EE 551 Linear Integrated Circuits
Homework 2

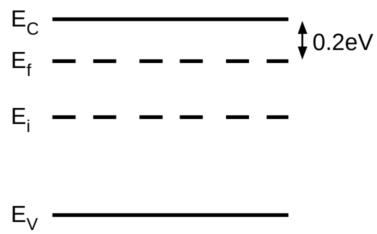
Silicon material parameters to be used in this homework set.

$$n_i=10^{10}cm^{-3},\ \mu_n=1360cm^2/Vs,\ \mu_p=460cm^2/Vs,\ \tau_n=\tau_p=100\mu s,\ E_g=1.12eV,$$
$$K_s=11.8,\ \varepsilon_0=8.854x10^{-12}F/m,\ T=300K,\ n=1$$

1. A piece of n-type silicon is doped with N_D = 2x10^{16}cm^{-3}.

    a. What is the probability of finding a hole in the valence band?
    b. What is the probability of finding an electron in the valence band?
    c. What is the probability of finding an electron 0.1meV above the conduction band?
    d. What is the probability of finding a hole in the conduction band?

2. Use the band diagram for silicon for the following parts of this problem.



    a. Is this n-type or p-type material? Why?
    b. What is the majority carrier and the majority carrier concentration?
    c. What is the minority carrier and the minority carrier concentration?
    d. What is the resistivity of this material?

3. A silicon cube (2mm on each side) has been doped with N_D = 1x10^{16}cm^{-3} and N_A = 5x10^{16}cm^{-3}.

    a. Is this n-type or p-type material? Why?
    b. What is the majority carrier and the majority carrier concentration?
    c. What is the minority carrier and the minority carrier concentration?
    d. Now, assume that a voltage of 5V is placed across two opposing sides if this material. What are the values of the hole current and the electron current?
    e. Instead of a voltage across this material, this silicon cube is exposed to light and undergoes photogeneration. Determine the diffusion length of the minority carrier in this material, assuming low-level injection.

4. A silicon p-n junction with a cross sectional area of 10^{-4}cm^2 has been doped on the p-type side with N_A = 10^{17}cm^{-3} and on the n-type side with N_D = 3x10^{17}cm^{-3}.

    a. Determine the built-in potential.
    b. Determine the equilibrium width of the depletion region.
    c. Determine the maximum electric field in the p-n junction in equilibrium.
    d. Determine the zero-bias junction capacitance.
    e. Determine the junction capacitance if the junction is reverse biased with 3V.

    For Parts f-h, a forward bias of 0.1V has been applied to the p-n junction diode.

    f. Determine the width of the depletion region under bias.
    g. Determine the maximum electric field under bias.
    h. Determine the total current that flows under bias.

5. A silicon p-n junction has been doped on the p-type side with $N_A = 10^{17}cm^{-3}$ and on the n-type side with $N_D = 10^{18}cm^{-3}$. Draw the following to scale. Be sure to label all important points and intercepts (exact values are not needed, but expressions are required).

   a. Band diagram in equilibrium.
   b. Charge density in equilibrium verses position along the p-n junction.
   c. Electric field in equilibrium verses position along the p-n junction.
   d. Repeat Parts a-c for a forward biased p-n junction. Emphasize the differences from the equilibrium conditions.
   e. Repeat Parts a-c for a reverse biased p-n junction. Emphasize the differences from the equilibrium conditions.