Recapitulation

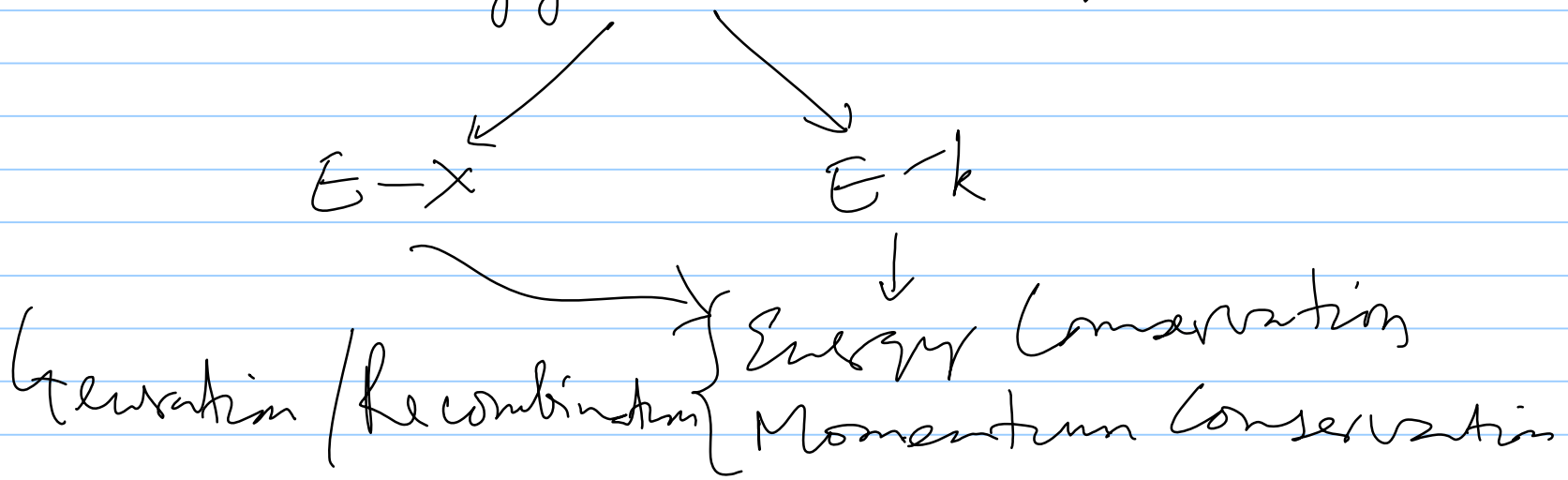
Band Model → Intrinsic Semiconductor

↓

n_i

Band Model

↳ Energy Band Diagram



E-X

How energy bands forms

(Conduction and Valence energy bands)

Energy gap between Conduction and Valence Bands

[E_g]

Conduction band Minimum (E_c)

Valence band Maximum (E_v)

$E_g = E_c - E_v$

Recombination Rate = Generation Rate
at Equilibrium

Mass action law $\boxed{np = n_i^2}$

Charge neutrality Rel^n

+ve charge = −ve charge

Extrinsic Semiconductor ⟵ dopant

Acceptor dopant ⟶ Eg. III element

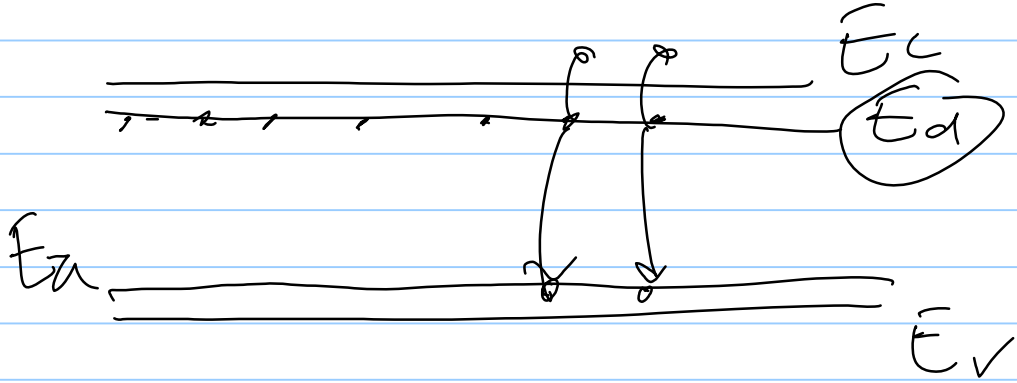
Donor dopant ⟶ Gp V element

Impurities → shallow (E_a or E_d near E_c or E_v)

→ Deep (E_a or E_d near $E_g/2$)

charge-neutrality Eqn.

$$\textcircled{p} + N_d^+ = \textcircled{n} + N_a^-$$



$n = p = n_i$

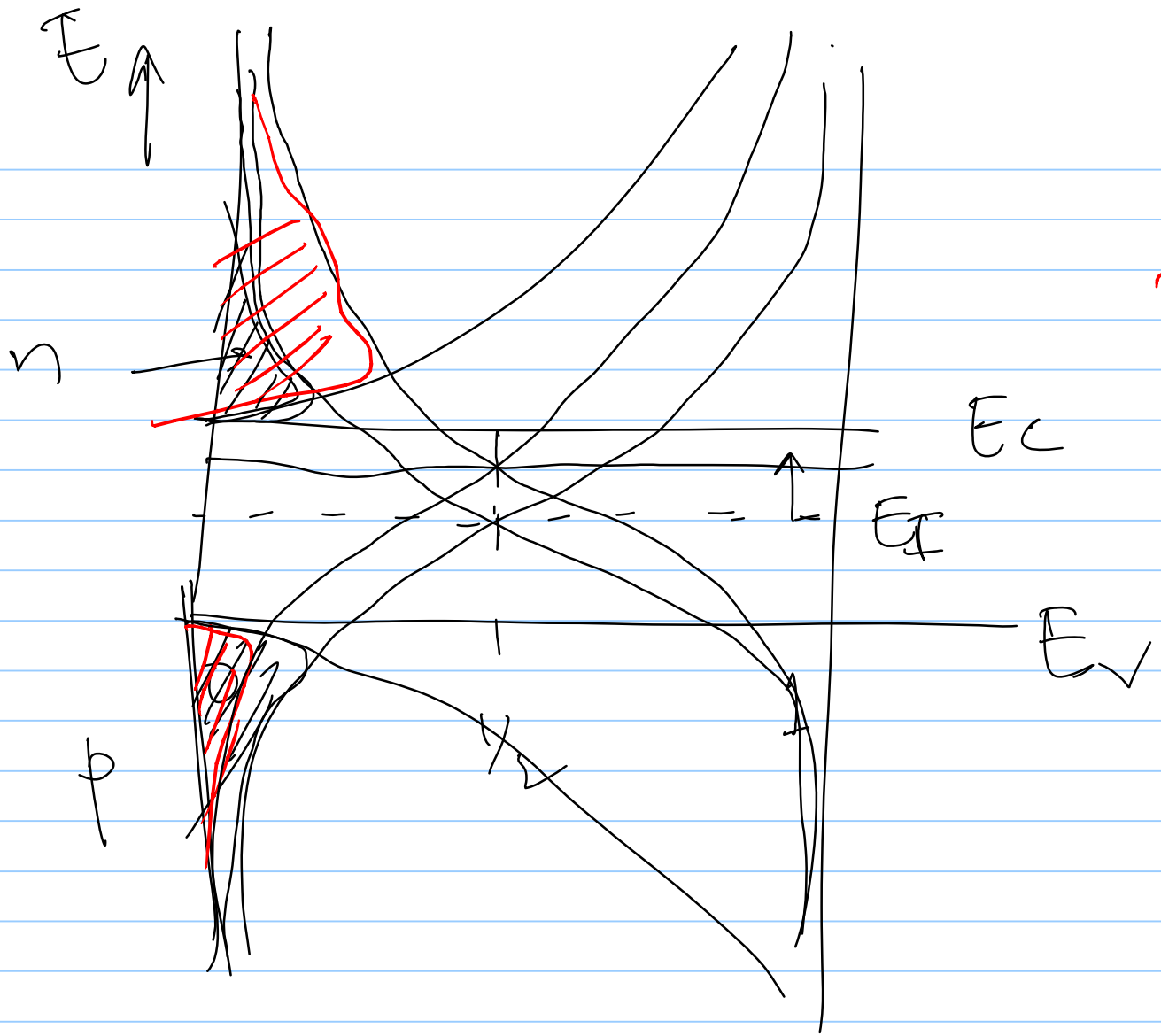
$$n = \int_{E_c}^{\infty} D_e(E) f(E)\, dE = N_c \exp\left\{-\frac{E_c - E_f}{kT}\right\}$$

$$p = \int_{-\infty}^{E_v} D_v(E)\left(1 - f(E)\right) dE = N_v \exp\left\{-\frac{E_f - E_v}{kT}\right\}$$

$E_f \rightarrow$ Fermi Energy level.

$$f(E) = \frac{1}{1 + \exp\left(\frac{E - E_f}{kT}\right)} \approx \exp\left\{-\frac{E - E_f}{kT}\right\}$$

$E - E_f \gg 3kT$



$n_p = n_i^2$

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

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

$$= E_{Fi} + kT \ln\left(\frac{p}{n_i}\right)$$

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

$$E_F = E_I + \frac{kT}{2} \ln\left(\frac{n_p}{p^2}\right)$$

$$= E_i + kT \ln\left(\frac{n_i}{p}\right)$$

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

$$p\,n = n_i^2$$

$E_F \rightarrow$ spatially constant

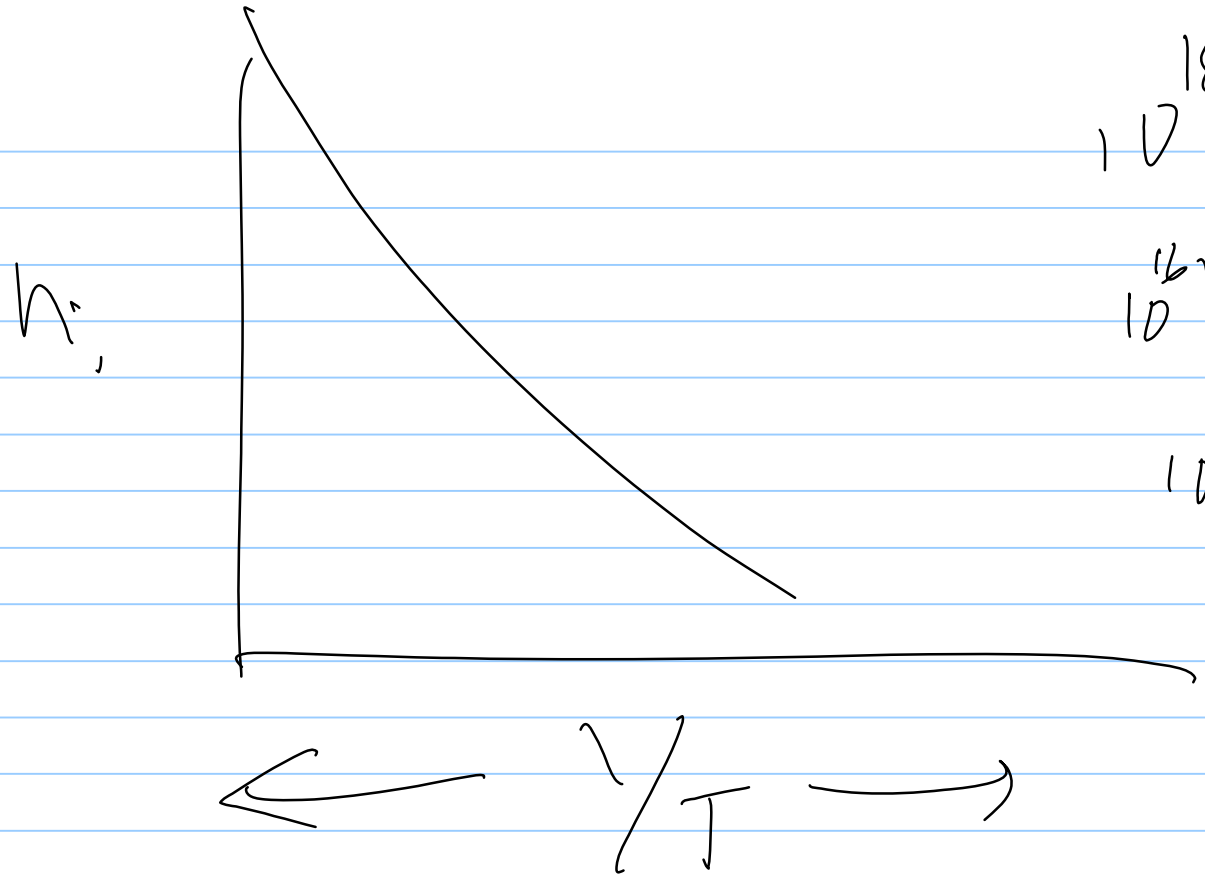
$\rightarrow$ defined only in Equilibrium

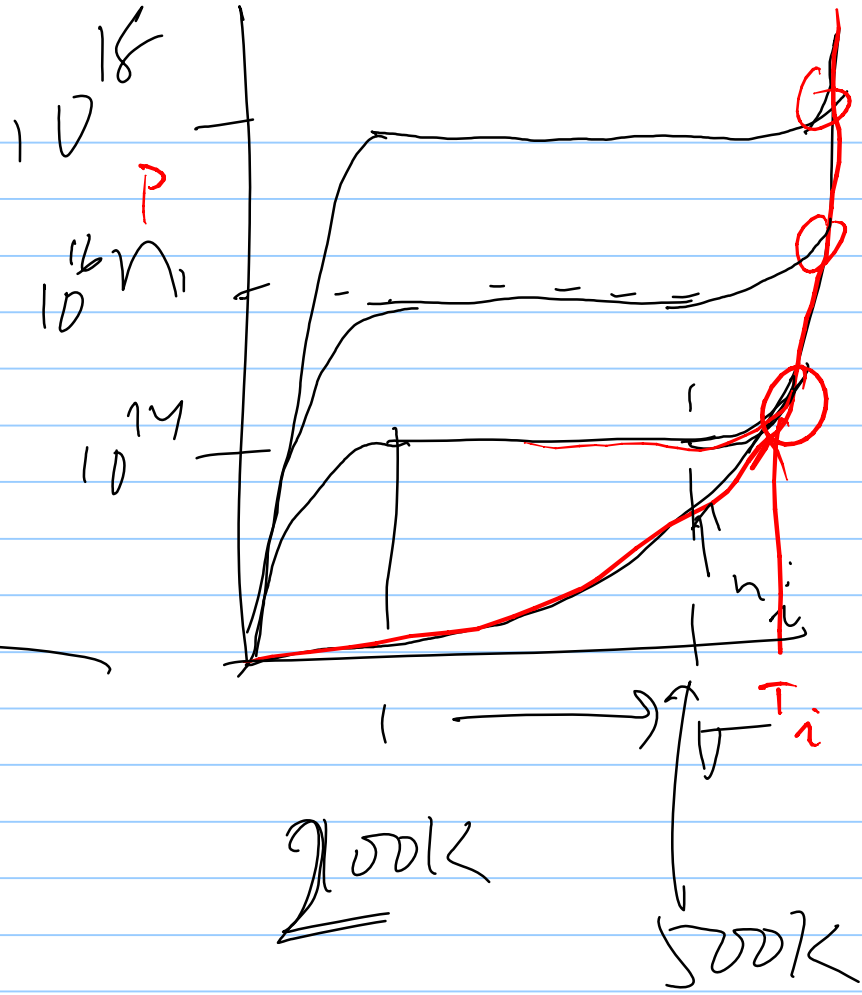
$$p = N_V \exp\left(-\frac{E_F - E_V}{kT}\right)$$

$$n = N_C \exp\left(-\frac{E_C - E_F}{kT}\right)$$

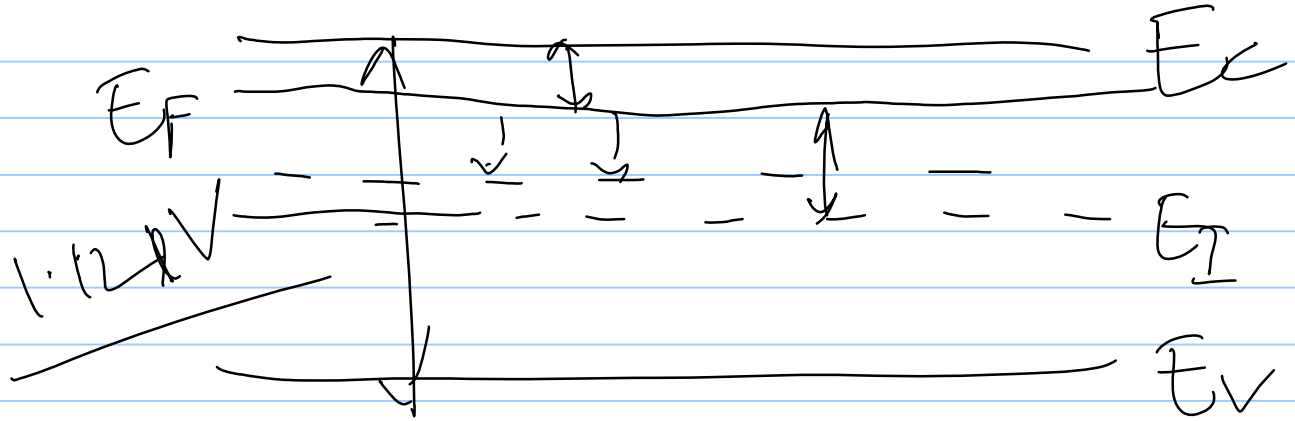
$$n_i = \sqrt{pn} = \sqrt{N_C N_V} \exp\left(-\frac{E_C - E_V}{2kT}\right)$$

$$\boxed{n_i = \sqrt{N_C N_V} \exp\left[-\frac{E_g}{2kT}\right]}$$





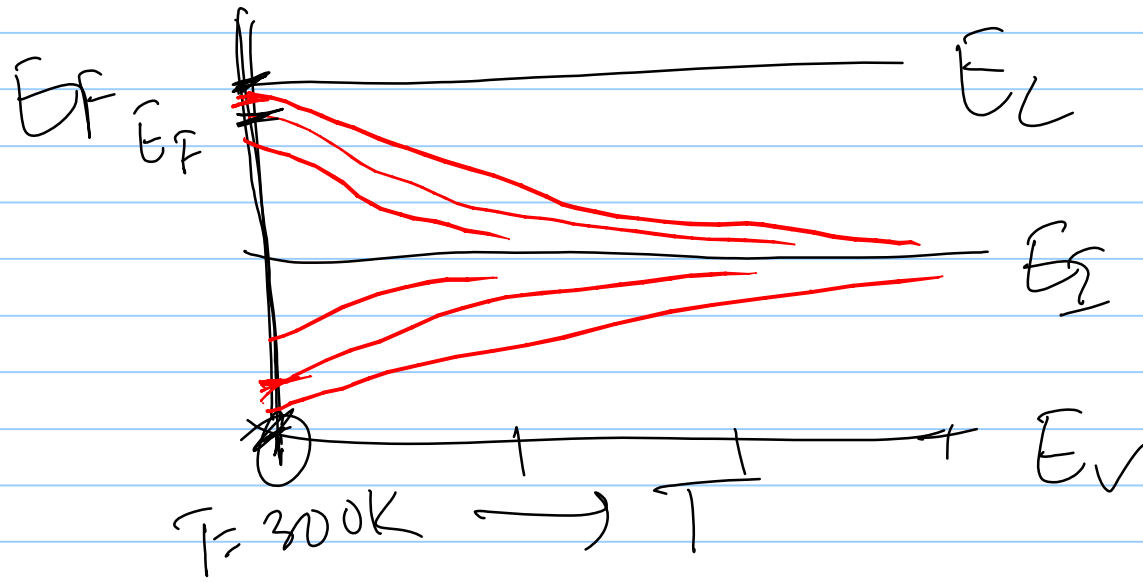
$E_c - E_d = 0.05\,eV$



$N_D = 10^{16}$

$T = 300K$

$n_D = ?$



$n = N_D^+$

$$n = n_i \exp\left(\frac{E_F - E_T}{kT}\right)$$