Semiconductor's in Equilibrium.

We know that

$$n = 2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2} \exp\left(\frac{E_F - E_E}{KT}\right)$$

In thermal equilibrium, we can write

$$n = n_0 = N_C \exp\left(\frac{E_F - E_E}{KT}\right)$$

where $N_C = 2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2} \rightarrow (1)$

'N_C' is called the "effective density of states function" in the conduction band".

Similarly

$$P = 2\left(\frac{2\pi m_p^* KT}{h^2}\right)^{3/2} \exp\left(\frac{E_V - E_F}{KT}\right)$$

In thermal equilibrium, we can write

$$P = P_0 = N_V \exp\left(\frac{E_V - E_F}{KT}\right). \rightarrow$$

where N_V is called "Effective density of states function in Valance band".

$$\therefore N_V = 2\left(\frac{2\pi m_p^* KT}{h^2}\right)^{3/2} \rightarrow (2)$$

Note: As per the above equations (1) & (2)

$$N_C \text{ (or) } N_V \propto T^{3/2}.$$

$$\boxed{\left(\frac{N_1}{N_2}\right) \propto \left(\frac{T_1}{T_2}\right)^{3/2}}$$

Intrinsic carrier concentration in terms of N_c & N_V.

We know that $n = p = n_i \Rightarrow n \times p = n_i^2$

$$\Rightarrow n_i^2 = N_c \exp\left(\frac{E_F - E_C}{KT}\right) N_V \exp\left(\frac{E_V - E_F}{KT}\right)$$

$$= N_C N_V \exp\left(\frac{E_V - E_C}{KT}\right).$$

$$\boxed{n_i^2 = N_C N_V \exp\left(\frac{-E_g}{KT}\right).}$$

Example :-

Q:- Calculate intrinsic carrier concentration in gallium arsenide at T = 300 K and 450K

Sol :- Boltzmann's constant "K" Value.

$= 1.38 \times 10^{-23}$ J/K

$= 8.62 \times 10^{-5}$ eV/K.

$$n_i = N_C N_V \exp\left(\frac{-E_g}{KT}\right).$$

$N_C = 4.7 \times 10^{17}$/cm^3 at 300 K

$N_V = 7.0 \times 10^{18}$/cm^3 at 300K.

Band gap of GaAs is 1.42eV.

$$\boxed{n_i = 3.85 \times 10^{10}/\text{cm}^3.}$$

Intrinsic Fermi level position: (E_{Fi})

We know that at thermal equilibrium

$n = p.$

$$\Rightarrow N_c \exp\left(\frac{E_{Fi}-E_C}{KT}\right) = N_V \exp\left(\frac{E_V-E_{Fi}}{KT}\right).$$

Applying log on both sides gives us

$$\Rightarrow E_{Fi} = \frac{1}{2}(E_C+E_V) + \frac{1}{2}KT\log\left(\frac{N_V}{N_C}\right).$$

$$\Rightarrow E_{Fi} = \frac{1}{2}(E_C+E_V) + \frac{3}{4}KT\log\left(\frac{m_p^*}{m_n^*}\right).$$

Since $\frac{E_C+E_V}{2}$ is exactly at mid-way between E_C & E_V, $\frac{1}{2}(E_C+E_V) = E_{midway}$

$$\boxed{\therefore E_{Fi} - E_{midway} = \frac{3}{4}KT\log\left(\frac{m_p^*}{m_n^*}\right)}.$$

~~productz of~~ product of $n \times p$.

At thermal equilibrium. n

$$n = N_c \exp\left(\frac{E_F-E_C}{KT}\right)$$

$$n = n_i \exp\left(\frac{E_{Ft}-E_{Fi}}{KT}\right)$$

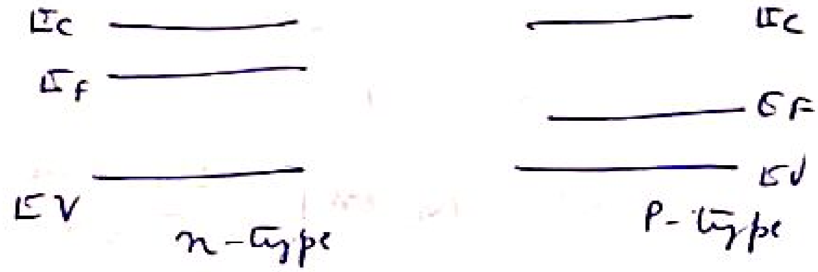
Similarly

$$p = n_i \exp\left(\frac{E_{Fi}-E_F}{KT}\right).$$

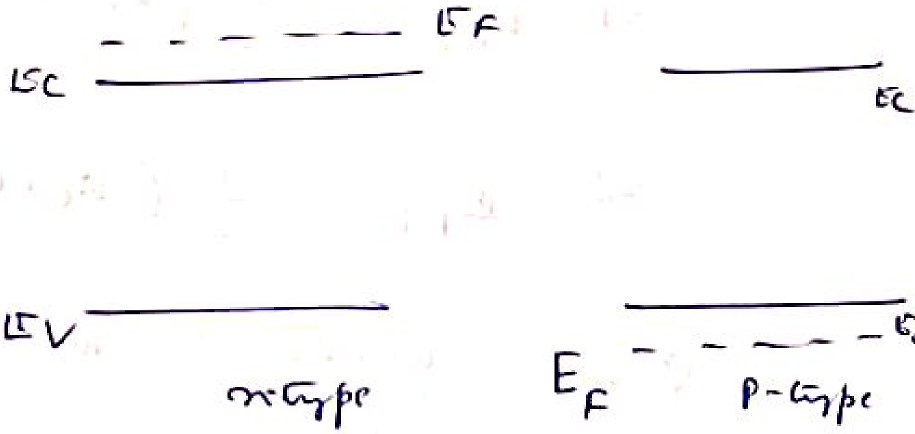
$$\Rightarrow \boxed{np = n_i^2}.$$

Degenerate & Non-degenerate Semiconductors

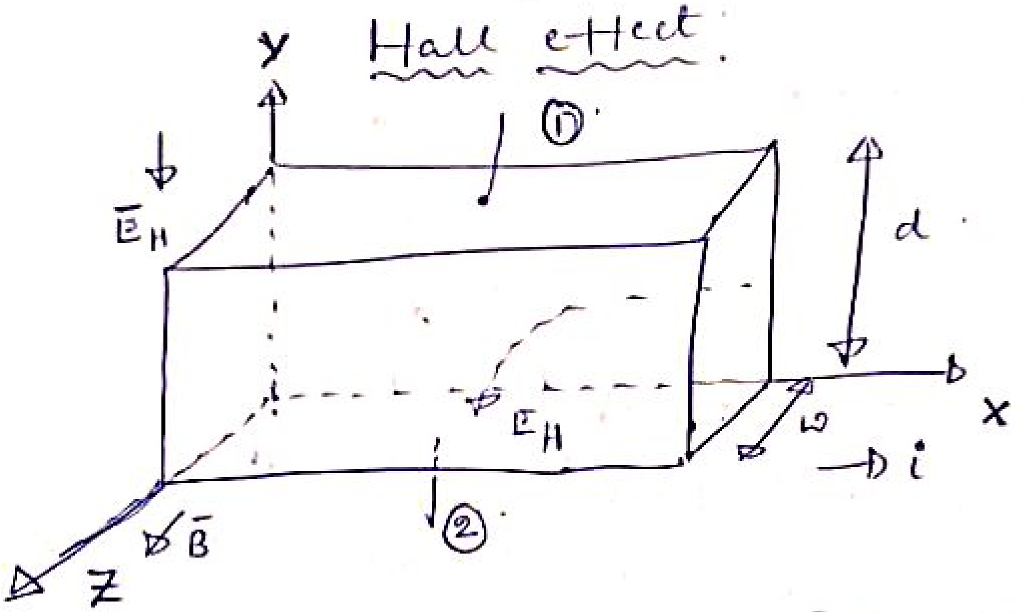
Non-degenerate

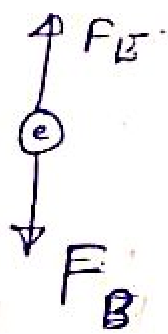


Degenerate



Hall effect:





$$F_B = q(\bar{v} \times \bar{B}) = qvB$$

$$F_E = Eq$$

At equilibrium $\quad F_B = F_E$

$$\cancel{q} vB = E \cancel{q}$$

$$\Rightarrow E_H = v_d B \qquad \left(\begin{matrix} E = E_H \\ v = v_d \end{matrix} \right).$$

$$V_H = E_H \cdot d$$

$$\Rightarrow V_H = v_d \cdot B \cdot d \quad \Rightarrow v_d = \frac{V_H}{Bd}.$$

$$J = \frac{i}{A} = \frac{i}{dw}.$$

$J = \rho v_d$; where ρ is charge density.

$$\therefore \frac{i}{dw} = \rho v_d \Rightarrow \rho = \frac{i}{dw \cdot v_d} = \frac{i}{\cancel{d} w \frac{V_H}{B \cancel{d}}}$$

$$\Rightarrow \boxed{\rho = \frac{iB}{V_H w}}$$

Hall coefficient $R_H = \frac{1}{e}$

$$\Rightarrow \boxed{R_H = \frac{V_H w}{i B}}$$

We know that,
charge density (ρ) = ne.
where 'n' is no. of charge carriers per unit volume.

$$\Rightarrow n = \frac{\rho}{e}.$$

$$\Rightarrow n = \frac{1}{e} \times \frac{IB}{V_H w}.$$

$$\boxed{\therefore n = \frac{iB}{e V_H w}}$$

<u>Applications</u>

(1) n type (or) P-type
(2) carrier concentration n.
(3). charge density ρ.
(4) drift speed v_d
(5) Hall coefficient.
(6) Mobility can be evaluated.
(7) Magnetic fields can be calibrated.