- Conductor :-

The pure SemiConductor, the number of electrons Generated in Conduction band 'n' is equal to the numbe of holes generated in Valence band.

$n = p = n_i$ (intrinsic Carrier Concentration)

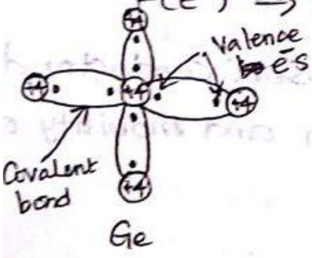
1.1. Density of Electron (n):-

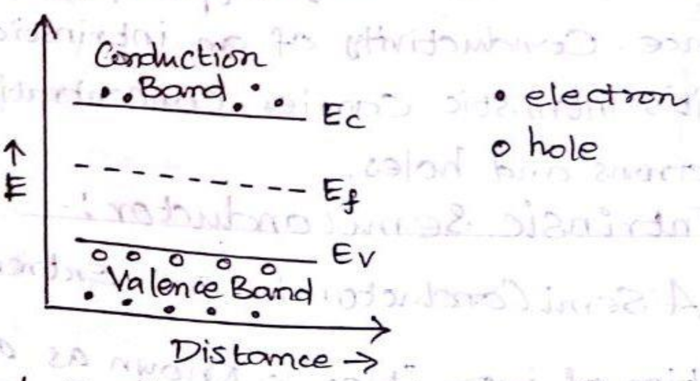
The number of electrons available in Conduction band is given by,

$$n = \int_{E_1}^{E_2} F(E)\, N(E)\, dE \longrightarrow (1)$$

$N(E)dE \Rightarrow$ Density of e^- in the energy interval of E and E+dE ;

$F(E) \Rightarrow$ fermi distribution function.





Under thermal equilibrium Condition,

$$n = \int_{E_c}^{\infty} F(E)\, N(E)\, dE \longrightarrow (2)$$

Where
$$F(E) = \frac{1}{1 + \exp\left[\frac{E - E_f}{KT}\right]} \longrightarrow (3)$$

$$N(E)dE = \frac{4\pi}{h^3} (2m_e^*)^{3/2} E^{1/2} dE \longrightarrow (4)$$

where $(E - E_c)$ represents the K.E of the Conduction band electron at higher energy levels,

$m^* \Rightarrow$ effective mass of electron due to the movement of electron. $N(E)dE = \frac{4\pi}{h^3}(2m_e^*)^{3/2}(E-E_c)^{1/2}dE \rightarrow (5)$

Sub the value of F(E) and N(E) in eqn (2).

$$n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\int_{E_c}^{\infty}\frac{(E-E_c)^{1/2}}{1+\exp\left[\frac{E-E_f}{kT}\right]}dE \rightarrow (6)$$

$\frac{E-E_f}{kT} >> 1$ ($\because E - E_f$ is greater than 20 times)

$$\frac{1}{1+\exp\left[\frac{E-E_f}{kT}\right]} = \frac{1}{1+\exp\left[\frac{E-E_f}{kT}\right]} = \exp\left(\frac{E_f - E}{kT}\right)$$

Sub equation (6)

$$n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\int_{E_c}^{\infty}(E-E_c)^{1/2}\exp\left(\frac{E_f-E}{kT}\right)dE \rightarrow (7)$$

Integral in equation (7)

$$\int_0^{\infty} x^{1/2} e^{-ax}dx = \frac{\sqrt{\pi}}{2a\sqrt{a}}$$

Where $a = 1/kT$

$$\therefore n = \frac{4\pi}{h^3}(2m_e^*)^{3/2}\exp\left(\frac{E_f-E_c}{kT}\right)\left(\frac{\sqrt{\pi}}{2}(kT)^{3/2}\right)$$

Rearranging the terms,

$$n = 2\left[\frac{2\pi m_e^* kT}{h^2}\right]^{3/2}\exp\left[\frac{E_f-E_c}{kT}\right] \longrightarrow (8)$$

1.2 Density of holes (P):-

If F(E) is the Probability of Occupancy of an energy state E by an electrons, Probability of vacant state is given $(1-F(E))$. Since a hole represents the unoccupied state in valence band probability of hole is equal is $(1-F(E))$

The no of holes (or) Vacancies in Valence band

$$P = \int_{E_1}^{E_2} N(E)\,[1 - F(E)]\,dE$$

Sub the values of $N(E)$ and $F(E)$ and effective mass of holes m_h^*.

$$P = \frac{4\pi}{h^3}(2m_h^*)^{3/2}\int_{\alpha}^{E_V} \exp\frac{(E-E_f)}{kT}(E_V - E)^{1/2}\,dE \longrightarrow (9)$$

Where, $E_V \Rightarrow$ Upper energy of Valence band

$-\alpha \Rightarrow$ minimum energy of Valence band

$E_V - E \Rightarrow$ K.E of a hole at higher energy level.

After integration,

$$P = 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} \exp\left[\frac{E_V - E_f}{kT}\right] \longrightarrow (10)$$

1.3. Density of intrinsic Carrier Concentration (n_i):-

The law of mass action states, that in the Case of any SemiConductors in thermal equilibrium, the product of number of holes and number of electrons is a Constant.

$$n = P = n_i$$

$$n_i^2 = n \times p = 2\left(\frac{2\pi m_e^* kT}{h^2}\right)^{3/2} \exp\left(\frac{E_f - E_c}{kT}\right) \times 2\left(\frac{2\pi m_h^* kT}{h^2}\right)^{3/2} \exp\left(\frac{E_V - E_f}{kT}\right)$$

$$= 4\left(\frac{2\pi kT}{h^2}\right)^{3}(m_e^* m_h^*)^{3/2} \exp\left(\frac{E_V - E_c}{2kT}\right)$$

$$n_i = 2\left(\frac{2\pi kT}{h^2}\right)^{3/2}(m_e^* m_h^*)^{3/4} \exp\left(\frac{-E_g}{2kT}\right) \longrightarrow (11)$$

Where E_g is the energy gap is equal to $(E_c - E_V)$