VE320 Homework Three

Due: 2021/6/7 23:59

1. (a) Consider silicon at $T = 300\ K$. Plot the thermal equilibrium electron concentration n_0 (on a log scale) over the energy range $0.2 \leq E_c - E_F \leq 0.4eV$.
   (b) Repeat part (a) for the hole concentration over the range $0.2 \leq E_F - E_V \leq 0.4eV$.

2. (a) The carrier effective masses in a semiconductor are $m_n^* = 1.21m_0$ and $m_p^* = 0.70m_0$. Determine the position of the intrinsic Fermi level with respect to the center of the bandgap at $T = 300\ K$.
   (b) Repeat part (a) if $m_n^* = 0.080m_0$ and $m_p^* = 0.75m_0$.

3. Silicon at $T = 300\ K$ is doped with boron atoms such that the concentration of holes is $p_0 = 5 \times 10^{15} cm^{-3}$.
   (a) Find $E_F - E_v$.
   (b) Determine $E_C - E_F$.
   (c) Determine n_0.
   (d) Which carrier is the majority carrier?
   (e) Determine $E_{Fi} - E_F$
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4. (a) Consider a germanium semiconductor at $T = 300\ K$. Calculate the thermal equilibrium electron and hole concentrations for (i) $N_d = 2 \times 10^{15} cm^{-3}$, $N_a = 0$, and (ii)$N_a = 10^{16} cm^{-3}$, $N_d = 7 \times 10^{15} cm^{-3}$.
   (b) Repeat part (a) for GaAs.
   (c) For the case of GaAs in part (b), the minority carrier concentrations are on the order of $10^{-3} cm^{-3}$. What does this result mean physically?

5. (a) Silicon at $T = 300\ K$ is uniformly doped with boron atoms to a concentration of $3 \times 10^{16} cm^{-3}$ and with arsenic atoms to a concentration of $1.5 \times 10^{16} cm^{-3}$. Is the material n type or p type? Calculate the thermal equilibrium concentrations of majority and minority carriers.
   (b) Additional impurity atoms are added such that holes are the majority carrier and the thermal equilibrium concentration is $p_0 = 5 \times 10^{16} cm^{-3}$. What type and concentration of impurity atoms must be added? What is the new value of n_0?

6. For a particular semiconductor, $E_g = 1.50eV$, $m_p^* = 10m_n^*$, $T = 300\ K$,and $n_i = 1 \times 10^5 cm^{-3}$.
   (a)Determine the position of the intrinsic Fermi energy level with respect to the center of the bandgap.
   (b) Impurity atoms are added so that the Fermi energy level is 0.45 eV below the center of the bandgap. (i) Are acceptor or donor atoms added? (ii) What is the concentration of impurity atoms added?

7. Silicon atoms, at a concentration of $7 \times 10^{15} cm^{-3}$, are added to gallium arsenide. Assume that the silicon atoms act as fully ionized dopant atoms and that 5 percent of the concentration added replace gallium atoms and 95 percent replace arsenic atoms. Let $T = 300\ K$.
   (a) Determine the donor and acceptor concentrations.
   (b) Is the material n type or p type?
   (c) Calculate the electron and hole concentrations.
   (d) Determine the position of the Fermi level with respect to E_{Fi}.