Intrinsic carrier concentration (n_i)

In intrinsic semiconductor, the number of $\bar{e}$ in CB is equal to the no of holes in VB.

In general, n_i is equal to $\bar{e}$ concentration in CB (n) or holes concentration in VB (p)

i.e., $n_i = n = p$

$$n_i \times n_i = n_i^2 = np$$

substituting expression for n & p in above we get,

$$n_i^2 = 2\left(\frac{2\pi m_e^* k_B T}{h^2}\right)^{3/2} e^{(E_F - E_C)/k_B T} \times 2\left(\frac{2\pi m_p^* k_B T}{h^2}\right)^{3/2} \cdot e^{(E_V - E_F)/k_B T}$$

$$n_i^2 = 4\left(\frac{2\pi k_B T}{h^2}\right)^{3/2}\left(\frac{2\pi k_B T}{h^2}\right)^{3/2} \cdot m_e^{*\,3/2} \cdot m_p^{*\,3/2} \times$$

$$e^{E_F/k_BT} \cdot e^{-E_c/k_BT} \cdot e^{E_v/k_BT} \cdot e^{-E_F/k_BT}$$

or $$n_i^2 = 4\left(\frac{2\pi k_B T}{h^2}\right)^{3}(m_e^* m_p^*)^{3/2} \cdot e^{(E_v - E_c)/k_BT}$$

& $n_i = (n_i^2)^{1/2}$ & $E_v - E_c = -E_g$ (band gap)

$$\therefore \boxed{n_i = 2\left(\frac{2\pi k_B T}{h^2}\right)^{3/2}(m_e^* m_p^*)^{3/4}\, e^{-E_g/2k_BT}}$$

The above expression is of intrinsic carrier concentration.

Fermi level :

In intrinsic semiconductor, the number of e^-s in CB is equal to number of holes in VB —

i.e $n = p$ —— (1)

$$\cancel{2}\left(\frac{\cancel{2\pi k_B T} m_e^*}{\cancel{h^2}}\right)^{3/2} e^{(E_F - E_c)/k_BT} = \cancel{2}\left(\frac{\cancel{2\pi k_B T} m_p^*}{\cancel{h^2}}\right)^{3/2} e^{(E_v - E_F)/k_BT}$$

Applying $\log_e$ on both sides

$$\log_e\left\{(m_e^*)^{3/2} \cdot e^{(E_F - E_c)/k_BT}\right\} = \log_e\left\{(m_p^*)^{3/2}\, e^{(E_v - E_F)/k_BT}\right\}$$

$$\log (m_e^*)^{3/2} + \log_e e^{(E_F - E_c)/k_BT} = \log_e (m_p^*)^{3/2} + \log_e e^{(E_v - E_F)/k_BT}$$

$$[\because \log(ab) = \log a + \log b]$$

or $$\frac{3}{2} \log_e m_e^* + (E_F - E_c)/k_BT = \frac{3}{2} \log_e m_p^* + (E_v - E_F)/k_BT$$

$$[\because \log_e e^x = x]$$

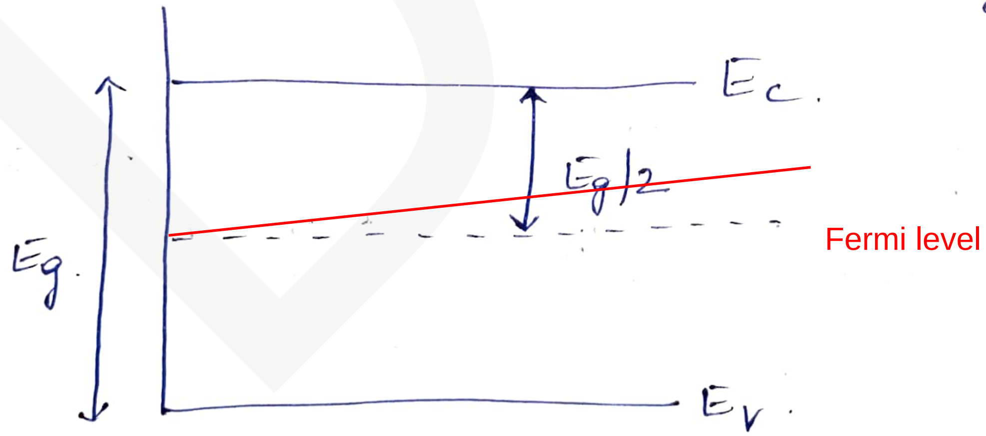
or $$\frac{3}{2} \log_e \left(\frac{m_e^*}{m_p^*}\right) + \left(\frac{-E_c - E_v}{k_BT}\right) = \frac{-E_F - E_F}{k_BT} \quad \left[\because \log a - \log b = \log(a/b)\right]$$

or $$-\frac{3}{2} \log_e \left(\frac{m_p^*}{m_e^*}\right) - \left(\frac{E_c + E_v}{k_BT}\right) = -\frac{2E_F}{k_BT} \quad \left[\because \log(a/b) = -\log(b/a)\right]$$

or $$\boxed{\frac{3}{4} \log_e \left(\frac{m_p^*}{m_e^*}\right) k_BT + \frac{E_c + E_v}{2} = E_F}$$

if $m_p^* = m_e^*$ then $E_F = \dfrac{E_c + E_v}{2}$.

if $T = 0$ then $E_F = \dfrac{E_c + E_v}{2}$.



→ As temperature raises, E_F shifts upward since $m_p^* > m_e^*$.