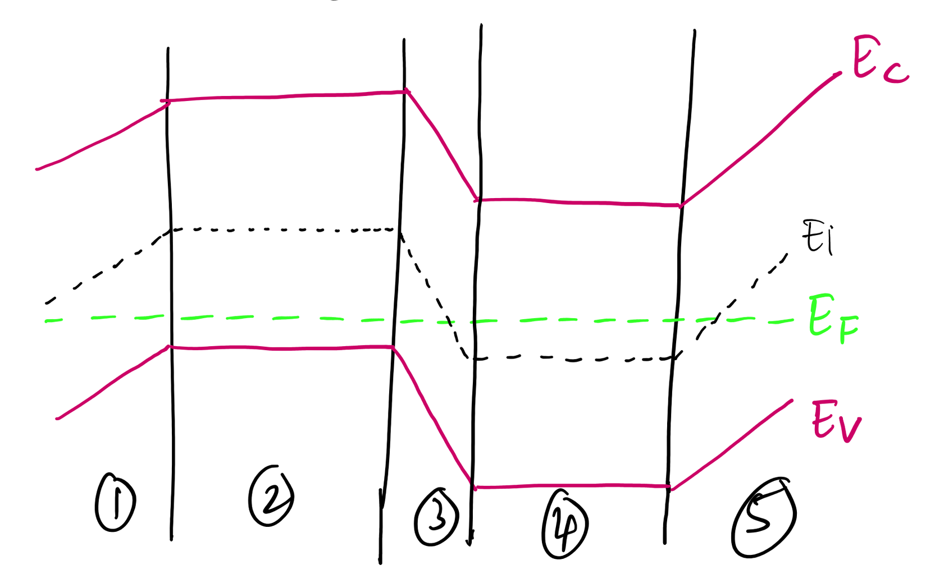
HKN ECE 340 Exam 1 problem set solutions

A1) *Band Diagrams*



(a) From the diagram:

Region 2: E_F is below E_i and closer to the valence band
$\Rightarrow$ p-type

Region 4: E_F is above E_i and closer to conduction band
$\Rightarrow$ n-type

(b) $\sigma = q(n\mu_n + p\mu_p)$

$\mu_n \approx 3\mu_p$

$n = n_i \exp\left(\frac{E_F - E_i}{kT}\right)$ → Region 4

$p = n_i \exp\left(\frac{E_i - E_F}{kT}\right)$ → Region 2

Assume p^+ doping over powers mobility effects

$\Rightarrow (\mu_n n)_{Region 4} < (\mu_p p)_{Region 2}$

$\Rightarrow$ **Region 2**

(c) $\rho = \frac{1}{\sigma} = \frac{1}{q(n\mu_n + p\mu_p)}$

→ Assume constant bandgap (E_G)

$\Rightarrow \rho_{Region 2} = \frac{1}{q(n\mu_n + p\mu_p)}$

$n\mu_n << p\mu_p$ ∵ p-type

$\Rightarrow \rho \approx \frac{1}{q p\mu_p}$

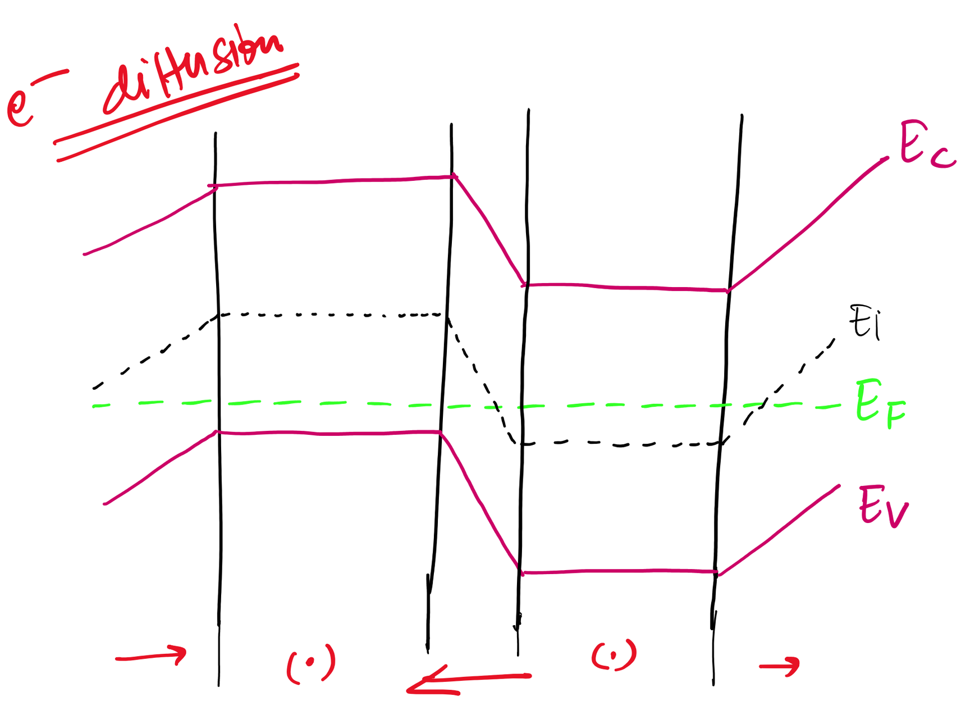
$\Rightarrow p = N_V \exp\left(\frac{E_V - E_F}{kT}\right)$ $(E_V < E_F)$

T ↓es $\Rightarrow$ n ↓es

$\Rightarrow$ μ ↓es as T ↓es ∵ low T region

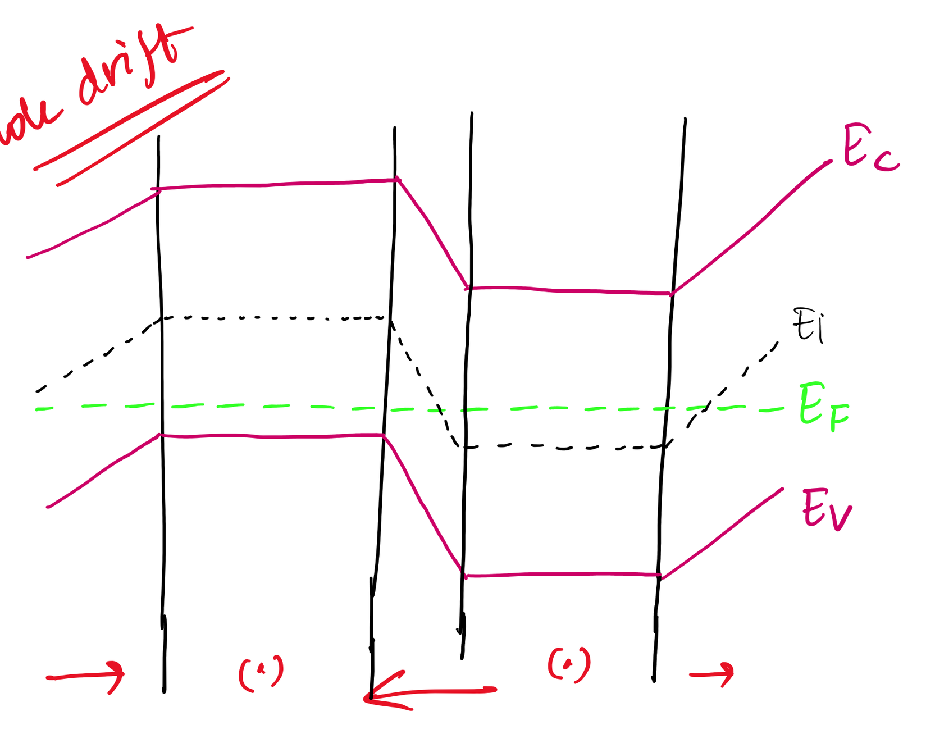
$\Rightarrow$ **ρ ↑es** as $\rho \propto \frac{1}{p\mu_p}$

(d) e^- diffusion



Diffusion: high concentration to low concentration

(e) hole drift



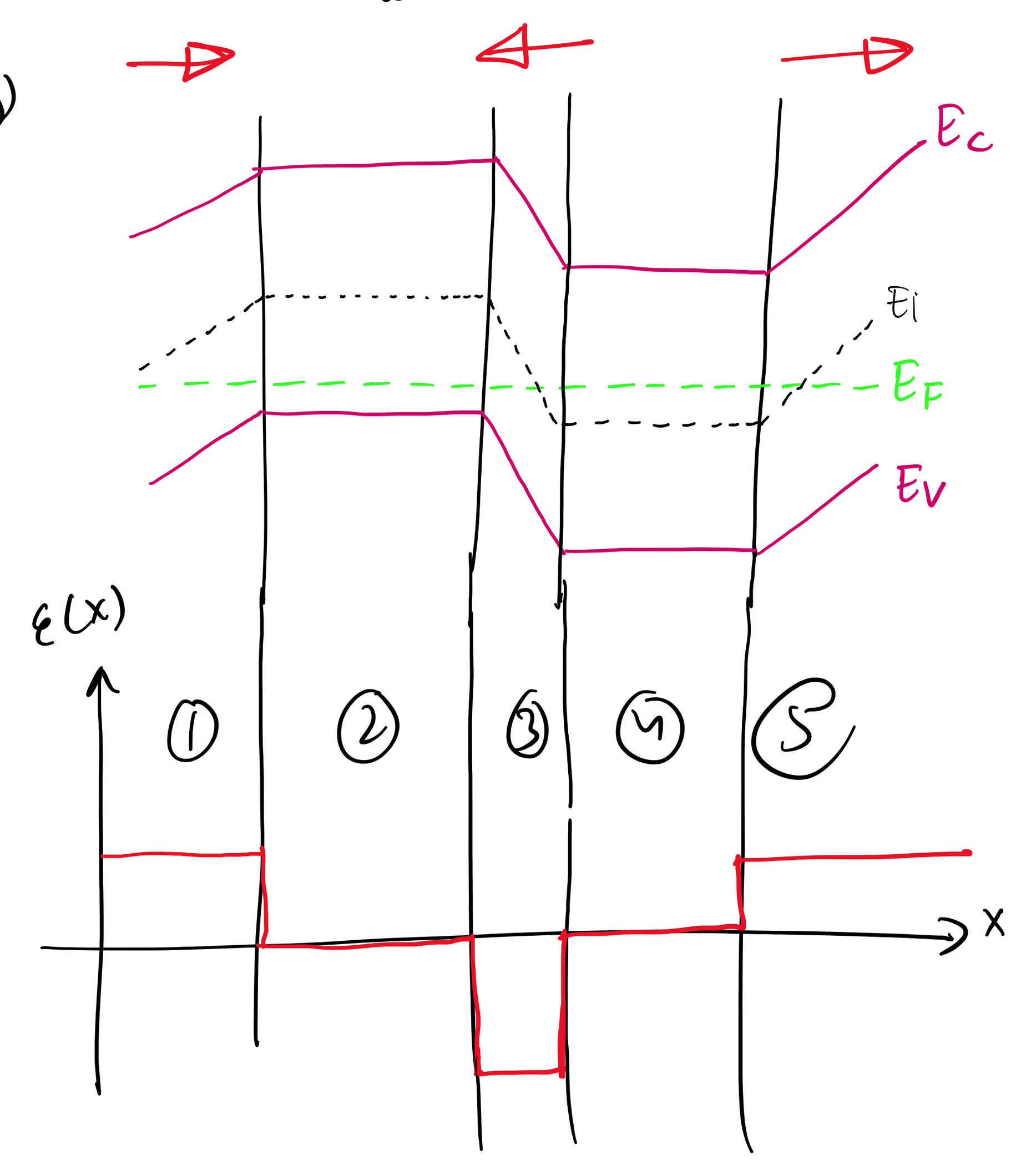
Drift: due to energy difference

(f) E_F → flat $\Rightarrow$ equilibrium

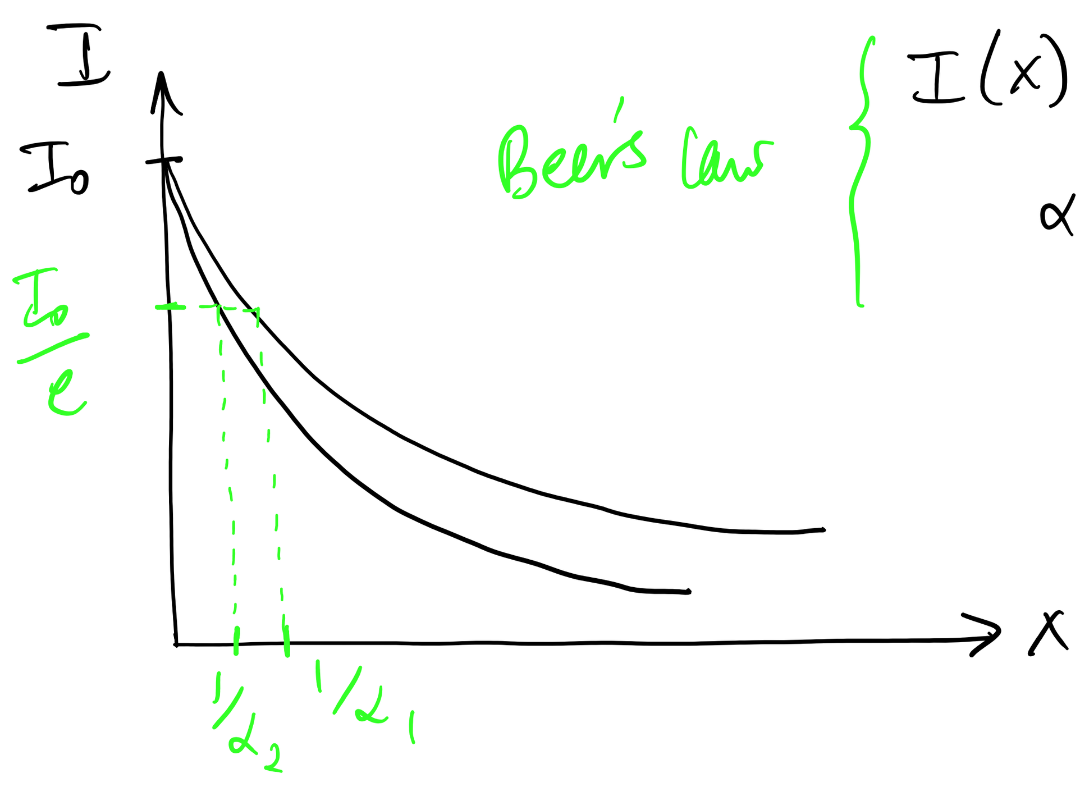
$\Rightarrow$ e^- diffusion cancels out e^- drift

$\Rightarrow$ h^+ diffusion cancels out h^+ drift

(g)



A2) (a)

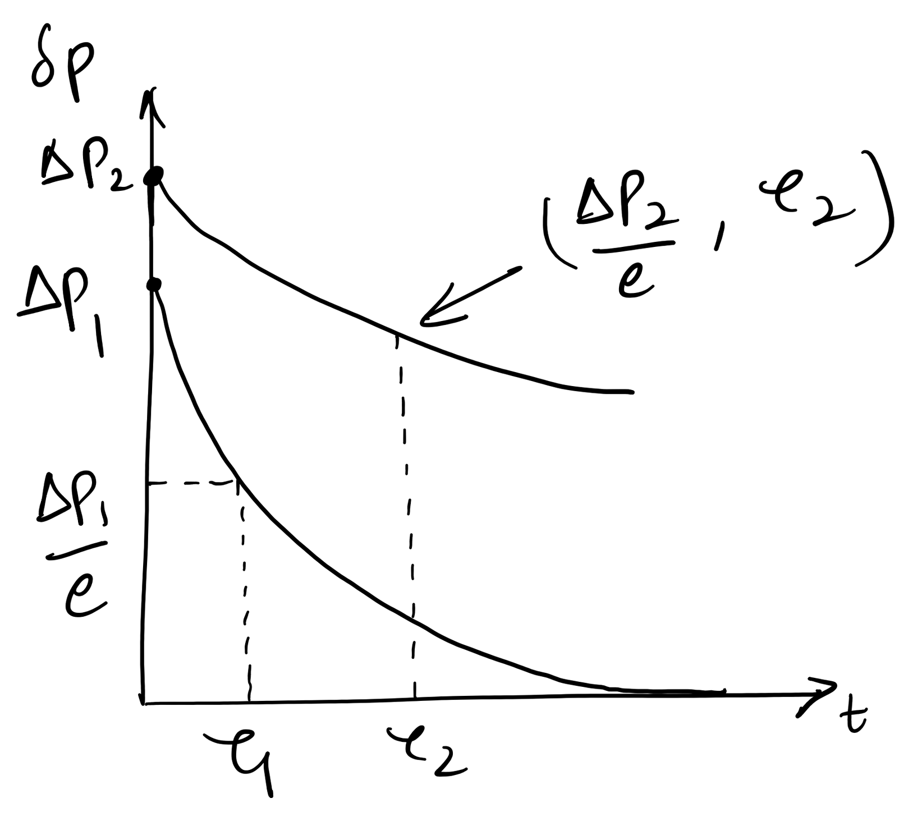


Beer's law $\left\{ I(x) = I_0 e^{-\alpha x} \right.$

$\alpha_1 < \alpha_2$

(b) $h\nu < E_G \Rightarrow$ no absorption

A3) (a)



→ ΔP_2 is higher because $\tau_2 > \tau_1$

$\Rightarrow$ carriers will stick around longer before light is turned off leading to higher eqbm conc.

$\delta p(t) \propto e^{-t/\tau}$

(b) $\tau_2 > \tau_1$

$p = p_0 + \delta p = n_i \exp\left(\frac{E_i - F_p}{kT}\right)$

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

$\Rightarrow$ higher τ $\Rightarrow$ higher $E_F - F_p$

$\Rightarrow$ τ_2 has larger $E_i - F_p$

A4) (a) p-type → check axis label

(b) (1) → Intrinsic (high T, more carriers)

(2) → Extrinsic (All impurities ionized)

(3) → Ionization (only some impurities ionized ∵ low T)

A5) (a) $f(E) = \frac{1}{1 + \exp\left(\frac{E - E_F}{kT}\right)}$

$\approx \exp\left(-\frac{(E - E_F)}{kT}\right)$

when $E >> E_F$ → non degenerate doping $|E_F - E_i| << 3kT$

(b) $|N_D - N_A| >> n_i$

and n type doping

(c) low level injection:

$\Delta n << n_0 + p_0$

→ doesn't affect majority carriers

$n(t) = n_0 + \delta n(t)$

$\delta n(t) = \Delta n\, e^{-t/\tau_n}$