Mid-Sem Answer Keys

Sol. 1) Given, $L = 1\,\mu m$

$\mu = 1350\ cm^2/V\text{-}s$

$E = 10\ V/cm$

we know, drift velocity, $v_d = \mu E$

$\Rightarrow v_d = 1.35 \times 10^4\ cm/s$

Now average time, $t = \dfrac{L}{v_d} = \dfrac{1 \times 10^{-4}\ cm}{1.35 \times 10^4\ cm/s}$

$\Rightarrow \boxed{t = 7.41 \times 10^{-9}\ s}$ — 2m

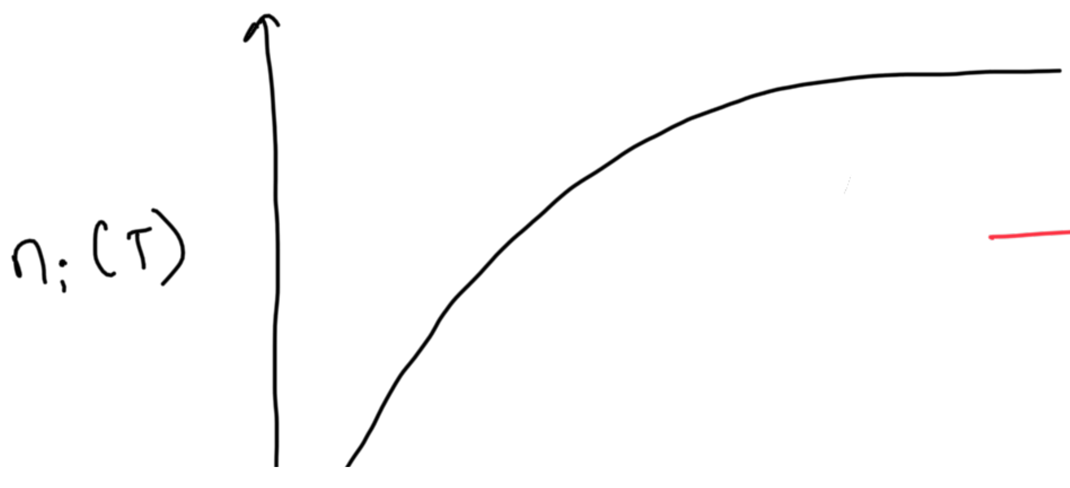
Sol. 2) Plot of $n_i(T)$ vs T

we know, $n_i(T) = \sqrt{N_c N_v}\, e^{-E_g/2KT}$

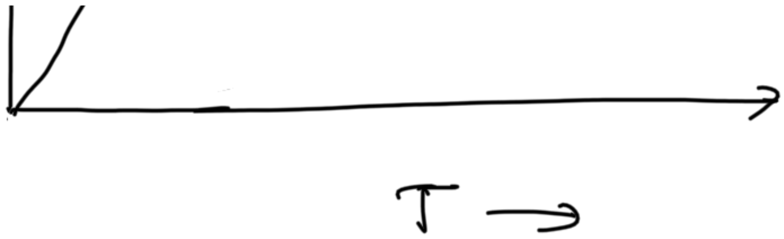
$\sqrt{N_c N_v} \propto T^{3/2}$

$\Rightarrow n_i(T) = A\, T^{3/2}\, e^{-E_g/2KT}$ — 1m

If we substitute a few values of T in the above relation, we will find that the exponential term dominates — 0.5m



— 0.5m



Sol. 3) we know, $n_i = \sqrt{N_c N_v}\, e^{-E_g/2KT}$

$$n_i(Si) = \sqrt{N_c N_v}\, e^{-\frac{1.12\,eV}{2\times 0.026\,eV}}$$

$$n_i(Ge) = \sqrt{N_c N_v}\, e^{-\frac{0.67}{2\times 0.026\,eV}}$$

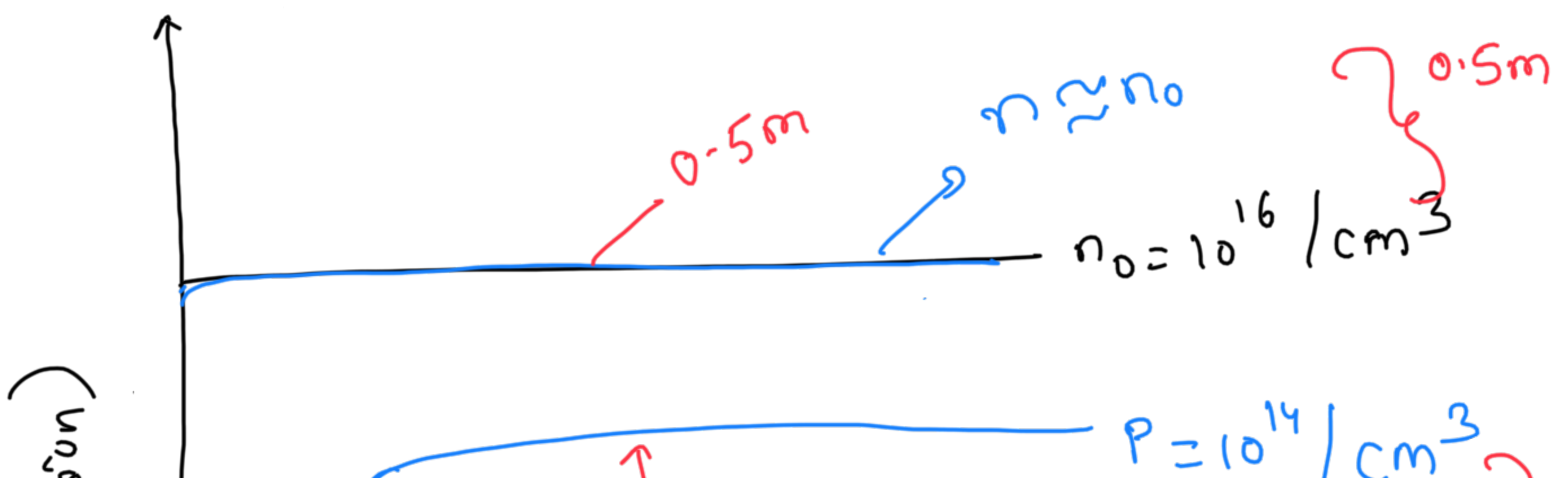
$$\Rightarrow \frac{n_i(Si)}{n_i(Ge)} = e^{-\frac{(1.12-0.67)}{2\times 0.026}}$$

$$\Rightarrow \boxed{\frac{n_i(Si)}{n_i(Ge)} = 0.0001744} \text{ — 2m}$$

Ans. 4) Given, $N_d = 10^{16}/cm^3$

$$\Delta = 10^{14}/cm^3$$

$$\tau_n = \tau_p = 5\,\mu s$$



Sol. 5) Given, $N_A = 10^{15}/cm^3$

$$g' = 10^{21}/cm^3\text{-}s$$

$$\tau_p = \tau_n = 10\,\mu s$$

$$\Delta = g'\tau = 10^{16}/cm^3$$

It's a case of high-level injection

We know, $\sigma = q(\mu_n n + \mu_p P)$

Here $n = P \approx \Delta$

$$\Rightarrow \sigma = q\Delta(\mu_n + \mu_p)$$

$$= 1.6\times10^{-19} \times 10^{16}(1350 + 450)$$

$$\Rightarrow \boxed{\sigma = 2.88\ s/cm} \text{ — 2m}$$

Sol. 6) Given that N_d varies from 0 to 10^{16} over

$x = 0$ to $x = 0.5\,\mu m$

$$J_n = q D_n \frac{dn}{dx}$$

$$= 1.6 \times 10^{-19} \times 30 \times \frac{\left(10^{16} - 1.5 \times 10^{10}\right)}{0.5 \times 10^{-4}}$$

[Assuming that the semiconductor is Silicon]

$$\Rightarrow J_n \cong 1.6 \times 10^{-19} \times 30 \times \frac{10^{16}}{0.5 \times 10^{-4}}$$

$$\Rightarrow \boxed{J_n = 960\ A/cm^2}$$ — 1m

$$J_p = -q D_p \frac{dp}{dx}$$

$$= -1.6 \times 10^{-19} \times 12 \times \left(\frac{2.25 \times 10^{4} - 1.5 \times 10^{10}}{0.5 \times 10^{-4}}\right)$$

$$\Rightarrow J_p \cong \frac{-1.6 \times 10^{-19} \times 12 \times \left(-1.5 \times 10^{10}\right)}{0.5 \times 10^{-4}}$$

$$\boxed{J_p = 5.76 \times 10^{-4}\ A/cm^2}$$ — 1m

Q 7) Given $\vec{E}$ is directed from left to Right

Ans. 7) Given [illegible]

h conc increases from right to left

$\therefore$ $J_{drift, n}$ will be in direction of $\vec{E}$

i.e left to right — 0.5m

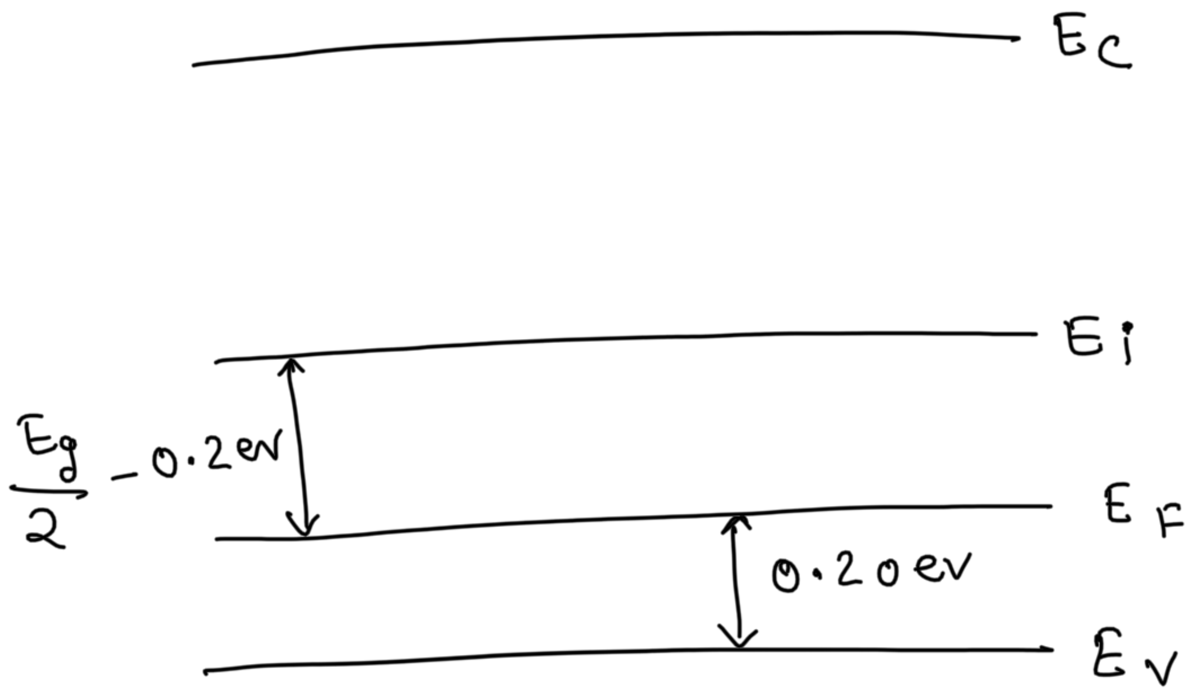
$\therefore$ $J_{drift, p}$ will also be in direction of $\vec{E}$

i.e. left to right — 0.5m

$\therefore$ $J_{diff, p}$ will be from left to right — 0.5m

$\therefore$ $J_{diff, n}$ will also be from left to right as e^- will move from right to left — 0.5m

Sol. 8) Given $E_F - E_V = 0.20\,eV$



i.e. $E_i - E_F = 0.36\,eV$

The semiconductor is P-doped

We know, $E_i - E_F = KT \ln\left(\frac{P_o}{n_i}\right)$

or $P_o = n_i \, e^{\frac{E_i - E_F}{KT}}$

$\Rightarrow P_o = 1.5 \times 10^{10} \cdot e^{\frac{0.36}{0.026}}$

$\Rightarrow \boxed{P_o = 1.03 \times 10^{16} / cm^3}$ — 1m

Under equilibrium, $n_o = \frac{n_i^2}{P_o} = 2.184 \times 10^4 / cm^3$ 1m

Sol. 9) Given, $N_d = 10^{15} / cm^3$

$g' = 10^{18} / cm^3 - s$

$D_p = 30 / cm^2 - s$

$L_p = 100 \, \mu m$

a) Lifetime, $\tau_p = \frac{L_p^2}{D_p} = \frac{(10^{-2})^2}{30}$

$\Rightarrow \boxed{\tau_p = 3.33 \, \mu s}$ — 1m

b) $\delta = \Delta e^{-t/\tau_p}$

Now, $\Delta = g' \cdot \tau_p = 3.33 \times 10^{12} / cm^3$

$$\Rightarrow \boxed{\delta = 3.33 \times 10^{12}\, e^{-t/3.3\times10^{-6}} \ /cm^3} - 1m$$

c) $$\delta(100\,ns) = 3.33\times10^{12}\, e^{-10^{-7}/3.3\times10^{-6}}$$

$$= 3.231 \times 10^{12} \ /cm^3$$

$$n = n_0 + \delta \approx n_0$$

$$p = p_0 + \delta \approx \delta$$

$$E_{Fn} - E_i = KT \ln\left(\frac{n_0}{n_i}\right)$$

$$\Rightarrow \boxed{E_{Fn} - E_i = 0.2887\,eV} \quad — \quad 0.5m$$

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

$$\Rightarrow \boxed{E_i - E_{Fp} = 0.139\,eV} \quad — \quad 0.5m$$