* Carrier Concentration in N-type SC:

$N_d \rightarrow$ no. of donor atoms in SC.

Temp ↑sed above 0K ; donor atoms get ioniz & electrons start moving from donor levels to (

$E_d \rightarrow$ energy required by e^- to move from donor levels to CB.

$n \rightarrow e^-$ conc. in CB.

$$n = N_d^+$$

$$\boxed{n = N_d - N_d^0}$$

$N_d^+ \rightarrow$ no. of ionized donor atoms

$N_d^0 \rightarrow$ no. of unionized donor atoms.

$$n = N_d - N_d f(E_d).$$

$$= N_d (1 - f(E_d))$$

$$n = N_d \left[1 - \frac{1}{1 + e^{(E_d - E_F)/KT}}\right]$$

$$\boxed{n = N_d \left[\frac{1}{1 + e^{-(E_d - E_F)/KT}}\right]}$$

$$\boxed{n = N_d \left[e^{+(E_d - E_F)/KT}\right]}$$

$$\boxed{n = N_c \left[e^{-(E_c - E_F)/KT}\right]}$$

$$N_d e^{+(E_d-E_F)/KT} = N_c e^{-(E_c-E_F)/KT}$$

log on both sides.

$$\log\left[N_d e^{-(E_d-E_F)/KT}\right] = \log\left[N_c e^{-(E_c-E_F)/KT}\right]$$

$$\cancel{\log\frac{N_d}{N_c} = E_d - E_F - E_c - E}$$

$$\log N_d + \frac{(E_d-E_F)}{KT} = \log(N_c) - \frac{(E_c-E_F)}{KT}$$

$$\log\left(\frac{N_d}{N_c}\right) = \frac{-E_d+E_F-E_c+E_F}{KT}$$

$$(E_d+E_c) - KT\ln\left(\frac{N_c}{N_d}\right) = 2E_F$$

$$\boxed{E_F = \frac{E_d+E_c}{2} + \frac{KT}{2}\ln\left(\frac{N_d}{N_c}\right)}$$

$$N_c = 2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2}$$

$$\boxed{E_F = \frac{E_d+E_c}{2} + \frac{KT}{2}\ln\left(\frac{N_d}{2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2}}\right)}$$

at T = 0K

$$\boxed{E_F = \frac{E_d+E_c}{2}}$$

Fermi level lies b/w bottom of CB & donor levels.

$$\boxed{n = N_c e^{\frac{(E_F-E_c)}{KT}}}$$

Substitute E_F in the above.

$$n = N_c \exp\left[\frac{E_d + E_c}{2KT} + \frac{1}{2}\ln\left(\frac{N_d}{2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2}}\right) - \frac{E_c}{KT}\right]$$

$$n = N_c \exp\left[\frac{E_d - E_c}{2KT} + \ln\left(\sqrt{\frac{N_d}{\underbrace{2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2}}_{N_c}}}\right)\right]$$

$$n = N_c\, e^{\frac{E_d - E_c}{2KT}} \cdot e^{\ln\sqrt{\frac{N_d}{N_c}}}$$

$$n = N_c \cdot \sqrt{\frac{N_d}{N_c}}\, e^{\frac{E_d - E_c}{2KT}}$$

$$n = \sqrt{N_c}\sqrt{N_d}\, e^{\frac{E_d - E_c}{2KT}}$$

$$N_c = 2\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/2}$$

$$\cancel{n = \sqrt{N_d}}$$

$$\boxed{n = \sqrt{2N_d}\left(\frac{2\pi m_e^* KT}{h^2}\right)^{3/4} e^{\frac{E_d - E_c}{2KT}}}$$

* CARRIER CONCENTRATION IN P-TYPE SC:

$N_a \rightarrow$ no. of acceptor atoms in SC

Temp. ↑sed above 0K ; the acceptor atoms get ionized & holes start appearing in VB.

$E_a \rightarrow$ energy required by e^- to move into acceptor levels from VB.

$p \rightarrow$ hole concentration in valence band.

$$p = N_a^-$$

$$N_a^- = N_a(f(E_a))$$

$$\boxed{p = N_a \exp\left(\frac{E_F - E_a}{KT}\right)}$$

$$\boxed{p = N_V \exp\left(-\left(\frac{E_F - E_V}{KT}\right)\right)}$$

$$N_a e^{\frac{E_F - E_a}{KT}} = N_V e^{-\left(\frac{E_F - E_V}{KT}\right)}$$

log on both sides.

$$\log N_a + \frac{E_F - E_a}{KT} = \log N_V - \frac{(E_F - E_V)}{KT}$$

$$\frac{E_F - E_a + E_F - E_V}{KT} = \log\left(\frac{N_V}{N_a}\right)$$

$$2E_F - (E_a + E_V) = KT \log\left(\frac{N_V}{N_a}\right)$$

$$E_F = \frac{KT}{2}\log\left(\frac{N_V}{N_a}\right) + \frac{E_a + E_V}{2}$$

~~at T = 0K~~

$$\boxed{E_F = \frac{E_a + E_V}{2} - \frac{KT}{2}\log\left(\frac{N_a}{N_V}\right)}$$

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

~~E_F~~ *

$$\boxed{E_F = \frac{E_a + E_v}{2} - \frac{KT}{2} \log \left(\frac{N_a}{2\left(\frac{2\pi m_h^* KT}{h^2}\right)^{3/2}} \right)}$$

at $T = 0K$

$$\boxed{E_F = \frac{E_a + E_v}{2}}$$

Fermi level lies exactly between acceptor energy level and top most level of VB.

$$p = N_v \exp\left(\frac{E_v - E_F}{KT} \right)$$

Substitute 'E_F' in above.

$$p = N_v \exp\left(\frac{E_v}{KT} - \left(\frac{E_a + E_v}{2KT}\right) + \frac{1}{2} \log \left(\frac{N_a}{2\left(\frac{2\pi m_h^* KT}{h^2}\right)^{3/2}} \right) \right)$$

$$p = N_v \exp\left(\frac{E_v - E_a}{2KT} + \log \sqrt{\frac{N_a}{N_v}} \right)$$

$$p = N_v \cdot e^{\frac{E_v - E_a}{2KT}} \cdot \sqrt{\frac{N_a}{N_v}}$$

$$p = \sqrt{N_v N_a} \cdot e^{\frac{E_v - E_a}{2KT}}$$

$$\boxed{p = \sqrt{2N_a} \left(\frac{2\pi \cdot m_h^* KT}{h^2} \right)^{3/4} e^{\frac{E_v - E_a}{2KT}}}$$