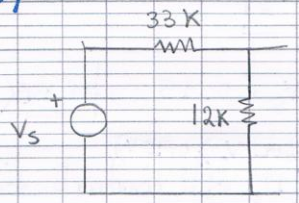
EECE 310 Homework 5

Problem 1

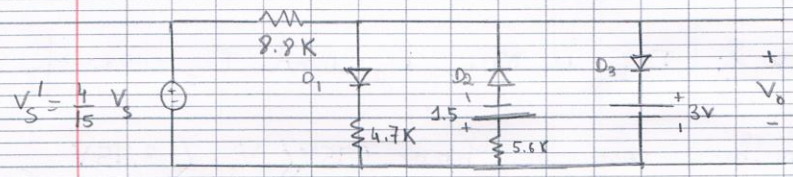
a)



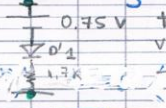
Let's find the thevenin equivalent of this circuit

$$V_{Th} = \frac{12K}{33K+12K} V_s = \frac{4}{15} V_s$$

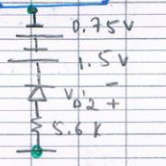
$$R_{th} = 33K \parallel 12K = 8.8K$$



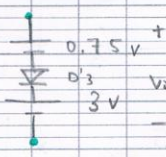
Case 1 : D_1, D_2 and D_3 are off

- D_1 is off →  → $V_{D'1} < 0 \rightarrow V_o - 0.75 < 0$

$$\boxed{V_o < 0.75V}$$

- D_2 is off →  → $V_{D'2} < 0 \rightarrow -V_o - 2.25 < 0$

$$\boxed{V_o > -2.25V}$$

- D_3 is off →  → $V_{D'3} < 0 \rightarrow V_o - 3.75 < 0$

$$\boxed{V_o < 3.75V}$$

Therefore

$$-2.25 < V_o < 0.75\ V$$

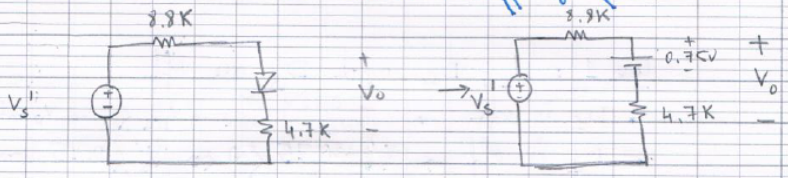
In this case $\boxed{V_o = \frac{4}{15} V_s}$

$$-2.25 < \frac{4}{15} V_s < 0.75 \rightarrow \boxed{-8.4375 < V_s < 2.8125}$$

Now if Vo > 0.75 V , D_1 will conduct but D_2 and D_3 will remain off; this brings us to the second case.

Case 2: D_1 is on, D_2 and D_3 are off.

In this case we have $0.75V < V_o < 3.75V$



$$V_o = 0.75 + \frac{V_s' - 0.75}{8.8K + 4.7K} \times 4.7K$$

$$V_o = \frac{47}{135} V_s' + \frac{22}{45} \quad ; \quad V_o = \frac{47}{135} \times \frac{4}{15} V_s + \frac{22}{45}$$

$$\boxed{V_o = \frac{188}{2025} V_s + \frac{22}{45}}$$

$$0.75 < V_o < 3.75 \quad ; \rightarrow \boxed{2.8125 < V_s < 35.13\ V}$$

Now, if $V_o = 3.75V$ D_1 and D_3 will conduct and D_2 will remain off → Case 3

Case 3:

D_1 and D_3 : ON

D_2 : off

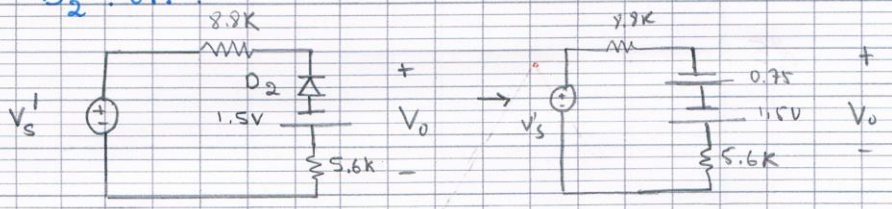
$V_o = 3.75V$

$V_s \geq 35.13V$

Case 4: $V_o \leq -2.25V$

D_1 and D_3 : off

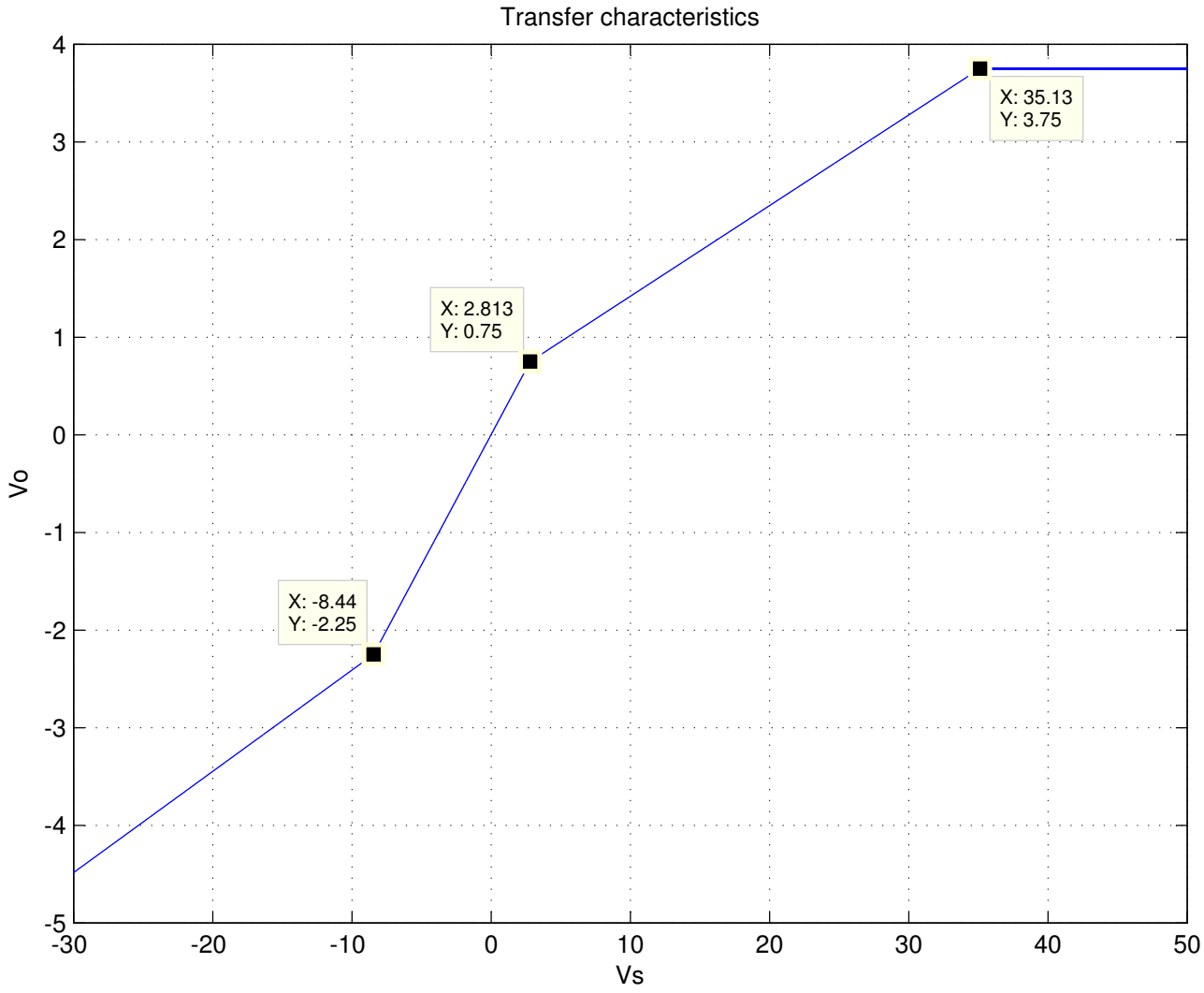
D_2 : on

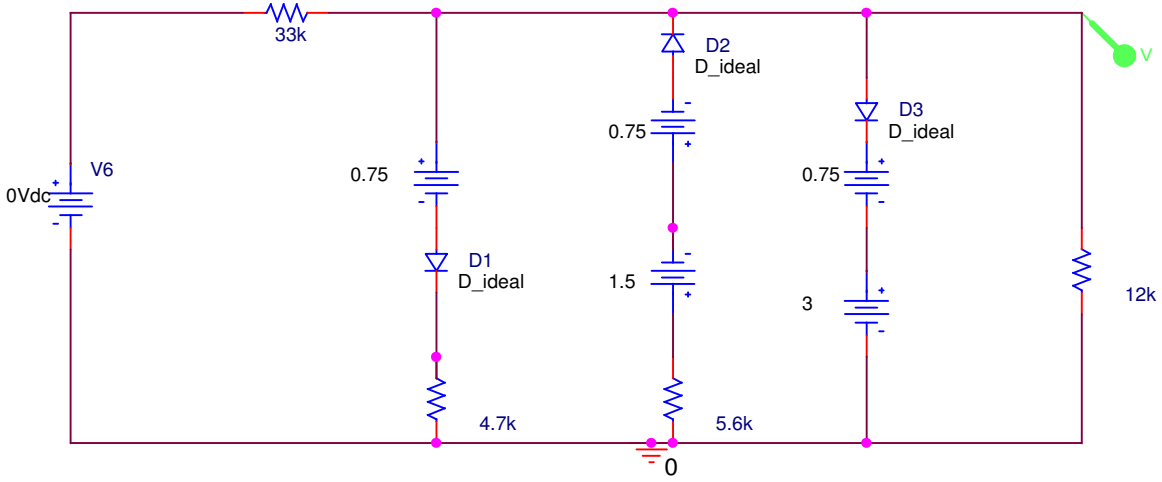


$$V_o = -2.25 + \frac{5.6}{8.8+5.6}\left(V_s' + 2.25\right)$$

$$V_o = \frac{7}{18}V_s' - 1.375 = \frac{7}{18} \times \frac{4}{15} V_s - 1.375$$

$$\boxed{V_o = \frac{14}{135}V_s - 1.375} \rightarrow \begin{cases} V_o \leq -2.25\ V \\ V_s \leq -8.4375\ V \end{cases}$$


Transfer characteristics
X: 35.13
Y: 3.75
X: 2.813
Y: 0.75
X: -8.44
Y: -2.25
Vo
Vs
4
3
2
1
0
-1
-2
-3
-4
-5
-30
-20
-10
0
10
20
30
40
50



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Date: Sunday, October 30, 2011	Sheet 1 of 1	

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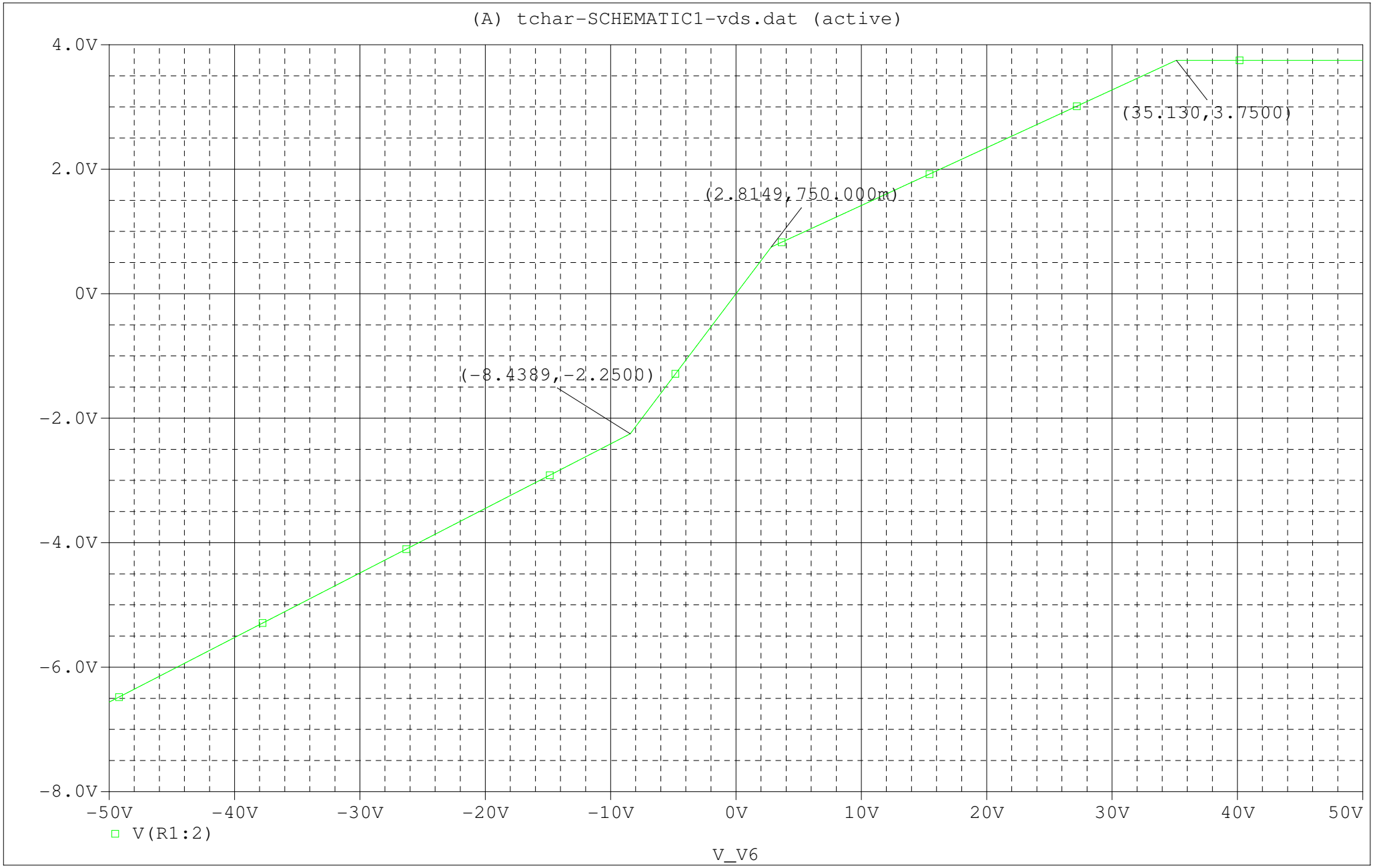


c) (1) $-8.4375 < V_s < 2.8125 \rightarrow V_o = \frac{4}{15} V_s$

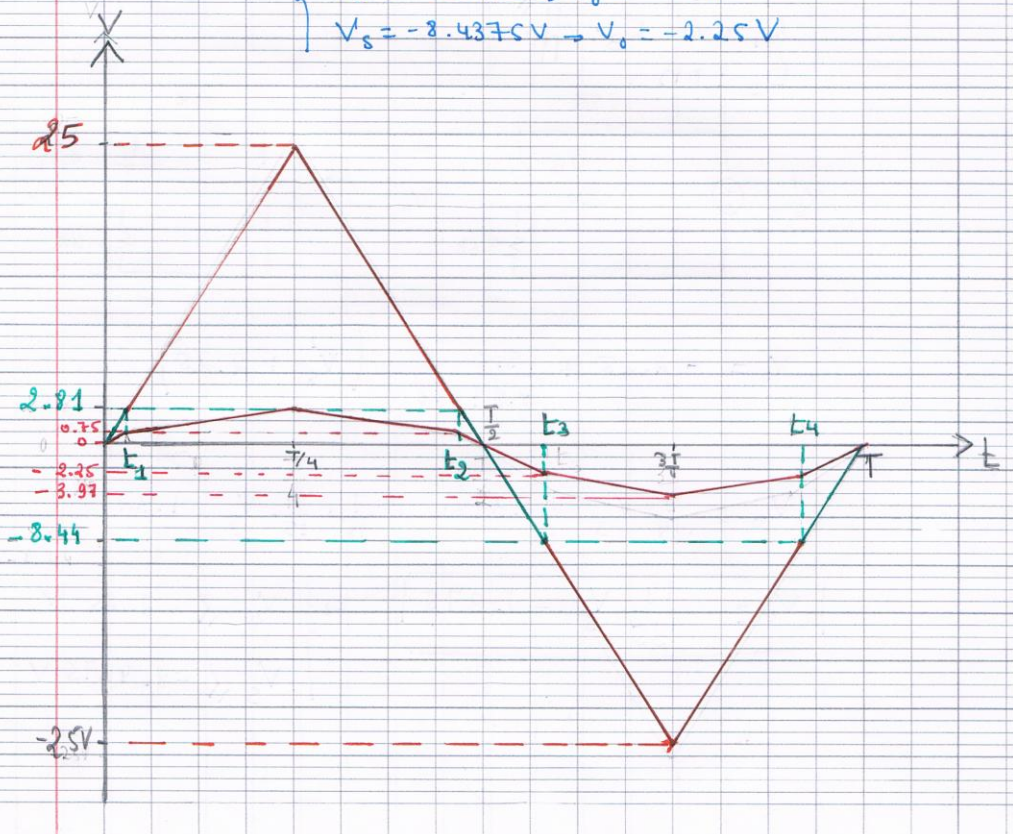
$\begin{cases} V_s = 0 \rightarrow V_o = 0V \\ V_s = 2.8125 \rightarrow V_o = 0.75V \\ V_s = -8.4375 \rightarrow V_o = -2.25V \end{cases}$

(2) $2.8125 < V_s \leq 25 \rightarrow V_o = \frac{188}{2025} V_s + \frac{22}{45}$

$\begin{cases} V_s = 2.8125V \rightarrow V_o = 0.75V \\ V_s = 25V \rightarrow V_o = 2.81V \end{cases}$

(3) $-25 \leq V_s < -8.4375V \rightarrow V_o = \frac{14}{135} V_s - 1.375$

$\begin{cases} V_s = -25V \rightarrow V_o = -3.97V \\ V_s = -8.4375V \rightarrow V_o = -2.25V \end{cases}$



Problem 2

a) n- type : electrons are majority carriers

doping level : $N_D = 3.5 \times 10^{17}\ cm^{-3} = n$

At 300 K, $n_i = 1.5 \times 10^{10}\ cm^{-3} \Rightarrow p = \frac{n_i^2}{N_D} = 643 \ll n$

hence we can neglect p to find J_n.

$J_n = q.n.v_n = 1.6 \times 10^{-19} \times 3.5 \times 10^{17} \times 10^{70}$

$= 5.6 \times 10^{5}\ A/cm^2$

b) $\sigma = q(p\mu_p + n\mu_n) \simeq qn\mu_n$

$= 1.6 \times 10^{-19} \times 3.5 \times 10^{17} \times 950$

$= 53.2\ \Omega^{-1}\ cm^{-1}$

$\rho = \frac{1}{\sigma} = 0.0188\ \Omega.cm$

c) $V = RI = \frac{\rho L}{A} I = \rho L J = 0.0188 \times 5 \times 5.6 \times 10^5$

$= 52.640\ V$.

Problem 3

$n(x) = 10^5 + 10^{17} e^{-\frac{x}{L_n}}$; $L_n = 2.5\ \mu m$

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

$\frac{dn}{dx} = -\frac{10^{17}}{L_n} e^{-\frac{x}{L_n}} = -\frac{10^{17}}{2.5 \times 10^{-4}} e^{-\frac{x}{L_n}} = -4 \times 10^{20} . e^{-\frac{x}{L_n}}$

$J_n = 1.6 \times 10^{-19} \times 13 \times (-4 \times 10^{20})\ e^{-\frac{x}{L_n}}$

$= -832\ e^{-\frac{x}{L_n}}\ A/cm^2$

b) $J_n = -832\, e^{-0.75} = -393 \text{ A/cm}^2$

$I = J_n A = -393 \times 5000 \times 10^{-8}$

$= -0.01965 \text{ A}$

$= -19.65 \text{ mA}$

Problem 4

$N_A = 2 \times 10^{17} \text{ cm}^{-3}$ p-side

$N_D = 7 \times 10^{15} \text{ cm}^{-3}$ n-side

a) p-type: $P_p = N_A = 2 \times 10^{17} \text{ cm}^{-3}$

n-type: $P_n = \frac{n_i^2}{N_D} = \frac{(1.5 \times 10^{10})^2}{7 \times 10^{15}} = 32\,143 \text{ cm}^{-3}$

b) p-type: $n_p = \frac{n_i^2}{N_A} = 1125 \text{ cm}^{-3}$

n-type: $n_n = N_D = 7 \times 10^{15} \text{ cm}^{-3}$

c) $V_0 = V_T \ln \frac{N_A N_D}{n_i^2}$

$= \frac{K \cdot T}{q} \ln \frac{N_A N_D}{n_i^2}$

$= \frac{1.38 \times 10^{-23} \times 300}{1.6 \times 10^{-19}} \times \ln\left(\frac{2 \times 10^{17} \times 7 \times 10^{15}}{(1.5 \times 10^{10})^2}\right) = 0.762 \text{ V}$