Intrinsic carrier concentration.

We know that

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

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

For an intrinsic semiconductor, we know that $n = P = n_i$

where 'n_i' is intrinsic carrier concentration.

$$\therefore \; n \times P = n_i \times n_i = n_i^2$$

$$\Rightarrow n_i^2 = 4\left(\frac{2\pi KT}{h^2}\right)^{\frac{3}{2}\times 2} \left(m_e^* m_h^*\right)^{3/2} \exp\left(\frac{E_V - E_C}{KT}\right)$$

$$= 4\left(\frac{2\pi KT}{h^2}\right)^{3} \left(m_e^* m_h^*\right)^{3/2} \exp\left(\frac{-E_g}{KT}\right).$$

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

Fermi level in an intrinsic semiconductors.

For an intrinsic semiconductor

$n = p.$

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

$$\Rightarrow (m_e^*)^{3/2} \exp\left(\frac{E_F - E_c}{KT}\right) = (m_h^*)^{3/2} \exp\left(\frac{E_V - E_F}{KT}\right)$$

$$\Rightarrow \exp\left(\frac{2E_F}{KT}\right) = \left(\frac{m_h^*}{m_e^*}\right)^{3/2} \exp\left(\frac{E_V + E_c}{KT}\right)$$

Taking log on both sides

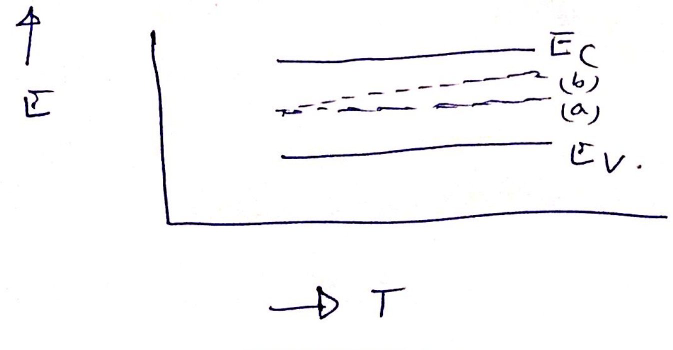
$$\frac{2E_F}{KT} = \frac{3}{2}\log\left(\frac{m_h^*}{m_e^*}\right) + \left(\frac{E_V + E_c}{KT}\right)$$

$$\Rightarrow E_F = \frac{3}{4} KT \log\left(\frac{m_h^*}{m_e^*}\right) + \left(\frac{E_V + E_c}{KT}\right)$$

If we assume that $m_h^* = m_e^*$

~~then~~ $E_F = \left(\frac{E_c + E_V}{2}\right)$

Effect of temperature on Fermi level.



(a) at $T = 0K$.

(b) at various temperatures.

Equation for electrical conductivity of semiconductor's :-

Electrical conductivity $\sigma = (ne)\mu_e$.

where 'n' is No. of charge carriers per unit volume.

'e' charge of each charge carrier.

'μ_e' Mobility of charge carriers.

For an intrinsic semiconductor

$$\sigma = (ne\mu_e + pe\mu_h)$$

where 'n' → electron carrier concentration per unit volume.

'p' → hole "

'μ_e' & μ_h are electron & hole mobilities respectively.

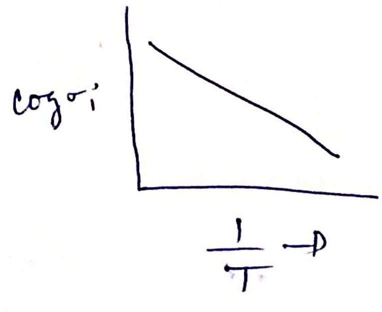
But for an intrinsic semiconductor

$$n = p = n_i.$$

$$\therefore \sigma = (\mu_e + \mu_h) n_i e.$$

$$\Rightarrow \sigma = \underbrace{(\mu_e + \mu_h) 2e \left(\frac{2\pi KT}{h^2}\right)^{3/2} (m_e^* m_h^*)^{3/4}}_{A} \exp\left(\frac{-E_g}{2KT}\right)$$

$$\Rightarrow \sigma_i = A \exp\left(\frac{-E_g}{KT}\right).$$



Taking log on both sides.

$$\log \sigma_i = \log A - \frac{E_g}{2KT}.$$

Determination of Band gap of a semiconductor

From the previous topic

$$\sigma_i = A \exp\left(\frac{-E_g}{2KT}\right)$$

Resistivity $\rho_i = \frac{1}{\sigma_i} = \frac{1}{A} \exp\left(\frac{E_g}{2KT}\right)$.

$$\frac{R_i\, a}{L} = \frac{1}{A} \exp\left(\frac{E_g}{2KT}\right).$$

$R_i \rightarrow$ Resistance of an intrinsic semiconductor

$a \rightarrow$ area of cross-section

$L \rightarrow$ Length of the material.

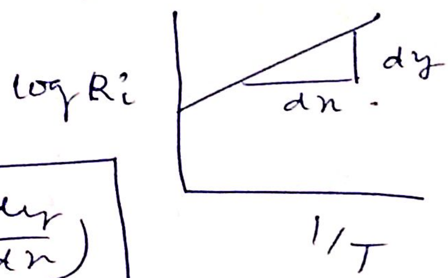
$$R_i = \frac{L}{aA} \exp\left(\frac{E_g}{2KT}\right).$$

$$\Rightarrow R_i = C \exp\left(\frac{E_g}{2KT}\right) \quad \left(C = \frac{L}{aA}\right)$$

$$\Rightarrow \log R_i = \log C + \frac{E_g}{2KT}.$$

$$(y = mx + c)$$

$m = \frac{E_g}{2K}$ (slope)



$$\therefore \frac{dy}{dx} = \frac{E_g}{2K} \Rightarrow \boxed{E_g = 2K\left(\frac{dy}{dx}\right)}.$$

'K' is Boltzmann constant.