2.2. Carrier Concentration and fermi level in P-type SemiConductor

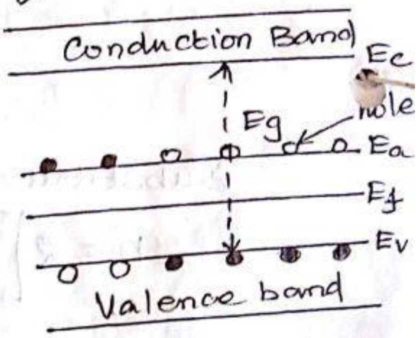
2.2.(a) Carrier Concentration:-

For P-type at absolute zero E_f will be exactly between E_a and E_v.

At low Temp. Some e^- from Valence band fills the holes in the acceptor energy level. ∴ Density of hole is

$$P = 2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} \exp\left(\frac{E_v - E_f}{kT}\right) \rightarrow (1)$$

Density of ionized acceptor,



$$= N_a F(E)$$

$$= \frac{N_a}{1 + \exp\frac{E_a - E_f}{kT}} \rightarrow (2)$$

Since $E_a - E_f \gg kT$

$$1 + \exp\frac{E_a - E_f}{kT} \approx \exp\frac{E_a - E_f}{kT}$$

∴ Density of ionized acceptor $= N_a \exp\frac{E_f - E_a}{kT} \rightarrow (3)$

Under the Condition of equilibrium.

Density of holes in the Valence band = Density of ionized acceptors

$$2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2} \exp\left(\frac{E_v - E_f}{kT}\right) = N_a \exp\left(\frac{E_f - E_a}{kT}\right) \rightarrow (4)$$

Taking logarithms on both side and rearranging.

$$2E_f - (E_a + E_v) = -kT \log \frac{N_a}{2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}}$$

$$E_f = \frac{E_a + E_v}{2} - \frac{kT}{2} \log \frac{N_a}{2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}} \rightarrow (5)$$

Substituting the energy level E_f from equ (5) in (1)

$$P = \left[2 N_a\right]^{1/2} \left[\frac{2\pi m_h^* kT}{h^2}\right] \exp\left[\frac{E_v - E_a}{2kT}\right] \longrightarrow (6)$$

(b) fermi energy level (E_f):

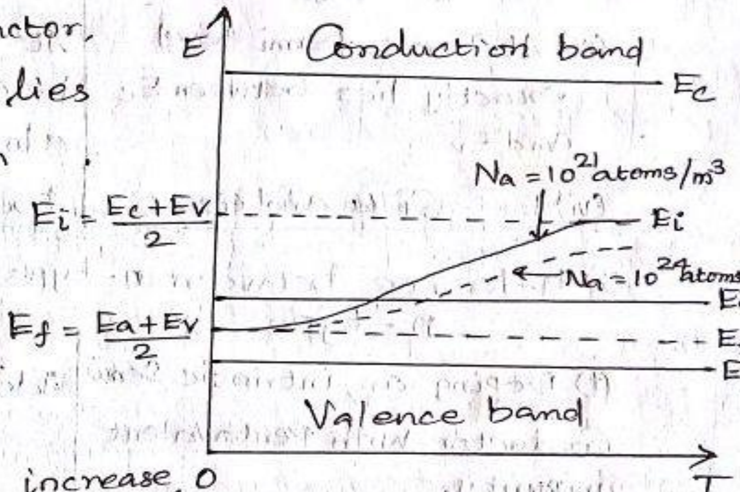
Fermi level in p-type Semiconductor is given by the equ (5)

$$E_f = \frac{E_a + E_v}{2} - \frac{kT}{2} \log \frac{N_a}{2\left[\frac{2\pi m_h^* kT}{h^2}\right]^{3/2}}$$

At T = 0K,

$$E_f = \frac{E_a + E_v}{2} \longrightarrow (7)$$

In p-type Semiconductor, Fermi energy level lies exactly halfway in between acceptor level and the top of the valence band E_v.



When the Temp. is increase, the ionized more and acceptor more and fermi level E_f shift upwards E_i.

1. State the law of mass action in semiconductors.

The law of mass action states that in the case of any semiconductors in thermal equilibrium, the product of no. of holes and no. of e⁻s is a constant. In Intrinsic Semiconductor, the no of free e⁻s is equal to no of vacancy (or) holes ($n = p$).