Problem 1:
Calculate the intrinsic carrier concentration, at T=200, 400, and 600 K for (a) silicon, (b) germanium.
Assume the following values of the effective densities of states at 300 K:
Silicon: \( N_C = 2.8 \times 10^{19} \text{cm}^{-3}, N_V = 1.04 \times 10^{19} \text{cm}^{-3} \).
Germanium: \( N_C = 1.04 \times 10^{19} \text{cm}^{-3}, N_V = 6.0 \times 10^{18} \text{cm}^{-3} \).
Remember that the effective density of state changes with temperature as \( T^{3/2} \).

Problem 2:
Two semiconductor materials have exactly the same properties except that material A has a bandgap energy of 1 eV and material B has a bandgap energy of 1.2 eV.
Determine the ratio of \( n \) of material A to that of material B for T=300 K.

Problem 3:
Consider a homogeneous gallium arsenide semiconductor at T=300 K with \( N_D=10^{16} \text{ cm}^{-3} \) and \( N_A=0 \).
(a) Calculate the thermal-equilibrium values of electron and hole concentrations. Is it n-type or p-type?
(b) Repeat part (a) if \( N_A=10^{16} \text{ cm}^{-3} \) and \( N_D=0 \). Is it n-type or p-type?

Problem 4:
Determine the values of the equilibrium electron and hole concentration for silicon at T=300 K if the Fermi energy is 0.22 eV above the valence band energy:
(a) Use the formula utilizing \( N_C \) and \( N_V \). Do not use \( n_i \) (Google the value \( N_C \) and \( N_V \) for Si at room T)
(b) \(!!!!\) Repeat calculations using the formula with \( n_i \). Google the value of \( n_i \) in Si at room T.
(c) \(!!!!\) “Repeat” (a) and (b) if Fermi energy is 0.88 eV below the conduction band energy (Band Gap = 1.1eV).

Problem 5:
Assume that silicon and germanium each have dopant concentrations of \( N_D=10^{13} \text{ cm}^{-3} \) and \( N_A=2.5 \times 10^{13} \text{ cm}^{-3} \) at T=300 K. For each of the two materials:
(a) Is this material n type or p type?
(b) Calculate equilibrium concentrations of electrons and holes
(Hint: be sure to look up and use the values of \( n_i \) for both materials at 300K).
(c) For each of the two materials, calculate the distance between the Fermi level and the valence band \( E_V \) (you may need to look up the values of the bandgap, in addition to \( n_i \). In this exercise use \( n_i \), do not use the effective densities of states \( N_C, N_V \)).

Problem 6:
Use MS Excel or similar to plot \( f(E) \); do analysis as asked in the problem description.
Calculate values of the Fermi function \( f(E) \) at 300K and plot vs energy in eV as in Fig.3-14. Choose \( E_F=1\text{eV} \) and make the calculated points closer together near the Fermi level to obtain a smoother curve.
Notice that \( f(E) \) varies rapidly within a few KT of \( E_F \).
Show that the probability that a state \( \Delta E \) above \( E_F \) is occupied is the same as the probability that the state \( \Delta E \) below \( E_F \) is empty.

Problem 7:
An Unknown semiconductor, \( E_g=1.1\text{eV} \), \( N_C=N_V \), \( N_D=10^{15}\text{cm}^{-3} \).
\( E_D \) is 0.2eV below \( E_C \), \( E_V \) is 0.25eV below \( E_C \). Calculate \( n_0 \) and \( p_0 \) at 300K.
Hint: Use the fact that \( E_C-E_D=0.2\text{eV} \), which means that the donors are shallow \( => \) all are ionized \( => n=……\). Then use \( n \) to calculate \( N_C \). Use \( N_C \) and \( N_V \) to calculate \( p \) and \( n_i \) using formulas (3-19) and (3-23).

Problem 8:
(a) Si, \( N_{[B]}=10^{16}\text{cm}^{-3} \), \( N_D=? \), \( E_F \) is 0.36eV above \( E_i \). Find \( N_D =? \)
(Hint: Use (3-25) to find \( n_0 \). Use \( n_0 \), \( N_A \), and the compensation principle to find \( N_D \).
(b) Si, \( N_{[In]}=10^{16}\text{cm}^{-3} \), \( N_D=2\). \( E_{[In]} \) is 0.16eV above \( E_V \), \( E_F \) is 0.26eV above \( E_V \). Find how many (cm\(^\text{3}\)) [In] atoms are NOT ionized (neutral).
Hint: Un-ionized (neutral) acceptors means that the particular energy level is NOT occupied with electrons. This is determined by \( f(E) \).