ECE 340 # Homework Assignment #7 **Fall 2015**

DUE: FRIDAY, OCTOBER 23, 2015

Print your **name** and **NetID** legibly. Follow the guidelines and format given in the syllabus. Staple multiple pages. Show all units. Homework must be turned in at the **beginning** of class and any late homework assignments will not be accepted. Please contact the course director, Professor Dallesasse, should any issues with late homework arise.

1. AN N-P JUNCTION

An abrupt Si **n-p** (note the order!) junction has a circular cross section with a diameter of 50 μm and the following properties at room temperature (T = 300 K): $N_d = 3\times10^{17}$ cm^{-3} and $N_a = 4\times10^{16}$ cm^{-3}

(A). Calculate the Fermi level positions in the n and p regions then calculate the contact potential V_0, assuming the junction is in equilibrium.

(B). Draw the equilibrium band diagram of the n-p junction, labeling the conduction and valence bands, intrinsic energy level, Fermi level, and contact potential. Please make sure the band diagram in the depletion has the correct functional form.

(C). Calculate W, x_{n0}, x_{p0}, Q_-, and E_0 (maximum value of the electric field).

(D). Derive expressions for the charge density and electric field as a function of x in the depletions region. Similar to Figure 5-12 in the book, separately plot the charge density and electric field (label the appropriate quantities which you calculated in part(c)). Please use MATLAB or another program to actually generate a plot, do not simply draw them.

(E). Derive an expression for the electrostatic potential V(x) in the depletion region. Assume V(0) = 0. Plot the electrostatic potential in the depletion region, labeling the appropriate quantities. Please use MATLAB or another program to actually generate a plot, do not simply draw them.

2. A Biased n-p Junction

For this problem, use the same doping values as the abrupt Si **n-p** (note the order!) in the previous problem, along with the same circular cross section diameter. Assuming room temperature (T = 300 K), also use the following table to calculate the properties when the junction is biased.

	n-side	**p-side**
Minority Carrier Lifetime	$\tau_p = 8.5\ \mu s$	$\tau_n = 0.3\ \mu s$
Majority Carrier Mobility	$\mu_n = 800\ cm^2/V\text{-}s$	$\mu_p = 400\ cm^2/V\text{-}s$
Minority Carrier Mobility	$\mu_p = 250\ cm^2/V\text{-}s$	$\mu_n = 1100\ cm^2/V\text{-}s$

Figure 2.1: Table of values to use for the abrupt Si **n-p** junction.

(A). How should the quantities calculated in part (c) of Problem 1 change assuming the Si **n-p** junction is forward biased (indicate if they increase, decrease, or remain the same)? Recalculate the quantities in part (c) of Problem 1 assuming a forward bias of $V_f = V_0/2$.

(B). Draw the qualitative band diagram for this forward biased diode, labeling the quasi-Fermi levels (your figure should be labeled as in Figure 5-15(b) in the book).

(C). Assuming the same $V_f = V_0/2$ forward bias, calculate the excess hole concentration on the edge of the **n-**side of the depletion region and the excess electron concentration on the edge of the **p-**side of the depletion region.

(D). Calculate the reverse saturation current due to holes and due to electrons (individually), then determine the total reverse saturation current. Calculate the total current with the same $V_f = V_0/2$ forward bias.

(E). Qualitatively plot I_p and I_n versus position for the $V_f = V_0/2$ forward bias. Be sure to label relevant values such as the depletion width and total current. Your plot does not need to be to scale.

(F). How should the quantities calculated in part (c) of Problem 1 change assuming the Si **n-p** junction is reverse biased (indicate if they increase, decrease, or remain the same)? Recalculate the quantities in part (c) of Problem 1 assuming a reverse bias of $V_f = -V_0$.

(G). Draw the qualitative band diagram for this reverse biased diode, labeling the quasi-Fermi levels (your figure should be labeled as in Figure 5-18(b) in the book).

3. Carrier Concentrations in a p-n Junction

The figure below is a dimensioned plot of the steady state carrier concentration inside a **n-p** step junction diode at room temperature (T = 300 K).

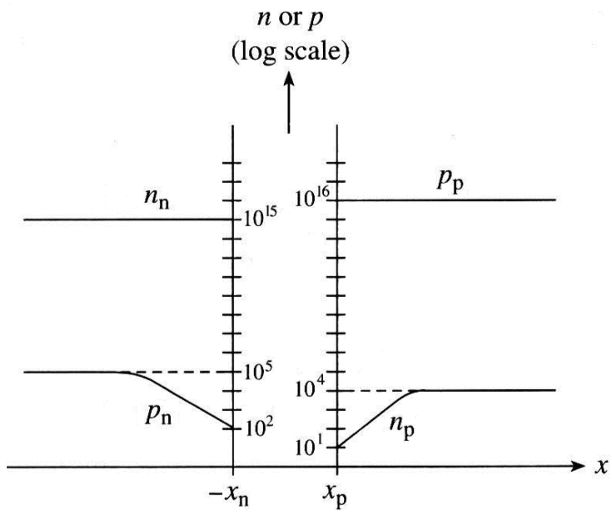

Figure 3.1: Minority carrier concentrations in an abrupt **n-p** junction

(A). Is the diode forward or reverse biased? Explain how you arrived at your answer.

(B). Do low-level injection conditions prevail in the quasi neutral regions of the diode? How do you know?

(C). What are the **p** and **n** side doping concentrations?

(D). Determine the applied voltage V_A.

(E). Assume the sample is now biased opposite from part (a). Is the diode forward or reverse biased? Generate a new qualitative plot (of the same form as the one given at the beginning of this problem) for the majority and minority carriers in each region assuming this new bias condition.

4. A p$^+$-n Junction

An abrupt Si **p$^+$-n** junction has the following properties at room temperature (T = 300 K): $N_a = 1\times10^{19}$ cm^{-3} and $N_d = 1\times10^{14}$ cm^{-3}

(A). Calculate the Fermi level positions in the n and p regions then calculate the contact potential V_0, assuming the junction is in equilibrium.

(B). Calculate W, x_{n0} and x_{p0}. Given your values, what is an appropriate approximation you could make for the width of the depletion region?

(C). The junction is now biased with a forward bias of $V_f = V_0/2$. Calculate the excess hole concentration on the edge of the **n-**side of the depletion region and the excess electron concentration on the edge of the **p**$^+$**-**side of the depletion region. What can you say about the current through this diode? In a few sentences, explain the usefulness of a heavily doped asymmetric junction such as this.