# ECE 3150 Homework 3 Solutions

Problem 3.1

a) $p(W_n + x_n) = 0$

b) $p(x_n) = \frac{n_i^2}{N_d} e^{\frac{qV_D}{kT}} = 9 \times 10^{11} /cm^3$

c) Short-base Limit:

$$p'(x) = \frac{n_i^2}{N_d}\left(e^{\frac{qV_D}{kT}} - 1\right)\left(\frac{W_n + x_n - x}{W_n}\right)$$

$$\text{Total charge} = qA\int_{x_n}^{W_n+x_n} p'(x)\,dx = qA\frac{n_i^2}{N_d}\left(e^{\frac{qV_D}{kT}} - 1\right)\int_{x_n}^{W_n+x_n} (W_n + x_n - x)\,dx$$

$$= \frac{1}{2} qA \frac{n_i^2}{N_d}\left(e^{\frac{qV_D}{kT}} - 1\right) W_n$$

$$= 1.4 \times 10^{-15} C$$

d) Short-base Limit

$$\frac{\partial^2 p'(x)}{\partial x^2} = 0 \Rightarrow p'(x) = \frac{n_i^2}{N_d}\left(e^{\frac{qV_D}{kT}} - 1\right)\left(\frac{W_n + x_n - x}{W_n}\right)$$

$J_p(0) = J_p'(x_n)$, $J_p^{diff}(x)$ on N-side

$$= -qD_p \frac{\partial p(x)}{\partial x}$$

$$= -qD_p \frac{n_i^2}{N_d}\left(e^{\frac{qV_D}{kT}} - 1\right) \cdot \frac{-1}{W_n}$$

$$= q n_i^2 \frac{D_p}{N_d W_n}\left(e^{\frac{qV_D}{kT}} - 1\right)$$ which is a constant

$$= 5.7 \times 10^{-3}\ A/cm^2$$

e)

$$\frac{1}{2} qA \frac{n_i^2}{N_a} (e^{\frac{qV_D}{KT}} - 1) W_p = \frac{1}{2} \times \frac{1}{2} qA \frac{n_i^2}{N_d} (e^{\frac{qV_D}{KT}} - 1) W_n$$

$$\Rightarrow \quad \frac{1}{N_a} = \frac{1}{2N_d} \quad \Rightarrow \quad N_a = 2N_d = 2 \times 10^{16} / cm^3$$

f) $$Q_d = \frac{1}{2} qA \frac{n_i^2}{N_a} (e^{\frac{qV_D}{KT}} - 1) W_p \times 3$$

$$= \frac{3}{2} qA \frac{n_i^2}{N_a} W_p (e^{\frac{qV_p}{KT}} - 1)$$

$$C_d = \frac{\partial Q_d}{\partial V_D} = \frac{3}{2} qA \frac{n_i^2}{N_a} W_p \frac{q}{KT} e^{\frac{qV_p}{KT}}$$

$$= 8.2 \times 10^{-14} \text{ F}$$

g) Short-base Limit

$$\frac{\partial^2 n'(x)}{\partial x^2} = 0 \Rightarrow n'(x) = \frac{n_i^2}{N_a} (e^{\frac{qV_D}{KT}} - 1) \left( \frac{W_p + x_p + x}{W_p} \right)$$

$$J_n(0) = J_n(-x_p) \quad J_n^{diff}(x) \quad \text{on P-side}$$

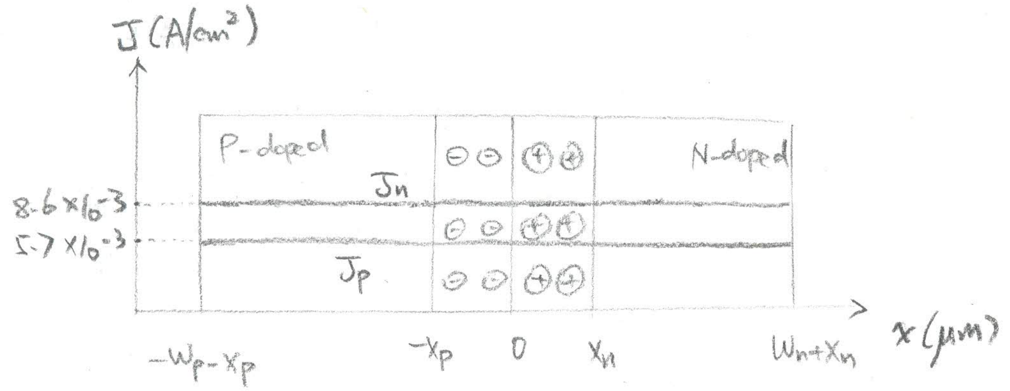
$$= qD_n \frac{\partial n'(x)}{\partial x}$$

$$= qD_n \frac{n_i^2}{N_a} (e^{\frac{qV_D}{KT}} - 1) \frac{1}{W_p}$$

$$= 8.6 \times 10^{-3} \text{ A/cm}^2$$

$$J_n(0) / J_p(0) = \frac{D_n}{D_p} \frac{N_d W_n}{N_a W_p} = 1.5$$

h)




i) On P-side

$$p'(x) = n'(x) = \frac{n_i^2}{N_a}\left(e^{\frac{qV_D}{kT}} - 1\right)\left(\frac{W_p + x_p + x}{W_p}\right)$$

$$J_p^{diff}(x) = -qD_p\frac{\partial p(x)}{\partial x} = -qD_p\frac{n_i^2}{N_a}\left(e^{\frac{qV_D}{kT}} - 1\right)\frac{1}{W_p} = -2.8\times10^{-3}\ A/cm^2$$

j) $$J_p^{drif} = J_p^T - J_p^{diff} = \frac{qn_i^2 D_p}{N_d W_n}\left(e^{\frac{qV_D}{kT}} - 1\right) + \frac{qn_i^2 D_p}{N_a W_p}\left(e^{\frac{qV_D}{kT}} - 1\right)$$

$$= qn_i^2 D_p\left(\frac{1}{N_d W_n} + \frac{1}{N_a W_p}\right)\left(e^{\frac{qV_D}{kT}} - 1\right)$$

$$= 8.6\times10^{-3}\ A/cm^2$$

k) $$J_p^{drif} = q\mu_n p_{po} E_x \quad , \quad p_{po} = N_a$$

$$\Rightarrow E_x = \frac{n_i^2}{\mu_n}\frac{D_p}{N_a}\left(\frac{1}{N_d W_n} + \frac{1}{N_a W_p}\right)\left(e^{\frac{qV_D}{kT}} - 1\right) \quad , \quad \frac{D_p}{\mu} = \frac{kT}{q}$$

$$= \frac{n_i^2}{N_a}\frac{kT}{q}\left(\frac{1}{N_d W_n} + \frac{1}{N_a W_p}\right)\left(e^{\frac{qV_D}{kT}} - 1\right)$$

$$= 8.7\times10^{-3}\ V/cm$$

l) $J_T = J_n(0) + J_p(0) = q n_i^2 \left( \frac{D_n}{N_a W_p} + \frac{D_p}{N_d W_n} \right) \left( e^{\frac{qV_D}{kT}} - 1 \right)$

$I_T = J_T A \quad = 1.4 \times 10^{-6}$ A

m) $J_n(0) = 5 J_p(0) \Rightarrow \frac{J_n(0)}{J_p(0)} = \frac{D_n}{D_p} \frac{N_d W_n}{N_a W_p} = 5$

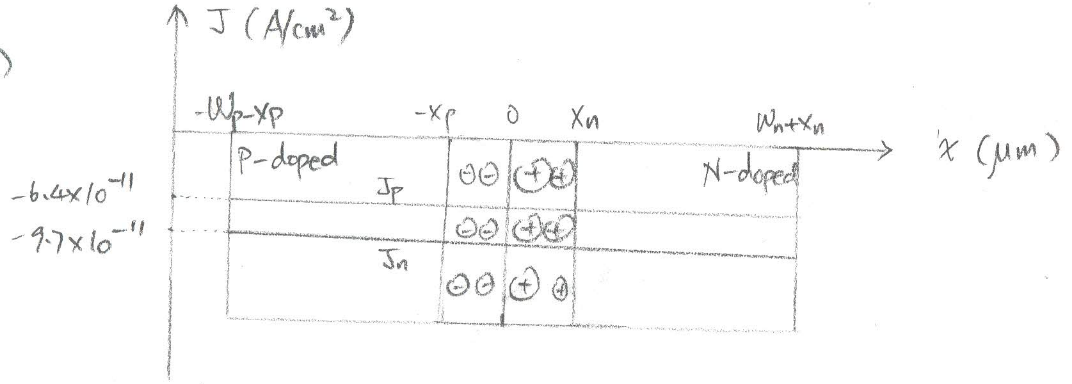
$\Rightarrow \frac{\mu_n}{\mu_p} \frac{N_d}{N_a} = 5 \Rightarrow N_a = \frac{\mu_n}{\mu_p} \frac{N_d}{5} = 0.6 N_d = 6 \times 10^{15} / cm^3$

n) $p(x)$ at metal is zero

o) $p(x_n) = \frac{n_i^2}{N_d} e^{\frac{qV_D}{kT}}$ , $V_D = -0.476$ V

$= 1.1 \times 10^{-4} / cm^3$

p)




q) $J_p^{diff}(x) = -q D_p \frac{n_i^2}{N_a} \left( e^{\frac{qV_D}{kT}} - 1 \right) \frac{1}{W_p}$

$= 3.2 \times 10^{-11}$ A/cm²

r) $J_p^{drif} = q n_i^2 D_p \left(\frac{1}{N_d W_n} + \frac{1}{N_a W_p}\right)\left(e^{\frac{qV_0}{kT}} - 1\right)$

$= -9.7 \times 10^{-11}\ A/cm^2$

s) $E_x = \frac{n_i^2}{N_a}\frac{kT}{q}\left(\frac{1}{N_d W_n} + \frac{1}{N_a W_p}\right)\left(e^{\frac{qV_p}{kT}} - 1\right)$

$= -9.8 \times 10^{-11}\ V/cm$

t) $I_T = -1.6 \times 10^{-14}\ A$