Derivation of n & p

$$n = \int_{E_c}^{E_c'} D(E)\, f(E)\, dE \qquad f(E) \approx \tilde{B}(E) \quad E \gg E_F$$

$$= \int_{E_c}^{E_c'} \frac{(2m_e^*)^{3/2}}{2\pi^2 \hbar^3} \sqrt{E-E_c} \cdot \frac{1}{1+\exp\left(\frac{E-E_F}{kT}\right)} dE$$

$$= \int_{E_c}^{E_c'} \frac{(2m_e^*)^{3/2}}{2\pi^2 \hbar^3} \sqrt{E-E_c}\, \exp\left[-\left(\frac{E-E_F}{kT}\right)\right] dE \qquad \boxed{E-E_F \geq 3kT}$$

$$= \int_{E_c}^{E_c'} \frac{(2m_e^*)^{3/2}}{2\pi^2 \hbar^3} \sqrt{E-E_c}\, \exp\left[-\left(\frac{E_c-E_F}{kT}\right)\right] \cdot \exp\left(-\left(\frac{E-E_c}{kT}\right)\right) dE$$

$$\frac{E - E_c}{kT} = \varepsilon$$

$$dE = kT\, d\varepsilon$$

$$E_c' - E_c \approx 4\,eV$$

$$\frac{E_c' - E_c}{kT} \approx 160$$

$$n = \frac{(kT)^{3/2} (2m_e^*)^{3/2}}{2\pi^2 \hbar^3} \exp\left(-\frac{E_c - E_F}{kT}\right) \int_0^\infty \sqrt{\varepsilon}\, \exp(-\varepsilon)\, d\varepsilon$$

$$\sqrt{\pi}/2$$

$$\boxed{n = 2\left(\frac{m_e^* kT}{2\pi \hbar^2}\right)^{3/2} \exp\left(-\left(\frac{E_c - E_F}{kT}\right)\right)}$$

$$n = N_c \exp\left\{-\left(\frac{E_c - E_F}{kT}\right)\right\}$$

(N_V) $N_c \rightarrow$ Effective density of states in the conduction band (Valence band)

$$p = \int_{-\infty}^{E_v} D_v(E)\left[1 - f(E)\right] dE$$

$$p = N_V \exp\left[-\left(\frac{E_F - E_V}{kT}\right)\right]$$

N_c replace m_e^* by m_h^*

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

$$n = N_c \exp\left\{-\left(\frac{E_c - E_F}{kT}\right)\right\}$$

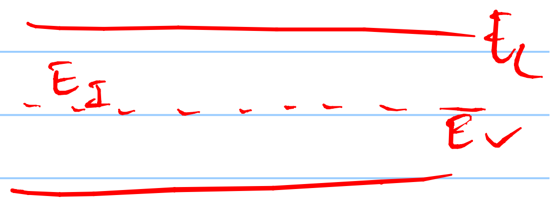
$$p = N_v \exp\left\{-\left(\frac{E_F - E_v}{kT}\right)\right\}$$

$$\frac{n}{p} = \frac{N_c}{N_v}\exp\left[\frac{+2E_F - (E_c+E_v)}{kT}\right]$$

$$E_F = \frac{E_c+E_v}{2} + \frac{kT}{2}\ln\frac{N_v}{N_c} + \frac{kT}{2}\ln\left(\frac{n}{p}\right)$$

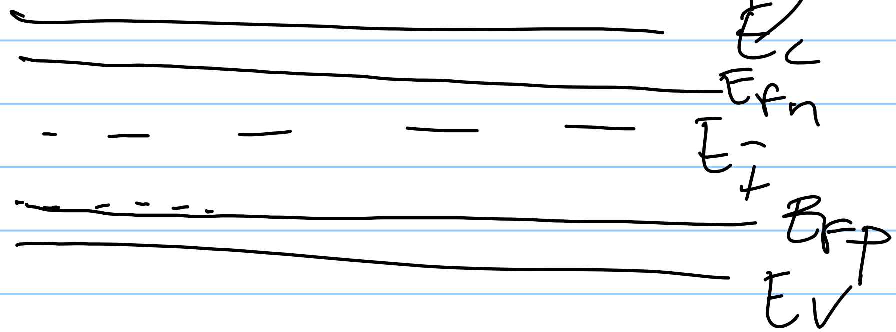
Fermi level of intrinsic semi-cond

$$E_I = \frac{E_c+E_v}{2} + \frac{kT}{2}\ln\left(\frac{N_v}{N_c}\right)$$



$$E_{Fn} = E_I + kT \ln\left(\frac{N_D}{n_i}\right)$$

$$E_{Fp} = E_i - kT \ln\left(\frac{N_A}{n_i}\right)$$

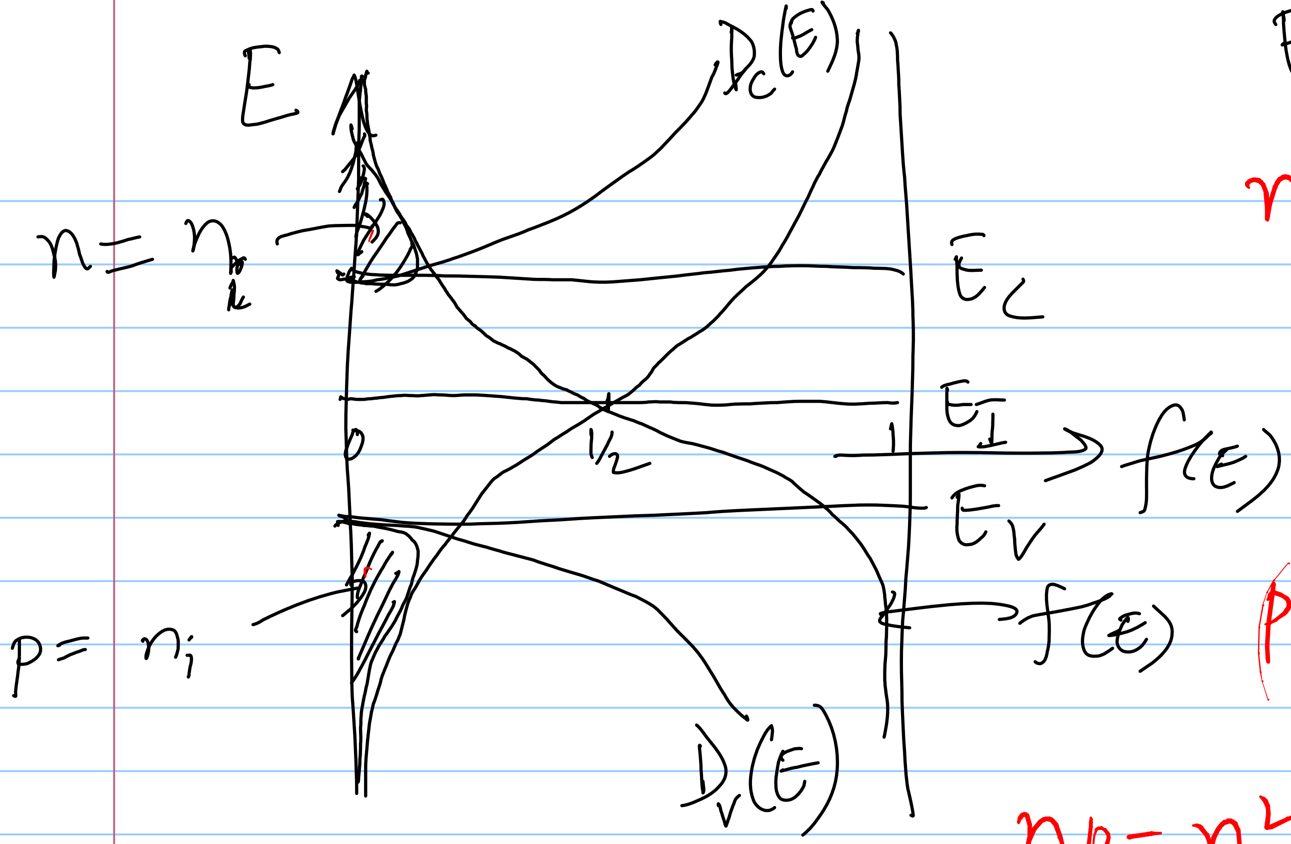


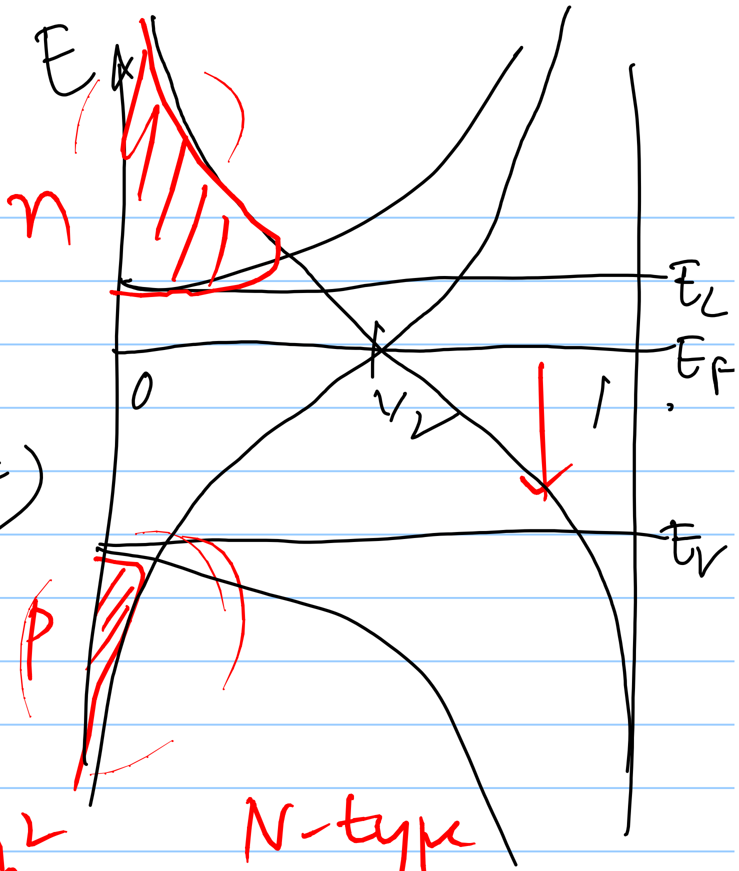
$$n \approx N_D$$

$$p = \frac{n_i^2}{N_D}$$

$$p = N_A$$

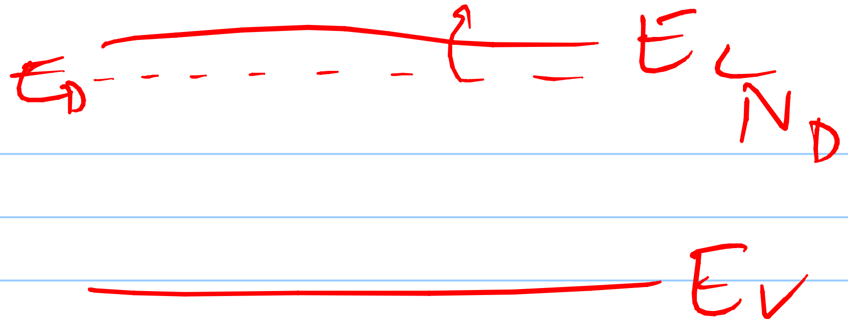
$$n = n_i^2 / N_A$$





$np = n_i^2$

N-type



$$n = N_D^+ \neq N_D$$

$$N_D^0 + N_D^+ = N_D$$

$$\eta_D = \frac{N_D^+}{N_D} \qquad f(E_D) = \frac{1}{1 + \frac{1}{2}\exp\left(\frac{E_D - E_F}{kT}\right)}$$

$$\frac{N_D^0}{N_D} = f(E_D) = \frac{1}{1 + \frac{1}{2}\exp\left(\frac{E_D - E_F}{kT}\right)}$$

$$\eta_D = \frac{N_D^+}{N_D} = 1 - \frac{N_D^0}{N_D} = \frac{1}{1 + 2\exp\left(\frac{E_F - E_D}{kT}\right)}$$

$$\rightarrow \eta_D = \frac{1}{1 + 2\exp\left(\frac{E_F - E_D}{kT}\right)}$$

$$n = N_D \eta_D = N_c \exp\left[-\left(\frac{E_c - E_F}{kT}\right)\right]$$

$$\eta_D = \frac{1}{1 + 2\exp\left[-\left(\frac{E_c - E_F}{kT}\right)\right] \exp\left(\frac{E_c - E_D}{kT}\right)}$$

$$\eta_D = \frac{1}{1 + 2 \cdot \frac{N_D \eta_D}{N_c} \exp\left(\frac{E_{ion}}{kT}\right)}$$

$$\frac{2N_D}{N_c} \exp\left(\frac{E_{ion}}{kT}\right) \eta_D^2 + \eta_D - 1 = 0$$

$$\eta_D = \frac{-1 + \sqrt{1 + \frac{8N_D}{N_c} \exp\left(\frac{E_{ion}}{kT}\right)}}{\frac{4N_D}{N_c} \exp\left(\frac{E_{ion}}{kT}\right)}$$

ionization coeff^n

$$\eta_A \simeq \eta_D \left(N_D \leftarrow N_A\right)$$