4.49 Consider silicon at $T = 300$ K with donor concentrations of $N_d = 10^{14}$, 10^{15}, 10^{16}, and 10^{17}, cm^{-3}. Assume $N_a = 0$. (*a*) Calculate the position of the Fermi energy level with respect to the conduction band for these donor concentrations. (*b*) Determine the position of the Fermi energy level with respect to the intrinsic Fermi energy level for the donor concentrations given in part (*a*).

For repetitive calculations, use MathCAD

Define some constants

$kB := 1.380649 \cdot 10^{-23}$ J/K $kB\_eV := 8.617333 \cdot 10^{-5}$ eV/K

$h := 6.62607015 \cdot 10^{-34}$ J-s $m0 := 9.1093837015 \cdot 10^{-31}$ kg

Table B.4, silicon values @ 300 K: $T := 300$ K $mne := 1.08 \cdot m0$

$Eg := 1.12$ eV $ni := 1.5 \cdot 10^{16}$ m^{-3}

(4.10) $Nc := 2 \cdot \left(\frac{2 \cdot \pi \cdot mne \cdot kB \cdot T}{h^2} \right)^{\frac{3}{2}}$ $Nc = 2.81649 \times 10^{25}$ m^{-3}

a) Per (4.63), $E_c - E_F$ is given by: $Ec\_EF(n0) := kB\_eV \cdot T \cdot \ln\left(\frac{Nc}{n0} \right)$

Since $N_d >> n_i$, we can say $n_0 \sim N_d$.

For $N_d = 10^{14}$ cm^{-3} = 10^{20} m^{-3}, $Ec\_EF(10^{20}) = 0.3244$ eV

For $N_d = 10^{15}$ cm^{-3} = 10^{21} m^{-3}, $Ec\_EF(10^{21}) = 0.26488$ eV

For $N_d = 10^{16}$ cm^{-3} = 10^{22} m^{-3}, $Ec\_EF(10^{22}) = 0.20535$ eV

For $N_d = 10^{17}$ cm^{-3} = 10^{23} m^{-3}, $Ec\_EF(10^{23}) = 0.14582$ eV

b) Per (4.65), $E_F - E_{Fi}$ is given by: $EF\_EFi(n0) := kB\_eV \cdot T \cdot \ln\left(\frac{n0}{ni} \right)$

Since $N_d >> n_i$, we can say $n_0 \sim N_d$.

For $N_d = 10^{14}$ cm^{-3} = 10^{20} m^{-3}, $EF\_EFi(10^{20}) = 0.22762$ eV

For $N_d = 10^{15}$ cm^{-3} = 10^{21} m^{-3}, $EF\_EFi(10^{21}) = 0.28715$ eV

For $N_d = 10^{16}$ cm^{-3} = 10^{22} m^{-3}, $EF\_EFi(10^{22}) = 0.34668$ eV

For $N_d = 10^{17}$ cm^{-3} = 10^{23} m^{-3}, $EF\_EFi(10^{23}) = 0.4062$ eV