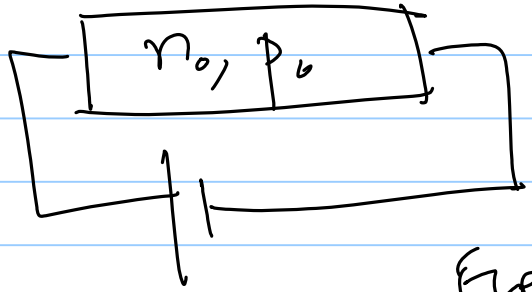
Excess Carriers

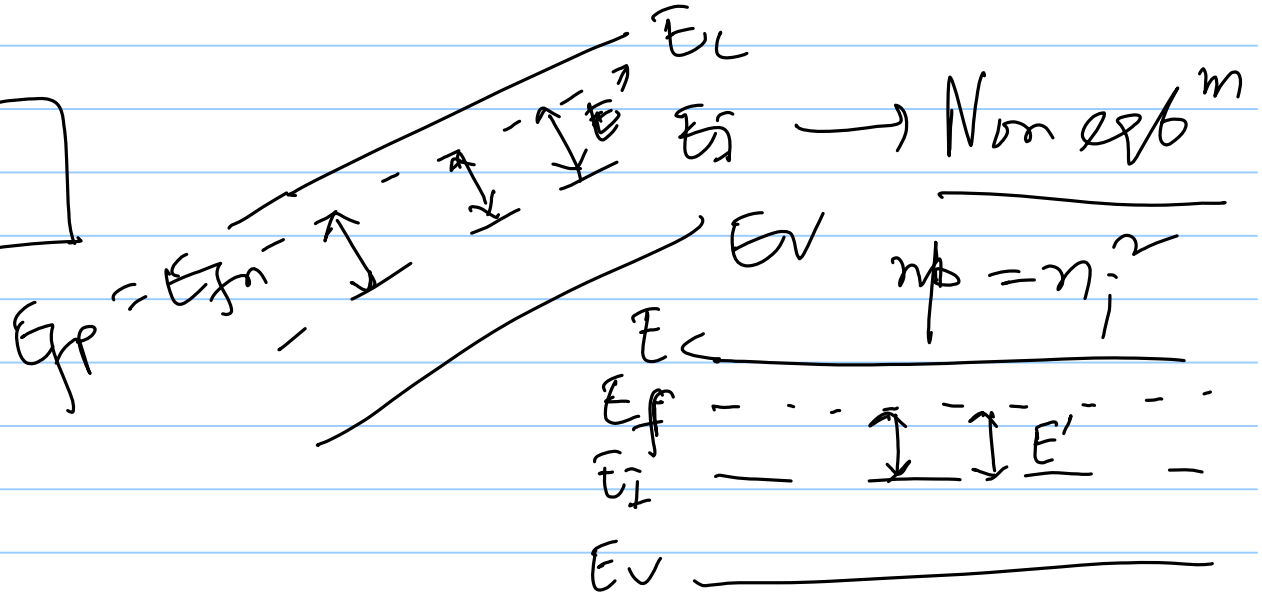
3/9/2014

Excess in comparison to Thermal Eqbm

$$np = n_i^2 \Longrightarrow \boxed{n_0 p_0 = n_i^2}$$

in Thermal Eqbm





$E_i \longrightarrow$ Non eqbm

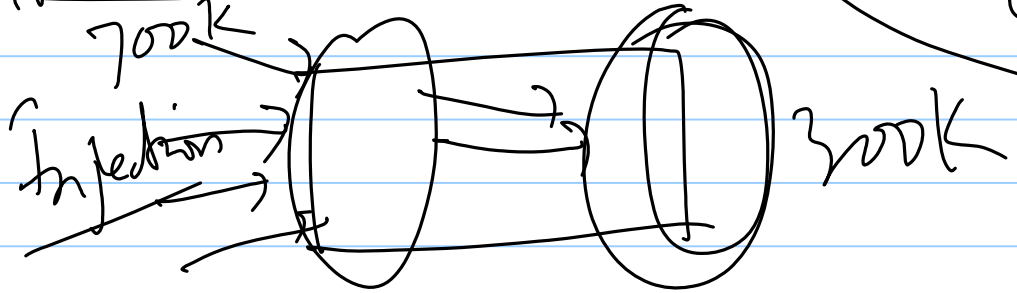
$np = n_i^2$

$n > n_0$

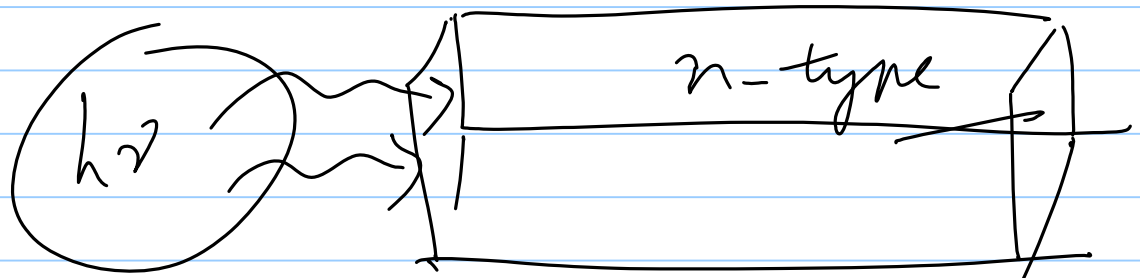
$p > p_0$

} Excess carriers

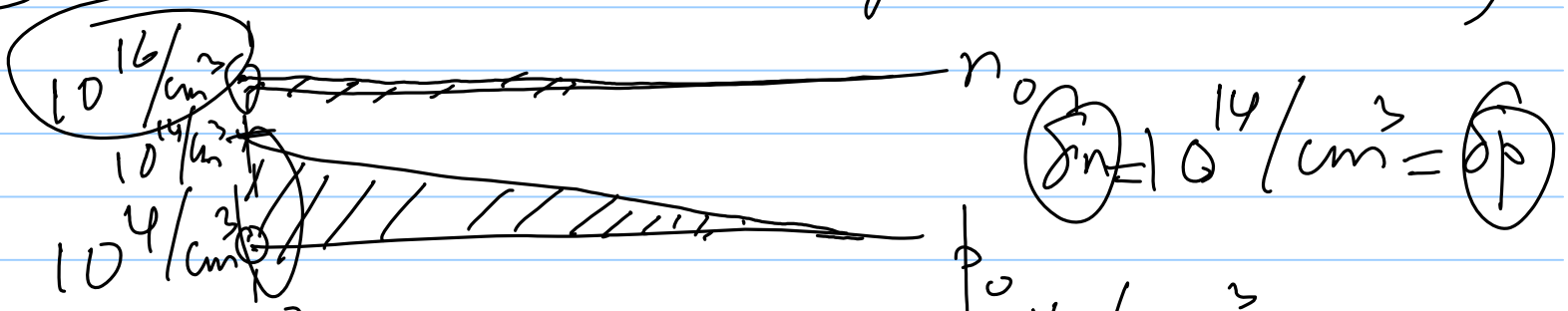
Non-Eqb $\begin{cases} np > n_i^2 \rightarrow \text{Excess carriers} \\ np < n_i^2 \rightarrow \text{Invert of excess carriers} \end{cases}$



Optical Generation



→ Electrons & holes are generated (EHP)



$$n = n_0 + \delta n = 1.01 \times 10^{16}/cm^3$$

$$p = p_0 + \delta p = 10^{14}/cm^3$$

Recombination rate $\propto np$

$$R = \alpha_r n(t) p(t)$$

Generation rate $\propto n_i^2$

$$G_{th} = \alpha_r n_i^2$$

$$\frac{dp(t)}{dt} = \alpha_r n_i^2 - \alpha_r n(t) p(t)$$

$$= \alpha_r n_i^2 - \alpha_r (n_0 + \delta p(t))(p_0 + \delta p(t))$$

$$= -\alpha_r (n_0 + p_0)\delta p(t) - \alpha_r \delta p^2(t)$$

$$\frac{d\delta p(t)}{dt} = \frac{dp(t)}{dt} = -\alpha_r n_0 \delta p(t)$$

$$\delta p(t) = \delta p(t=0) \exp(-t/\tau_p)$$

$$\frac{d}{dt}\delta p(t) = -\alpha_r n_0 \delta p(t)$$

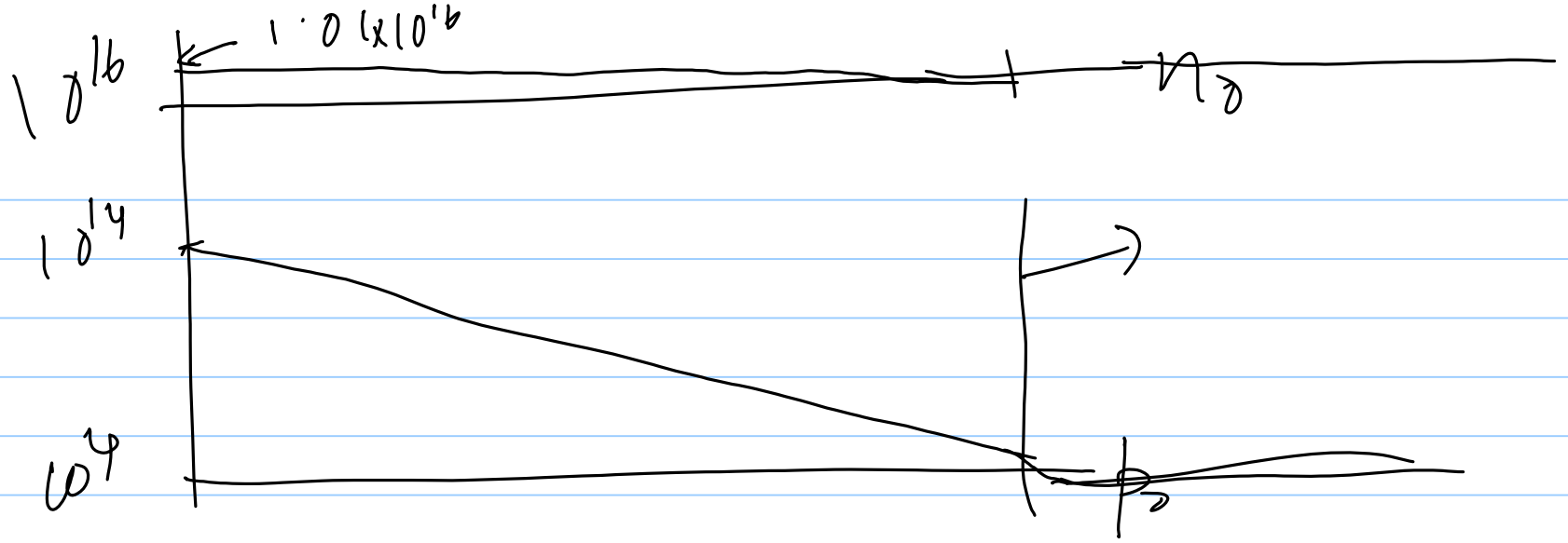
$$\tau_p = \frac{1}{\alpha_r (n_0 + p_0)}$$

→ Minority Carrier life time

p-type

$$\delta n(t) = \delta n(t=0) \exp(-t/\tau_n)$$

$$\tau_n = \frac{1}{\alpha_r p_0} = \frac{1}{\alpha_r (p_0 + n_0)}$$

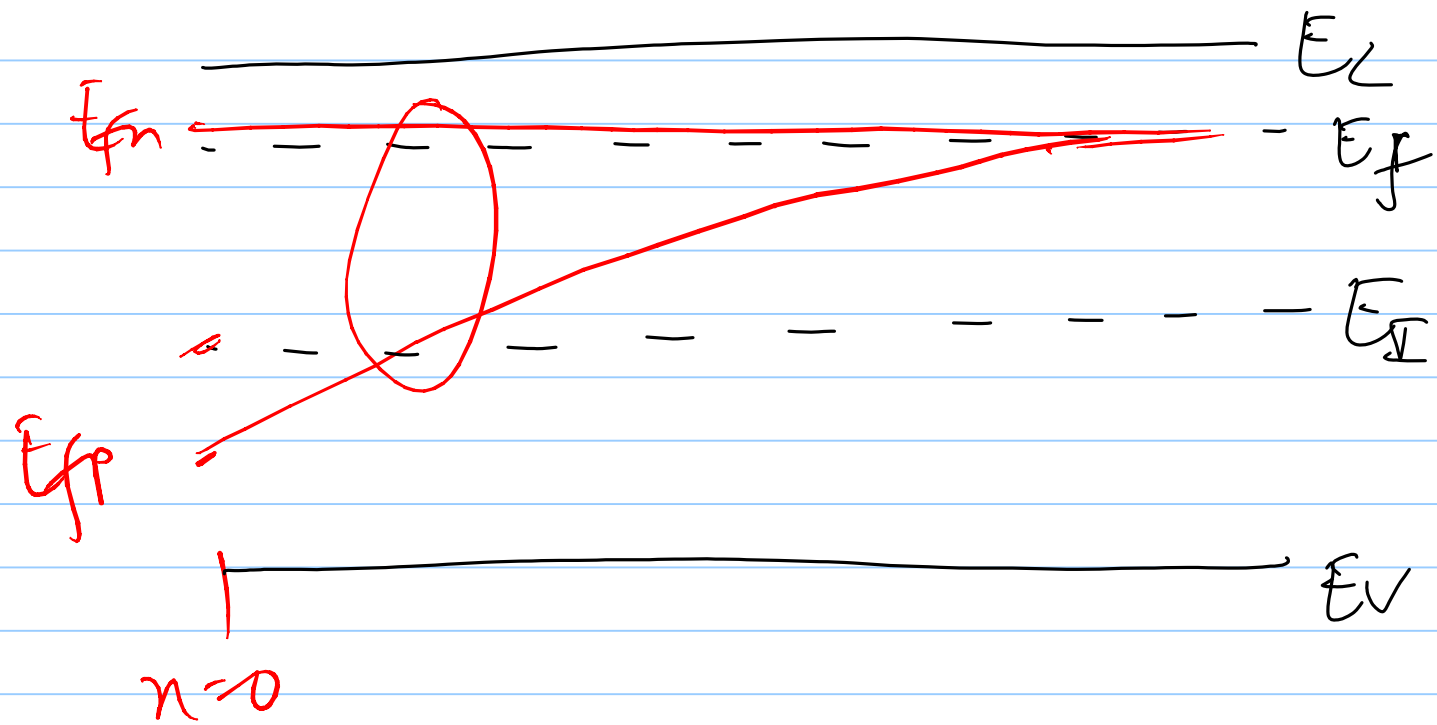


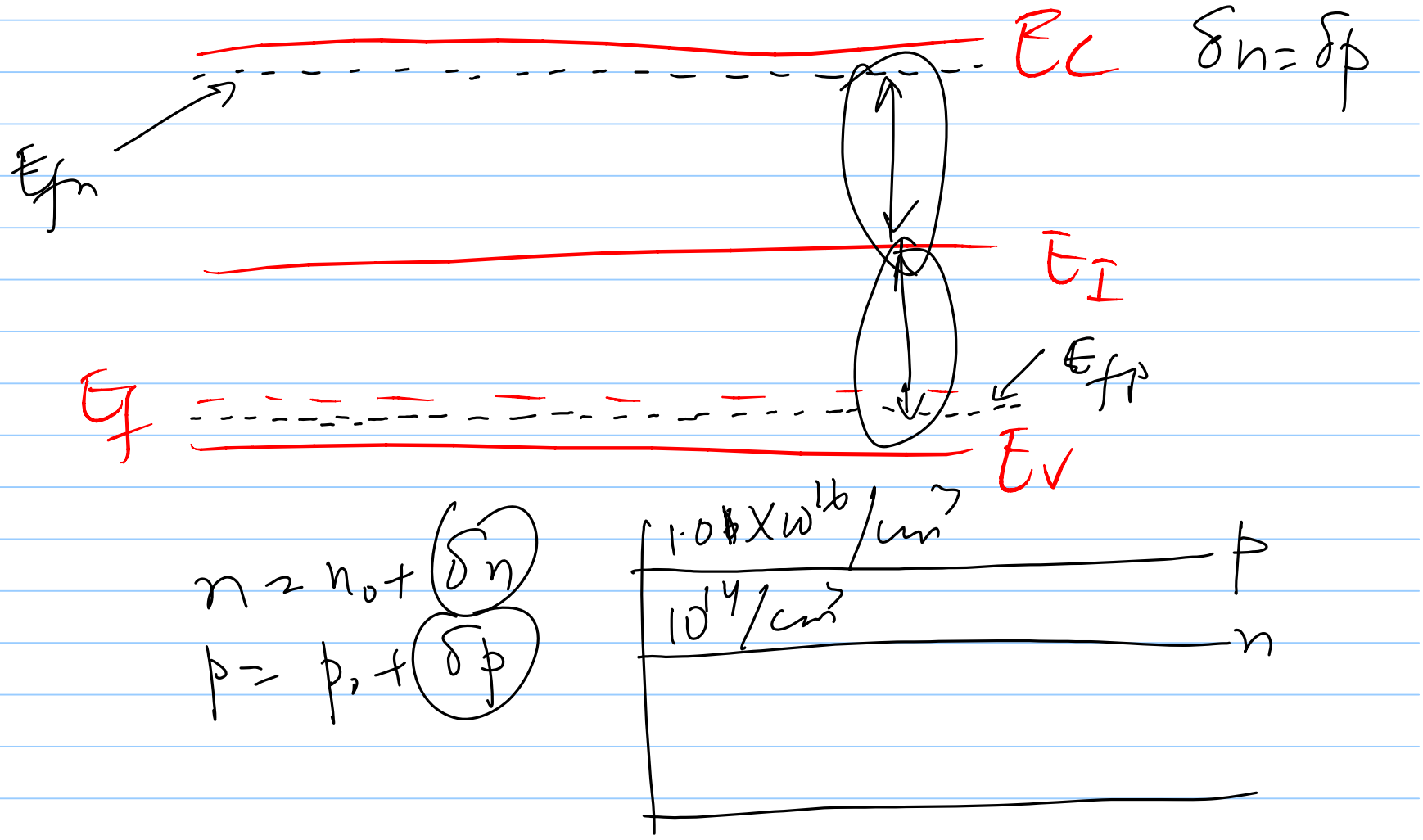
$$n = n_i \exp\left(\frac{E_{fn} - E_i}{kT}\right)$$

$$p = n_i \exp\left(\frac{E_i - E_{fp}}{kT}\right)$$

$$np = n_i^2 \exp\left(\frac{E_{fn} - E_{fp}}{kT}\right)$$

$E_{fn} > E_{fp}$


E_C
E_{fn}
E_f
E_i
E_{fp}
E_V
$n=0$


E_C
$\delta n = \delta p$
E_{fn}
E_I
E_{fp}
E_f
E_V
$n = n_0 + \delta n$
$p = p_0 + \delta p$
$10^{16}/cm^3$
$10^4/cm^3$
p
n

Steady State process

Recombination rate

= Generation rate

$$g_{op} + G_{th} = R = \alpha_r (np) = g_{op} + \alpha_r n_i^2$$

$$\alpha_r (n_0 + \delta n)(p_0 + \delta p) = g_{op} + \alpha_r n_i^2$$

$$\alpha_r (n_0 + p_0)\delta n + \alpha_r \delta n^2 = g_{op}$$

low level injection $\rightarrow$ $g_{op} = \alpha_r n_0 \delta n = \frac{\delta p}{\tau_p}$

$$\delta p = \tau_p g_{op}$$

$$\delta n = \delta_p = g_{np} \zeta_p = g_{np} \zeta_n$$

$$\sigma = n e \zeta / \mu_n + p e \zeta / \mu_p$$

$$\Delta\sigma = \delta n e \zeta / \mu_n + \delta p e \zeta / \mu_p$$

$$\boxed{\Delta\sigma = g_{np} e \zeta \left(\mu_n \zeta_n + \mu_p \zeta_p \right)}$$

photo-conductivity