ECE113A Fall 2003 **2nd Midterm Exam** Name:______________________

11-10-2003 ID no.:______________________

Sec.A: Peter Burke 10:00 to 10:50 am

PROBLEM ONE: (50 points)

1) For a Si p-n diode at 300 K, with no applied voltage, with $N_A = 10^{19}$ cm^{-3}, and $N_D = 10^{16}$ cm^{-3}
   a. Calculate V_{bi} in units of V (15 points). No partial credit.

$$V_{bi} = \frac{kT}{q} \ln\left[\frac{N_A N_D}{n_i^2}\right]$$

$$= 0.0259\,(V) \ln\left[\frac{10^{19}\,cm^{-3}\;10^{16}\,cm^{-3}}{[10^{10}\,cm^{-3}]^2}\right]$$

$$= 0.0259\,(V) \ln\left[10^{15}\right]$$

$$= 0.0259\,(V) \times 34.539$$

$$= 0.8946\ V$$

PROBLEM ONE: (*continued*)

b. Calculate x_p in units of μm (10 points). No partial credit.

$$X_P = \sqrt{\frac{2K_s\varepsilon_o}{q}\frac{N_D}{(N_A+N_D)N_A}V_{bi}}$$

$$= \sqrt{\frac{2\cdot 11.8\cdot 8.85\times10^{-14}\,F/cm}{1.6\times10^{-19}\,C}\frac{10^{16}\,cm^{-3}}{[10^{19}\,cm^{-3}]^2}\,0.8946\,V}$$

$$= 0.0003417\,\mu m = 3.417\times10^{-4}\,\mu m$$

c. Calculate x_n in units of μm (10 points). No partial credit.

$$X_n = \frac{N_A}{N_D}X_P \quad \text{(eq. 5.22 of book)}$$

$$= \frac{10^{19}\,cm^{-3}}{10^{16}\,cm^{-3}}\,3.417\times10^{-4}\,\mu m$$

$$= 3.417\times10^{-1}\,\mu m = 0.3417\,\mu m$$

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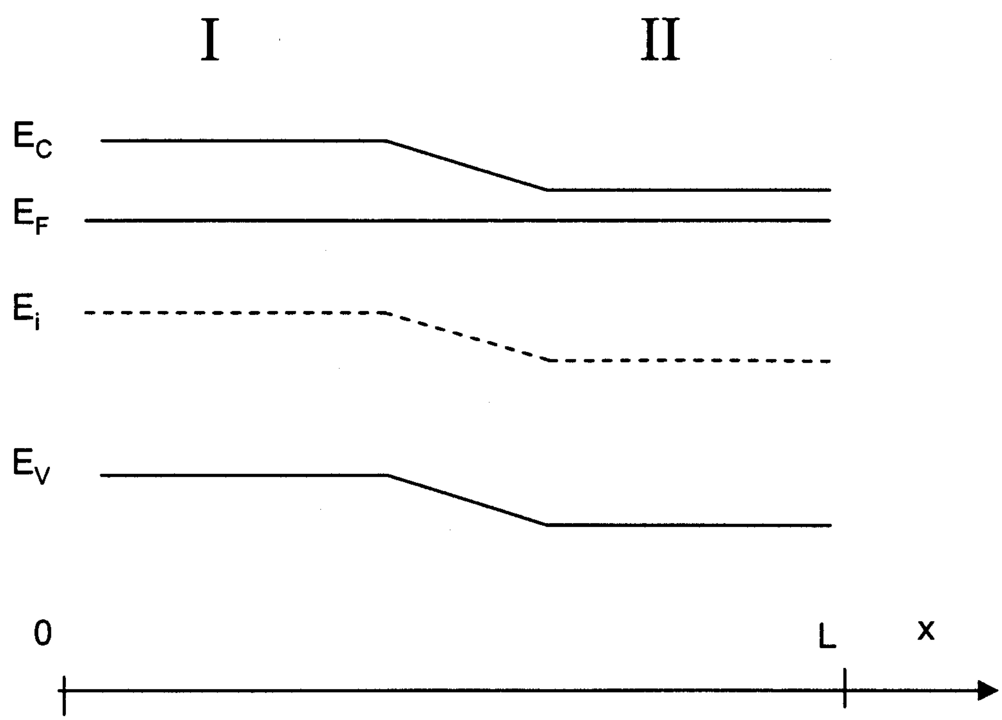
PROBLEM TWO: (50 points)



2) For the band diagram shown above,

a. Is region I p-type or n-type? (5 points)

n

b. Is region II p-type or n-type? (5 points)

n

c. Which region (I or II) has higher majority carrier density? (5 points)

II

d. Why for c? (10 points)

On both sides, electrons are the majority carriers. This is because $n > p$ on both sides.

Since E_F closer to E_c on side II, n is larger on side II than I.

Because $n = N_c e^{(E_F - E_c)/kT}$

$= n_i e^{(E_F - E_i)/kT}$

PROBLEM TWO: *(continued)*

e. Which region (I or II) has higher minority carrier density? (5 points)

I

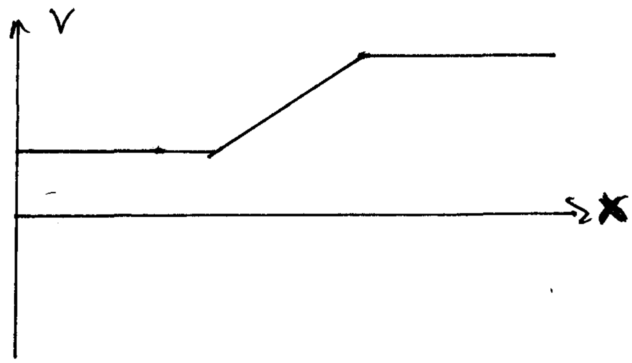
f. Why for e? (10 points)

On both sides, holes are minority carriers since n > p on both sides.

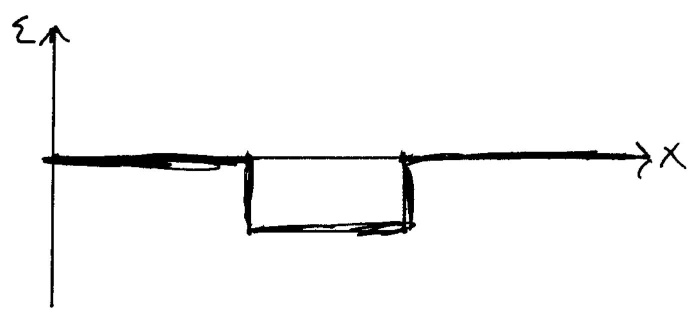
$p = n_i^2/n$. side II has larger n so side I has larger p.

or: $p = n_i e^{(E_i - E_F)/kT}$ or $p = N_V e^{(E_V - E_F)/kT}$

g. Sketch the electrostatic potential (V) inside the semiconductor as a function of x. (10 points)



h. Sketch the electric field (ε) inside the semiconductor as a function of x. (10 points)



i. Do equilibrium conditions prevail and why? (5 points)

Yes, E_F constant.