

EE 2800 Test 2 Solution

Q1. a. $\vec{E} \longrightarrow$

(3')

Left side has higher electrostatic potential (3')

b. Electron drift current $\longrightarrow$ Hole drift current $\longrightarrow$ (3' each)

(4' if wrong but consistent with answer in a,

but the answer should be correct for both electron & hole)

c. Since Fermi level is flat, left side should have more electrons and right side more holes.

Electron diffusion $\longrightarrow$ Hole diffusion $\longleftarrow$ (4' each)

Q2. a. A: neutral ; B: negative ; C: positive ; D: neutral

b. A: holes ; B: depleted ; C: depleted ; D: electrons

(2' each)

Q3. a. Net doping = $N_A - N_D = 8 \times 10^{15} \text{ cm}^{-3}$ (p-type)

$$P \approx 8 \times 10^{15} \text{ cm}^{-3}$$

>> n_i $\leftarrow$ (This is required to get p, otherwise full solution should be given. 3')

i. $E_F - E_i = \frac{kT}{q} \ln \frac{n_i}{P} = 0.026 \text{ eV} \ln \frac{1.5 \times 10^{10} \text{ cm}^{-3}}{8 \times 10^{15} \text{ cm}^{-3}} = -0.34 \text{ eV}$

(2')

(2')

(2')

(-1' if getting correct answer in Joules but fail to convert to eV)

$$\begin{aligned}
 \text{ii. } \bar{E}_F - E_c &= E_F - \bar{E}_i + \bar{E}_i - E_c \\
 &= E_F - E_i - \frac{1}{2} E_g \\
 &= -0.34 \text{ eV} - 0.56 \text{ eV} \\
 &= -0.9 \text{ eV}
 \end{aligned}$$

(4')

(3' if wrong but consistent with)

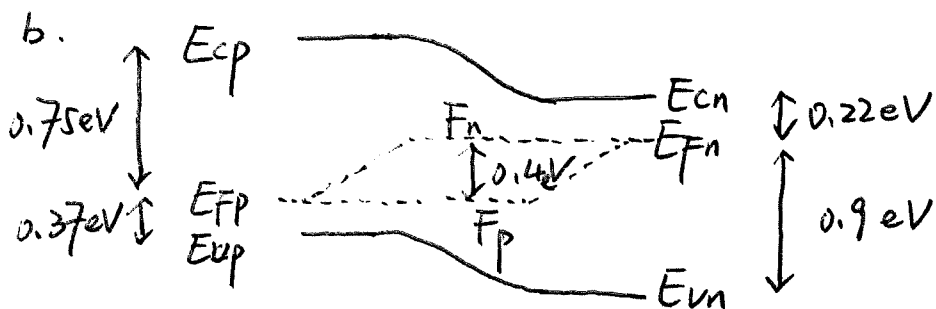
b.

$$\begin{aligned}
 \frac{N_A^-}{N_A} &= \frac{1}{1 + 4 \exp[(E_A - E_F)/kT]} = \frac{1}{1 + 4 \exp\left(\frac{0.044 - 0.22 \text{ eV}}{kT}\right)} \\
 &= 99\%
 \end{aligned}$$

(~~in each case~~, 3' for equation, 3' for correct use of impurity level numbers, 2' for solutions, ~~steps~~ full marks are only given with steps)

c. The net free carrier concentration will decrease (3')
 since the ionization ratio will drop ("freeze-out")
 ↓ ↓
 (either keyword gives 3')

Q4. a. $V_0 = 0.53 \text{ eV}$ (6')



(4' for overall trend of E_c & E_v ; 4' for trend of F_n/F_p .
 2' for label of F_n/F_p ; 2' for 0.4V between F_n/F_p ;
 3' for other labels of energy differences (at least 3)

c. diffusion (2')

$n \rightarrow p$ (2')

$p \rightarrow n$ (2')

minority (2')

$$d. \frac{p(x_{no})}{p_n} = \frac{p_n + \Delta p_n}{p_n} = e^{\frac{qV_f}{kT}} = e^{\frac{0.4\text{eV}}{0.026\text{eV}}} = 4.8 \times 10^6$$

(4') (2') (2')