3.1 Calculate the intrinsic carrier concentration, $n_i$, at $T = 200$, 400, and 600 K for
(a) silicon, (b) germanium, and (c) gallium arsenide.

3.11 (a) The value of $n_0$ in silicon is $1.5 \times 10^{16}$ cm$^{-3}$. Determine $E_c - E_F$. (b) The
value of $p_0$ in silicon is $5 \times 10^{15}$ cm$^{-3}$. Determine $E_F - E_v$. (c) Repeat part (a) for
GaAs. (d) Repeat Part (b) for GaAs.

3.14 Calculate $E_{Fi}$ with respect to the center of the bandgap in silicon for $T = 200,
400$, and 600 K.

3.18 Calculate the ionization energy and radius of the donor electron in germanium
using the Bohr theory. (Use the density of states effective mass as a first
approximation.)

3.20 The electron concentration in silicon is $n_0 = 3 \times 10^4$ cm$^{-3}$. (a) Determine $p_0$. (b)
Is this material n or p type? (c) Determine $E_F - E_v$.

3.26 The value of $p_0$ in silicon at $T = 300$ K is $10^{15}$ cm$^{-3}$. Determine (a) $E_c - E_F$ and
(b) $n_0$.

3.27 (a) Consider silicon at $T = 300$ K. Determine $p_0$ if $E_{Fi} - E_F = 0.35$ eV. (b)
Assuming that $p_0$ from part (a) remains constant, determine the value of $E_{Fi} - E_F$
when $T = 400$ K. (c) Find the value of $n_0$ in both parts (a) and (b).

3.30 Consider silicon at $T = 300$ K, which has $n_0 = 5 \times 10^{19}$ cm$^{-3}$. Determine $E_c - E_F$.

3.34 Consider a germanium semiconductor at $T = 300$ K. Calculate the thermal
equilibrium concentrations of $n_0$ and $p_0$ for (a) $N_d = 10^{13}$ cm$^{-3}$, $N_a = 0$, and (b) $N_d$
$= 5 \times 10^{15}$ cm$^{-3}$, $N_a = 0$.

3.36 Determine the equilibrium electron and hole concentrations in silicon for the
following conditions :
(a) $T = 300$ K, $N_d = 2 \times 10^{15}$ cm$^{-3}$, $N_a = 0$
(b) $T = 300$ K, $N_d = 0$, $N_a = 10^{16}$ cm$^{-3}$
(c) $T = 300$ K, $N_d = N_a = 10^{15}$ cm$^{-3}$
(d) $T = 400$ K, $N_d = 0$, $N_a = 10^{14}$ cm$^{-3}$
(e) $T = 500$ K, $N_d = 10^{14}$ cm$^{-3}$, $N_a = 0$
3.43 Consider a sample of silicon doped at \( N_d = 0 \) and \( N_a = 10^{14} \) cm\(^{-3}\). Plot the majority-carrier concentration versus temperature over the range \( 200 \leq T \leq 500 \) K.

3.48 In silicon at \( T = 300 \) K, we have experimentally found that \( n_0 = 4.5 \times 10^4 \) cm\(^{-3}\) and \( N_d = 5 \times 10^{15} \) cm\(^{-3}\). (a) Is the material n type or p type? (b) Determine the majority-and minority-carrier concentrations. (c) What types and concentrations of impurity atoms exist in the material?

3.50 Consider germanium at \( T = 300 \) K with donor concentrations of \( N_d = 10^{14}, 10^{16}, \) and \( 10^{18} \) cm\(^{-3}\). Let \( N_a = 0 \). Calculate the position of the Fermi energy level with respect to the intrinsic Fermi level for these doping concentrations.

3.53 Consider silicon at \( T = 300\)K with \( N_a = 0 \). Plot the position of the Fermi energy level with respect to the intrinsic Fermi level as a function of the donor doping concentration over the range \( 10^{14} \leq N_d \leq 10^{18} \) cm\(^{-3}\).

3.55 Silicon at \( T = 300 \) K contains acceptor atoms at a concentration of \( N_a = 5 \times 10^{15} \) cm\(^{-3}\). Donor atoms are added forming an n-type compensated semiconductor such that the Fermi level is 0.215 eV below the conduction band edge. What concentration of donor atoms are added?

3.59 Determine the Fermi energy level with respect to the intrinsic Fermi level for each condition given in Problem 3.36.

Please submit your homework to R514, EE-II