End-Sem Answer Keys

Sol.1) Given $R = 2K\ \Omega$

$L = 200\ \mu m$

$A = 10^{-6}\ cm^2$

$\mu_n = 8000\ cm^2/V\text{-}s$

Doping efficiency = 90%

$$\rho = \frac{R \times A}{L} = \frac{2\times10^{3} \times 10^{-6}}{200\times10^{-4}}$$

$$\rho = 0.1\ \Omega\text{-}cm$$

$$\therefore \boxed{\sigma = 10\ S/cm} \text{ — 1m}$$

$$\sigma = \mu n e \Rightarrow 10 = 8000 \times n \times 1.6\times10^{-19}$$

$$\Rightarrow \boxed{n = 7.8125\times10^{15}/cm^3} \text{ — 0.5m}$$

Since doping efficiency, $\eta = 90\% = \frac{n}{N_D}$

$$\Rightarrow N_D = \frac{7.8125\times10^{15}}{90}\times100$$

$$\Rightarrow \boxed{N_D = 8.68\times10^{15}/cm^3} \text{ — 0.5m}$$

sol-2) Given, $N_D = 3\times10^{15}/cm^3$

$n_i = n_0 = P_0 = 5\%$ of $3\times10^{15}/cm^3$

$$\Rightarrow \boxed{n_i = n_0 = P_0 = 1.5\times10^{14}/cm^3}$$

we know, $n_i(T) = \sqrt{N_c N_v}\, e^{-E_g/2KT}$ — 1m

$n_i(300) = 2.43\times10^{13}/cm^3$

$n_i(T) = 1.5\times10^{14}/cm^3$

$$\frac{n_i(T)}{n_i(300)} = \frac{1.5\times10^{14}}{2.43\times10^{13}} = \left(\frac{T}{300}\right)^{3/2} e^{-E_g/2K\left(\frac{1}{T}-\frac{1}{300}\right)}$$

$$\Rightarrow 6.17 = \left(\frac{T}{300}\right)^{3/2} e^{-3882.4\left(\frac{1}{T}-\frac{1}{300}\right)}$$ — 1.5m

This equation has a non-trivial solution and can be found through numerical methods or hit-trial method.

$$\boxed{T \simeq 580\,K}$$ — 0.5m

sol.3) a) The built-in potential is the area under the triangle

$V_0 = \frac{1}{2} E_m W = \frac{1}{2} E_m (x_n - x_p)$

$$\Rightarrow V_0 = \frac{1}{2} \times 10^{4} \times 1 \times 10^{-4}$$

$$\Rightarrow \boxed{V_0 = 0.5\,V} \quad \text{—— 1m}$$

b) $$\boxed{\frac{N_A}{N_D} = \frac{x_n}{x_p} = \frac{0.4}{0.6} = \frac{2}{3}} \quad \text{— 1m}$$

c) $$E_m = \frac{q}{\varepsilon} N_A x_p$$

[By poisson's Equation]

$$\Rightarrow N_A = \frac{\varepsilon E_m}{q x_p} = \frac{8.85\times10^{-14} \times 11.8 \times 10^{4}}{1.6\times10^{-19} \times 0.6\times10^{-4}}$$

$$\Rightarrow \boxed{N_A = 10.87 \times 10^{14} \,/\mathrm{cm}^3} \quad \text{— 1.5m}$$

$$\boxed{N_D = \frac{3}{2} N_A = 1.63 \times 10^{15} \,/\mathrm{cm}^3} \quad \text{— 1.5m}$$

Ans 4 a) EB – reverse biased
CB – reverse biased } — 0.5m

∴ Cut-off (npn BJT) — 0.5m

b) EB – reverse biased } — 0.5m

CB- forward biased

$\therefore$ Reverse active (npn BJT) — 0.5m

sol. 5)

a) $C_{ox} = 0.34\ \mu F/cm^2$

↳ From the C-V plot

$$t_{ox} = \frac{\varepsilon_{ox}}{C_{ox}} = \frac{3.9 \times 8.85 \times 10^{-14}}{0.34 \times 10^{-6}}$$

$$\Rightarrow \boxed{t_{ox} = 1.015 \times 10^{-6}\ cm}$$ — 1m

b) $C_{min} = 0.24\ \mu F/cm^2$

$$C_{min} = \frac{C_{ox} \cdot C_{d,min}}{C_{ox} + C_{d,min}}$$

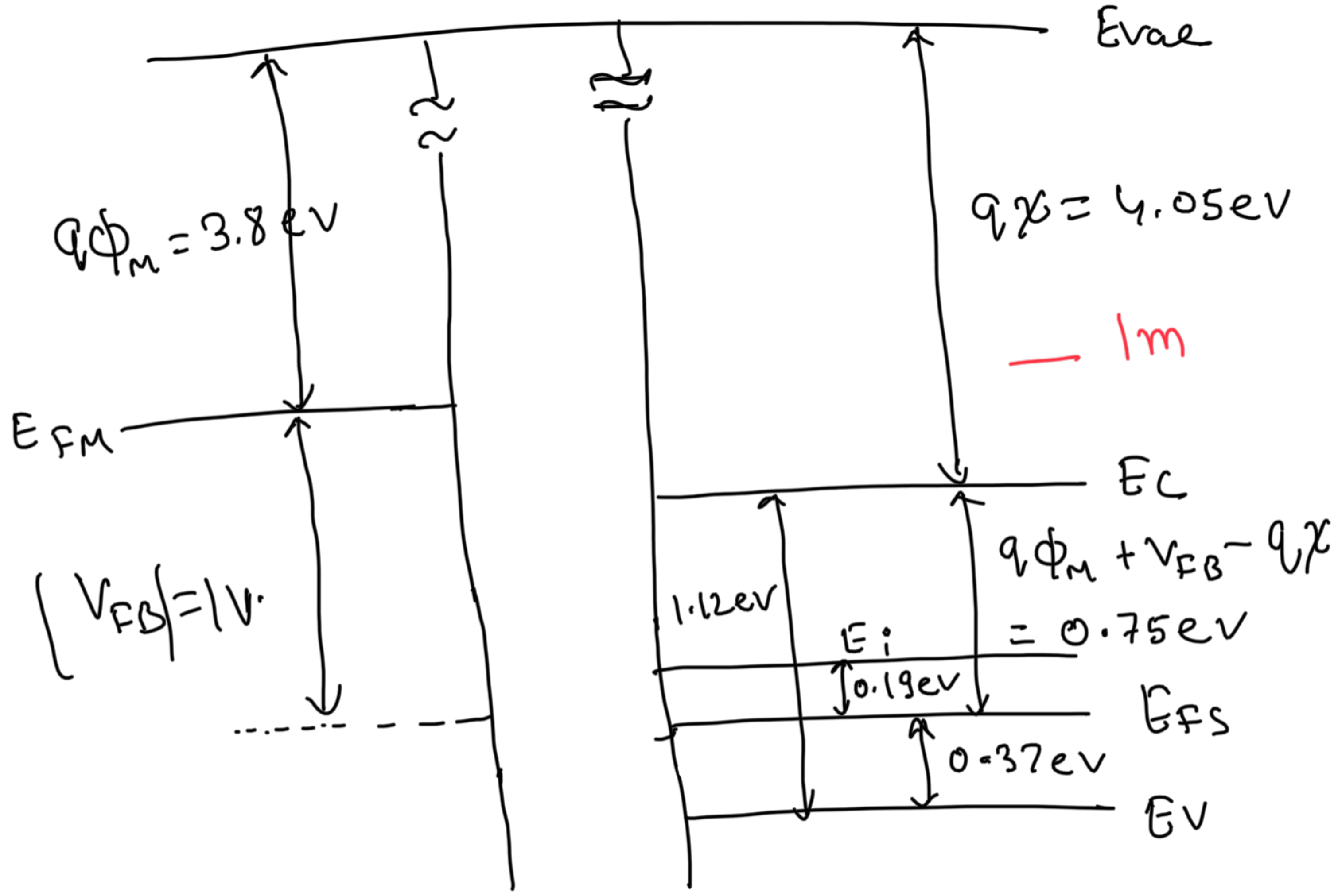
$$\Rightarrow 0.24 \times 10^{-6} = \frac{0.34 \times 10^{-6} \times C_{d,min}}{0.34 \times 10^{-6} + C_{d,min}}$$

$$\Rightarrow \boxed{C_{d,min} = 0.816\ \mu F/cm^2}$$ — 1m

$$W_{max} = \frac{\varepsilon_{siox}}{C_{d,min}} = \frac{11.8 \times 8.85 \times 10^{-14}}{0.816 \times 10^{-6}}$$

$$\Rightarrow \boxed{W_{max} = 1.279 \times 10^{-6}\ cm}$$ — 1m

c) The given band structure is as follows:



$$E_i - E_F = 0.19 = KT \ln\left(\frac{N_A}{n_i}\right)$$

Assuming RT, $n_i(Si) = 1.5 \times 10^{10} / cm^3$

$$N_A = n_i\, e^{0.19/0.026}$$

$$\Rightarrow \boxed{N_A = 2.23 \times 10^{13} / cm^3}$$ — 1m

Sol. 6) We Know

$$I_E = I_{ES}\left(e^{V_{EB}/V_T} - 1\right)$$

If $V_{EB} \gg V_T$, then $e^{V_{EB}/V_T} \gg 1$

$$I_E = I_{ES}\, e^{V_{EB}/V_T}$$

If $I_E' = 2 I_E$

$$\therefore \frac{I_E'}{I_E} = 2 = \frac{e^{V_{EB}'/V_T}}{e^{V_{EB}/V_T}}$$

$$\Rightarrow e^{(V_{EB}' - V_{EB})/V_T} = 2$$

$$\Rightarrow \frac{V_{EB}' - V_{EB}}{V_T} = \ln 2$$

$$\Rightarrow V_{EB}' = V_{EB} + V_T \ln 2$$

$$\Rightarrow \boxed{V_{EB}' = V_{EB} + 0.018\ V}$$ — 2m

Sol. 7) $$I_D = I_0\left(e^{V_f/V_T} - 1\right)$$

$$\approx I_0\, e^{V_f/V_T} \quad \text{if } V_f \gg V_T$$

$\sim I_0 e$

$$\Rightarrow 50\times10^{-3} = I_0\, e^{0.7/0.026}$$

$$\Rightarrow I_0 = \frac{50\times10^{-3}}{4.926\times10^{11}}$$

$$\Rightarrow \boxed{I_0 = 1.014\times10^{-13}\ A}$$ — 2m

Sol. 8)

$$I_{D,sat} = \bar{\mu}_n C_{ox} \frac{Z}{2L}\left(V_{GS} - V_{Th}\right)^2$$

$$= 450\times\frac{3.9\times8.85\times10^{-14}}{35\times10^{-7}}\times\frac{30}{2\times2}\left(4-0.8\right)^2$$

$$\Rightarrow \boxed{I_{D,sat} = 3.408\ mA}$$ — 2m

$$g_m = \frac{\partial I_{D,sat}}{\partial V_{GS}} = \bar{\mu}_n C_{ox}\frac{Z}{L}\left(V_{GS} - V_{Th}\right)$$

$$= 450\times\frac{3.9\times8.85\times10^{-14}}{35\times10^{-7}}\times\frac{30}{2}\left(4-0.8\right)$$

$$\Rightarrow \boxed{g_m = 2.13\ mA/V}$$ — 2m

$\partial_m = 2 \cdot 15$