HW4 /50

①

Problem I

20

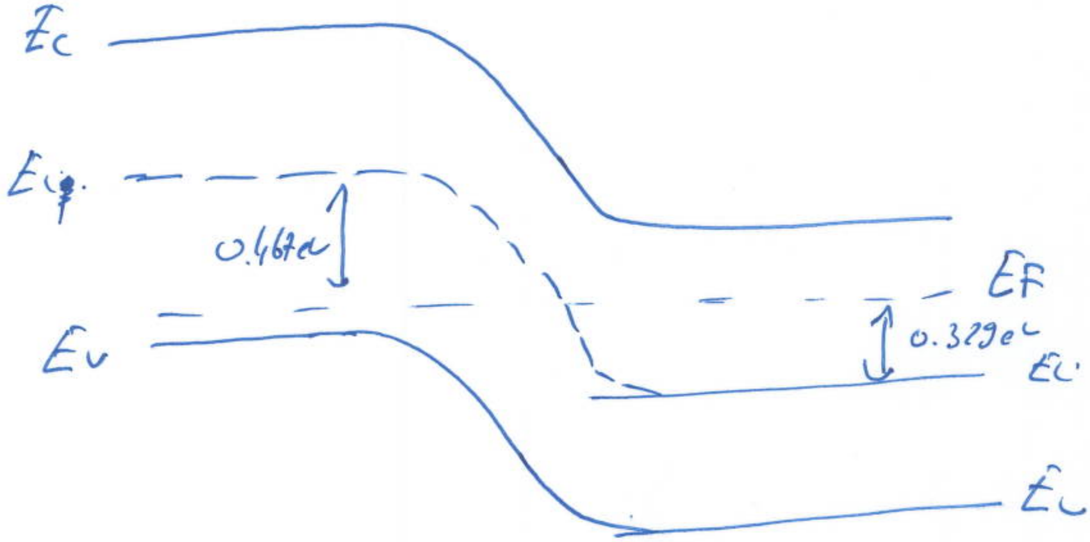
$N_A = 10^{18}/cm^3 \quad N_D = 5 \cdot 10^{15}/cm^3$

here ($n_i = 1.5 \cdot 10^{10}/cm^3$)

5/ (1) $(E_i - E_F)|_p = k_0 T \ln \frac{p_p}{n_i} \simeq 0.467 eV$

$(E_F - E_i)|_n = k_0 T \ln \frac{n_n}{n_i} \simeq 0.329 eV$

5/ (2)



From the graph $qV_0 = 0.467 + 0.329 \simeq 0.796 V$

(3)

4/ $qV_0 = k_BT \ln \frac{N_a N_d}{n_i^2} = 0.796\ eV.$ identical.

(4) using the formula for x_n, x_p,

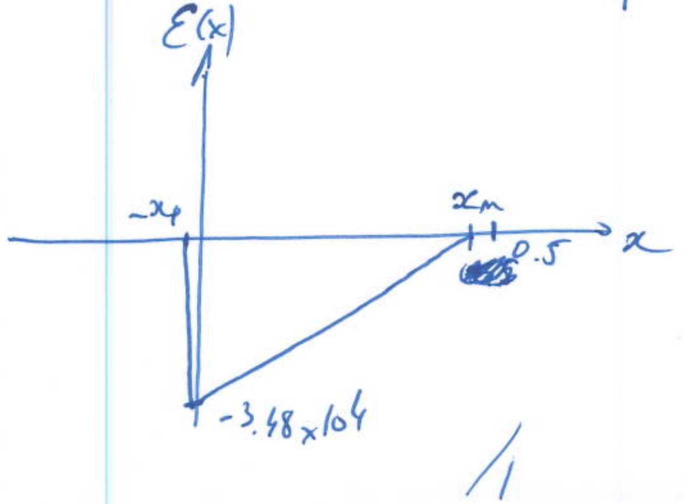
8/

$\Rightarrow$ $\boxed{x_n = 0.455\ \mu m}$ /1 $\boxed{x_p = 2.27\times10^{-3}\ \mu m}$ /1

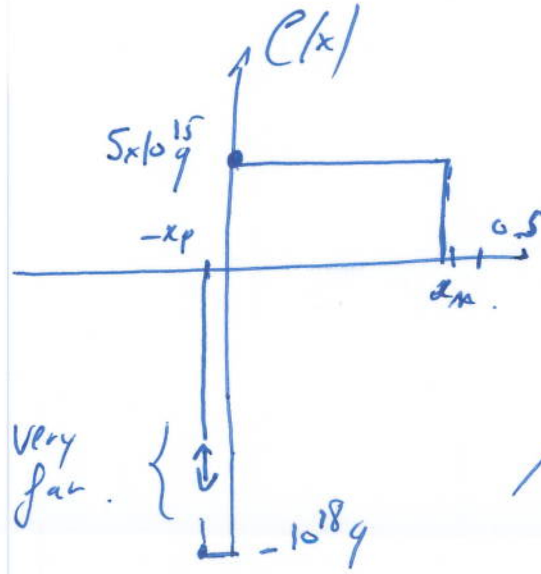
also $\boxed{\mathcal{E}_{max} = -\frac{q}{\epsilon} x_n N_d = -\frac{q}{\epsilon} x_p N_A = -3.48\times10^{4}\ V/cm}$ /2

$\boxed{Q = qA\, x_n N_d = qA\, x_p N_A = 2.85\times10^{-14}\ C}$ /2

since $A = \frac{\pi}{4}\cdot\left[10\times10^{-6}\right]^2\ m^2$



/1



/1

Problem 2 $\quad A = 10^{-4}\ cm^2 \quad T = 300K$

/10

$$I = q\underbrace{A\left[\frac{D_p}{L_p}p_n + \frac{D_n}{L_n}n_p\right]}_{I_0}\left[\exp\left[\frac{qV_A}{k_BT}\right] - 1\right]$$

$V_A = 0.5V$

$$\begin{cases} p_n = \dfrac{n_i^2}{n_n} = \underline{2.25 \times 10^5 / cm^3} & /1 \\ n_p = \dfrac{n_i^2}{p_p} = \underline{2.25 \times 10^3 / cm^3} & /1 \end{cases}$$

For minority carriers

N-side $\quad D_p = \frac{k_BT}{q}\mu_p = 0.0259 \times 450 = \boxed{11.66\ cm^2/s} \quad /1$

P-side $\quad D_n = \frac{k_BT}{q}\mu_n = 0.0259 \times 700 = \boxed{18.13\ cm^2/s} \quad /1$

④

$$L_p = \sqrt{D_p \tau_p} = 1.08 \times 10^{-2}\ cm$$ /1

$$L_n = \sqrt{D_n \tau_n} = 1.35 \times 10^{-2}\ cm$$ /1

$$\Longrightarrow \boxed{I_o = 4.370 \times 10^{-15}\ A}$$

if $V_A = 0.5V$ Forward bias $\boxed{I = I_o \left[e^{q\frac{V_A}{k_BT}} - 1\right] = 1.058 \times 10^{-6}\ A}$

if $V_A = -0.5V$ Reverse bias /2

$$\boxed{I \simeq -I_o = \cancel{1.058 \times 10^{-6}} - 4.37 \times 10^{-15}\ A}$$ /2

Problem 3

① $I_o = 10^{-18}\ A$, $I = 10\ mA = 10^{-3}\ A$

$$I = I_o \left[\exp\left(q\frac{V_A}{k_BT}\right) - 1\right] \Rightarrow V_A?$$

$$\frac{I}{I_o} + 1 = \exp\left[q\frac{V_A}{k_BT}\right] \Rightarrow \left(V_A = \frac{k_BT}{q} \ln\left[\frac{I}{I_o} + 1\right]\right)$$

$$\Rightarrow \boxed{V_A \simeq 0.96V}$$

2

/2

P	N
$10^{16}/cm^3$	$5 \cdot 10^{16}/cm^3$

- $$\boxed{V_0 = \frac{k_B T}{q} \ln\left(\frac{N_D N_A}{n_i^2}\right) = 0.76 V}$$ /2

- $$\boxed{W = \sqrt{\frac{2\epsilon_s}{q}\frac{(N_A+N_D)}{N_A N_D}(V_0 - V_A)}}$$

- $E_{max} = -q\frac{N_D x_n}{\epsilon_s}$ $\quad W = x_n + x_p \quad x_n N_d = x_p N_A$

$$\Rightarrow x_n = \frac{W N_A}{(N_A+N_D)}$$

$$\Rightarrow \boxed{E_{max} = \frac{-q N_D N_A W}{\epsilon_s (N_A+N_D)}} \Rightarrow \boxed{\frac{-2(V_0 - V_A)}{W}}$$

- $V(x) = -\frac{qN_D}{2\epsilon}(x - x_n)^2 + V_0$ inside depletion region.

in the n-type the potential drop is.

$$\boxed{V_{nA} = V(x_n) - V(0) = \cancel{V_0} + \frac{qN_D}{2\epsilon}x_n^2 \cancel{- V_0} = \frac{(V_0 - V_A)N_A}{N_A + N_D}}$$

6

	$V_A = 0V$	$0.5V$	$-2.5V$
$W(\mu m)$	0.35	0.205	0.72
$\mathcal{E}(kV/cm)$	-43.8	-25.9	-90.7
$V_m(V)$	0.125	0.042	0.54

~~$2 \times 9 = 18$~~