4.56 (*a*) Determine the position of the Fermi energy level with respect to the intrinsic Fermi level in silicon at $T = 300$ K that is doped with boron atoms at a concentration of $N_a = 2 \times 10^{16}$ cm^{-3}. (*b*) Repeat part (*a*) if the silicon is doped with phosphorus atoms at a concentration of $N_d = 2 \times 10^{16}$ cm^{-3}. (*c*) Calculate n_0 and p_0 in parts (*a*) and (*b*).

From Table B.4, $E_g = 1.12\,eV$ & $n_i = 1.5 \times 10^{10}\ \#/cm^3$

a) Per (4.68), $E_{Fi} - E_F = k_B T \ln(p_o/n_i)$

Per (4.62), $p_o = \frac{N_a - N_d}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2}$

Since $N_d = 0$ & $N_a >> n_i$, $p_o = N_a = 2\times 10^{16}\ cm^{-3}$.

$E_{Fi} - E_F = 8.617333\times 10^{-5}(300)\ln\left(\frac{2\times 10^{16}}{1.5\times 10^{10}}\right)$

$E_{Fi} - E_F = 0.3646\ eV$

b) Per (4.65), $E_F - E_{Fi} = k_B T \ln\left(\frac{n_o}{n_i}\right)$

Per (4.60), $n_o = \frac{N_d - N_a}{2} + \sqrt{\left(\frac{N_d - N_a}{2}\right)^2 + n_i^2}$

Since $N_a = 0$ & $N_d >> n_i$, $n_o = N_d = 2\times 10^{16}\ \#/cm^3$

$E_F - E_{Fi} = 8.617333\times 10^{-5}(300)\ln\left(\frac{2\times 10^{16}}{1.5\times 10^{10}}\right)$

$E_F - E_{Fi} = 0.3646\ eV$

c) use (4.43) $n_o p_o = n_i^2$

part a) $p_o = 2\times 10^{16}\ \#/cm^3$ & $n_o = \frac{(1.5\times 10^{10})^2}{2\times 10^{16}} = 1.125\times 10^4\ \frac{\#}{cm^3}$

part b) $n_o = 2\times 10^{16}\ \#/cm^3$ & $p_o = \frac{(1.5\times 10^{10})^2}{2\times 10^{16}} = 1.125\times 10^4\ \frac{\#}{cm^3}$