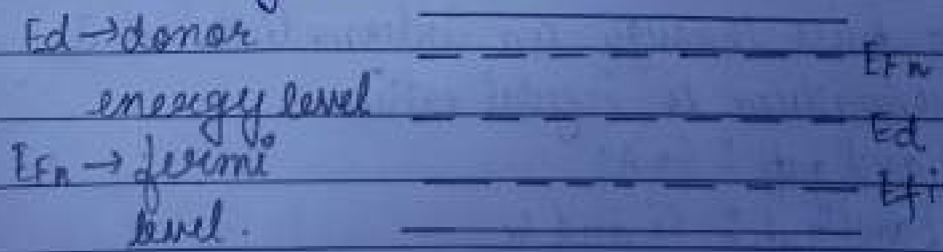
6) In a slab of specimen of width 4mm, electrons have drift velocity 3×10^{3} m/s under the influence of externally applied electric field along the x-axis. Calculate the hall voltage if specimen is subjected to magnetic field of $4\,Wb/m^2$ along the z-axis

7) Describe the P and N type semiconductor and indicate the fermi level and energy level of impurity atoms in band diagram.

→ P type semiconductor:- The majority carriers are hole and minority carrier are electrons.



→ N type semiconductor:- The majority are electrons and minority carrier are hole.



Date

(8) What are the charge carrier responsible for current conduction in pure semiconductor? Find the expression for conductivity of such semiconductor?

→ The more abundant charge carriers are called majority carrier which are primarily responsible for current transport in a piece of semiconductor. In n-type semiconductor they are electrons while in p-type semiconductor they are holes.

The conductivity of a semiconductor

$$\sigma = n_e e V_e + n_n e U_n$$

where

n_e is the number of electrons

e is the electronic charge

u_e and u_n is the mobility of e^- and hole

for n-type $\Rightarrow \sigma = ne\, u_n$

for p-type $\Rightarrow \sigma = pe\, u_p$.

(9) Explain the direct and indirect bandgap semiconductors with examples.

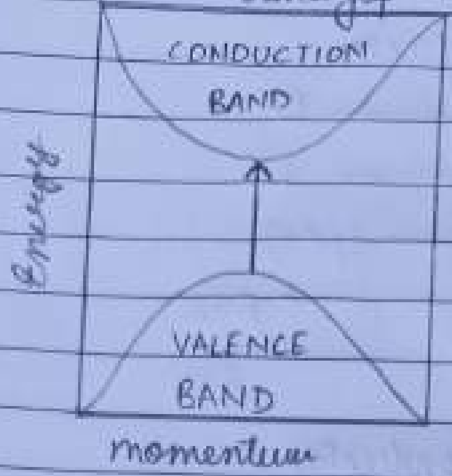
→ DIRECT BANDGAP:- If the crystal momentum of electrons and holes in the same in both the conduction and valence band.

INDIRECT BANDGAP:- A photon can be emitted because the electron must be pass through an intermediate state and transfer momentum to crystal lattice.

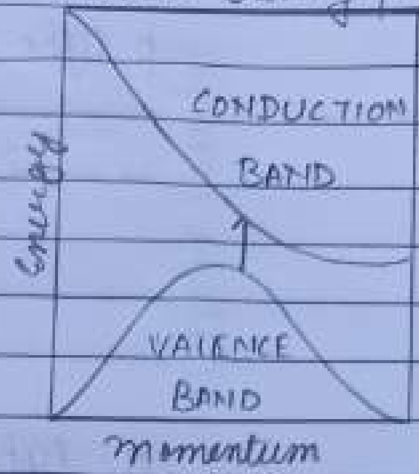
Eg. of direct band gap: GaAS

Eg. of indirect band gap: Si and Ge

Direct band gap



Indirect band gap



(10) Hall coefficient of a semiconductor is $3.22 \times 10^{-4}\ m^3/C$. Its resistivity is 9×10^{-3} ohm-meter. Calculate the mobility and carrier in the semiconductor.

$\longrightarrow$

$$R_H = 3.22 \times 10^{-4}\ m^3/C$$

$$\rho = 9 \times 10^{-3}\ \text{ohm-meter}$$

$$\mu = \sigma R_H = \frac{1}{\rho} R_H$$

$$= \frac{3.22 \times 10^{-4}}{9 \times 10^{-3}} = 3.5$$

$$n = \frac{1}{R_H e} = \frac{1}{3.22 \times 10^{-4} \times 1.6 \times 10^{-19}} = 1.94 \times 10^{22}$$

(11) How does fermi level changes with increasing temperature in p-type semiconductor and n-type semiconductor? Sketch the diagram.

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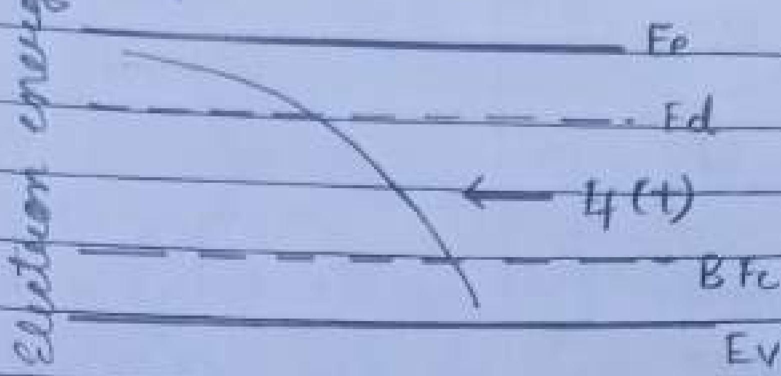
→ p-type semiconductor



n-type semiconductor