TUTORIAL 3

1. (a) Explain briefly the charge condition for N and P materials at room temperature.
   (b) Why is there a majority carrier flow when the N and P materials are adjacent to each other?
   (c) Why is the flow of the majority carriers not continuous until all of the carriers are recombined?

   Draw suitable diagrams to assist you in providing the explanation.

2. (a) Calculate the ratio of the current flowing through a p-n junction when the junction is forward biased by a 0.05 V, to the current flowing through the same junction when it is reverse biased by a voltage of the same magnitude at 300°K.

   (b) Calculate the voltage that will generate a reverse current equivalent to 90% of its saturated value at 300°K in a Germanium diode p-n junction.

3. Draw and describe briefly on the energy band structure of an open circuit p-n junction.

4. A 1 mA forward current was generated at 300°K when a voltage V_I was supplied across a Silicon p-n junction diode having the following parameters:

   Donor density, $N_D = 10^{16} cm^{-3}$

   Acceptor density, $N_A = 5x10^{18} cm^{-3}$

   Average lifetime, $\tau_n = \tau_p = 1\ \mu s$

   Cross-section area, $A = 0.01\ cm^2$

   Electron mobility in P material, $\mu_n = 120\ cm^2/Vs$

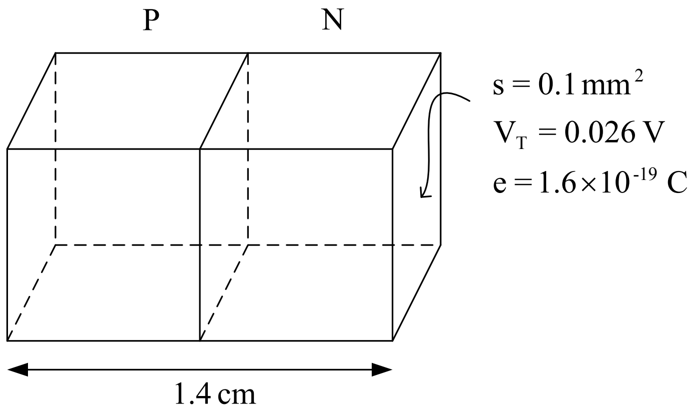
   Hole mobility in N material, $\mu_p = 1100\ cm^2/Vs$

   Calculate V_I when the length of the materials P and N are much larger than the minority carrier diffusion length. Given: $n_i = 1.5x10^{10} cm^{-3}$ and $V_T = 26$ mV at 300°K.

5. In a p-n material, conductivity of the P material is 1/Ωcm. The conductivity of the N material is 0.1/Ωcm. The acceptor impurity concentration in the P material is $5x10^{22}/cm^3$. Determine the reverse saturated current at 300°K if the material's cross-section area is 4 mm^2. Given $N_D = 1x10^{22}/cm^3$ and $n_i = 5x10^{16}/m^3$.

   Note: Mobility of electron, $\mu_n = e\tau_n/m$, and mobility of hole, $\mu_p = e\tau_p/m$, where τ_n and τ_p is the lifetime of the electron in the P material and hole in the N material, respectively. m is the electron mass.

6. A Silicon p-n diode is shown by the following diagram. The length of P is equivalent to the length of N. The diode has $N_A = N_D = 10^{22}$ atoms/m^3 and the majority carrier lifetime is 100 μs in each P and N. Resistivity in the P material is $1.3\text{x}10^{-3}$ Ωm and the resistivity in the N material is $4.6\text{x}10^{-3}$ Ωm at room temperature. Resistance of the intrinsic Silicon material is 5.5 MΩ. Electron mobility in N and hole mobility in P is 1/3 of the electron and hole mobility in the intrinsic material, respectively. Calculate the saturated current at room temperature.



7. A Si p-n junction is formed by a P material with $1.3\text{x}10^{-3}$ Ωm resistivity and an N material with $4.6\text{x}10^{-3}$ Ωm resistivity at room temperature (293°K). The lifetime for the minority carriers in P and N is 100 μs and 150 μs, respectively. The junction area is 1 mm^2. If $\mu_p = 4.8\text{x}10^{-2}$ m^2/Vs, $\mu_n = 0.135$ m^2/Vs and $n_i = 6.5\text{x}10^{16}/\text{m}^3$, calculate the reverse bias saturated current with the assumption that the P and N regions are much longer than the diffusion length.

Note: $p_n = n_i^2 / n_n$ and $n_p = n_i^2 / p_p$