ECE 321L (2015) HW5 Solution:

2.11. $N_D(eff) = 10^{18} - 10^{16} = 9.9\times10^{17}\ cm^{-3} \Rightarrow n_oP_o = n_i^2$

$\Rightarrow 9.9\times10^{17}\times P_o = (1.062\times10^{10})^2, \therefore \underline{P_o = 114\ cm^{-3}}$

2.13. $P_o = 4\times10^{-6}\ cm^{-3}, \quad N_D - N_A = 4.99\times10^{18}\ cm^{-3}$

$\because P_o = \frac{n_i^2}{N_D - N_A}, \quad \therefore n_i = \sqrt{P_o\cdot(N_D-N_A)} = \sqrt{4\times10^{-6}\times4.99\times10^{18}}$

$= 4.468\times10^{12}\ \frac{\text{carries}}{cm^3}$

Further, $n_i = BT^{\frac{3}{2}}e^{\frac{-E_g}{2KT}}$

From textbook, $B = 5.23\times10^{15}\ (cm^{-3})K^{-3/2}$, $E_g = 1.12\ eV$, $K = 86.17\ \frac{MeV}{K}$

$\therefore 4.468\times10^{12} = 5.23\times10^{15}\cdot T^{\frac{3}{2}}\cdot e^{\left(\frac{-1.12}{2\cdot86.17\cdot T}\right)}$

Solve T by MATLAB or case testing, get $\underline{T = 404.43\ K}$

2.15 a) $\mathcal{E} = V/d = \frac{10}{20\times10^{-4}\ cm} = \underline{500\ V/cm}$

b) $n_oP_o = n_i^2; \quad n_i = BT^{3/2}e^{\frac{-E_g}{2KT}}$

$\therefore n_i = 5.23\times10^{15}\cdot(280)^{\frac{3}{2}}\cdot e^{\left(\frac{-1.12}{2\times86.17\times280}\right)} = 2.04\times10^{9}\ cm^{-3}$

$n_o\times10^{18} = (2.04\times10^{9})^2$ ~~$\Rightarrow n_o = 2.04\times10^{9}\ cm^{-3}$~~

$\Rightarrow \underline{n_o = 4.16\ cm^{-3}}$

Continue...

Continue 2-15

c). $J = \mu_n q \mathcal{E} n_o + \mu_p q \mathcal{E} p_o$

$= 1500 \times 1.6\times10^{-19} \times 500 \times 2.04\times10^{9} + 500\times1.6\times10^{-19}\times 500\times10^{8}$

$= \underline{40050\ A/cm^2}$

D) $J = \cancel{40050}\ 40050\ A/cm^2 \times (10^{-4}\ cm/\mu)^2$

$= \underline{400.5\ \mu A/\mu m^2}$

2.20 From question, $D_n = 35\ cm^2/s$, $D_p = 12\ cm^2/s$, $J = 15\ mA/cm^2$

From textbk, $J_{n\,diff} = q D_n \frac{dn_o}{dx}$, $J_{p\,diff} = q D_p \frac{dp_o}{dx}$

$J = J_{n\,diff} + J_{p\,diff} = q D_n \frac{dn_o}{dx} + q D_p \frac{dp_o}{dx}$

$\because \frac{dn_o}{dx} = 3\frac{dp_o}{dx}$

$J = q \cdot D_n \cdot 3 \frac{dp_o}{dx} + q \cdot D_p \cdot \frac{dp_o}{dx} = q D_n \frac{dn_o}{dx} + q \cdot D_p \frac{1}{3}\frac{dn_o}{dx}$

$\therefore 15\ mA/cm^2 = 1.6\times10^{-19} \times 35 \times 3 \frac{dp_o}{dx} + 1.6\times10^{-19} \cdot 12 \times \frac{dp_o}{dx}$

$\therefore \underline{\frac{dp_o}{dx} = 8.013\times10^{14}\ cm^{-1}}$

$15\ mA/cm^2 = 1.6\times10^{-19} \times 35 \times \frac{dn_o}{dx} + 1.6\times10^{-19} \times 12 \times \frac{1}{3} \times \frac{dn_o}{dx}$

$\therefore \underline{\frac{dn_o}{dx} = 2.404\times10^{15}\ cm^{-1}}$

2.24. From question, $N_D = 10^{18}\ cm^{-3}$, $N_A = 10^{16}\ cm^{-3}$

(a) $V_{bi} = \frac{KT}{q} \ln\left(\frac{N_A N_D}{n_i^2}\right)$ when $T = 300\ K$,

$$\therefore V_{bi} = \frac{1.38066 \times 10^{-23} \times 300}{1.6 \times 10^{-19}} \cdot \ln\left(\frac{10^{16} \cdot 10^{18}}{(1.062 \times 10^{10})^2}\right)$$

$$= \underline{831\ mV}$$

(b) $T = 400\ K$.

$V_{bi} = \frac{KT}{q} \ln\left(\frac{N_A \cdot N_D}{n_i^2}\right)$, here $n_i = BT^{3/2} e^{\frac{-E_g}{2KT}}$

$$= 5.23 \times 10^{15} \cdot (400^{\frac{3}{2}}) \cdot e^{\frac{-1.12}{2 \times 86.17 \times 10^{-6} \times 400}}$$

$$= 3.678 \times 10^{12}$$

$$\therefore V_{bi} = \frac{1.38066 \times 10^{-23} \times 400}{1.6 \times 10^{-19}} \ln\left(\frac{10^{16} \cdot 10^{18}}{(3.678 \times 10^{12})^2}\right)$$

$$= \underline{0.705\ V}$$

2.28, From question, $I_S = 10\ pA$, $T = 300K$, $V_D = 0.625V$.

$$I_D = I_S\left(e^{\frac{qV_D}{KT}} - 1\right)$$

$$= 10\ pA \cdot \left(e^{\frac{1.6 \times 10^{-19} \times 0.625}{1.38066 \times 10^{-23}}} - 1\right) = \underline{275\ mA}$$

2.30 $I_D = I_S(e^{\frac{V_D}{V_{th}}} - 1) \approx I_S \cdot e^{\frac{V_D}{V_{th}}}$

$$\therefore \frac{I_{D1}}{I_{D2}} = e^{\frac{V_{D1} - V_{D2}}{V_{th}}} = e^{\frac{\Delta V}{V_{th}}}$$

$$\therefore \Delta V = V_{th} \cdot \ln\left(\frac{I_{D1}}{I_{D2}}\right) \Rightarrow \Delta V = 25.9^{mV} \cdot \ln(100)$$

$$\therefore \underline{\Delta V = 0.119\ V}$$