6.32 Consider n-type silicon doped at $N_d = 5 \times 10^{15}$ cm^{-3}. It is found that $E_{Fn} - E_F = 1.02 \times 10^{-3}$ eV. (*a*) What is the excess carrier concentration? (*b*) Determine $E_{Fn} - E_{Fi}$. (*c*) Calculate $E_{Fi} - E_{Fp}$.

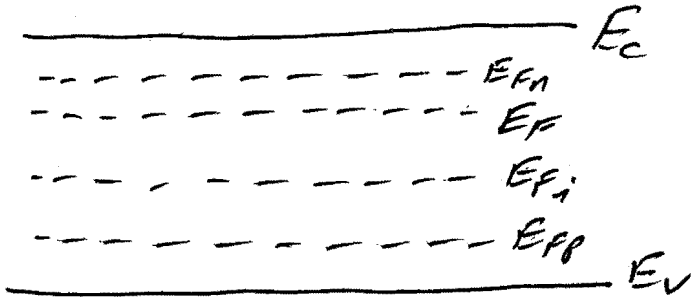
➢ First, find the electron and hole concentrations at thermal equilibrium.

From Table B.4, $n_i = 1.5 \times 10^{10}$ #/cm^3 for Si @ 300 K.

Since $N_d >> n_i$, $\underline{n_0 \simeq N_d = 5 \times 10^{15} \text{ cm}^{-3}}$

Per (4.43), $p_0 = \frac{n_i^2}{n_0} = \frac{(1.5 \times 10^{10})^2}{5 \times 10^{15}} \Rightarrow \underline{p_0 = 45{,}000 \text{ cm}^{-3}}$

a) From Fig 6.15



So, $E_{Fn} - E_F = (E_{Fn} - E_{Fi}) - (E_F - E_{Fi})$

Per (6.84a), $n_0 = n_i e^{(E_F - E_{Fi})/k_B T} \Rightarrow E_F - E_{Fi} = k_B T \ln\left(\frac{n_0}{n_i}\right)$

Per (6.85a), $n_0 + \delta n = n_i e^{(E_{Fn} - E_{Fi})/k_B T} \Rightarrow E_{Fn} - E_{Fi} = k_B T \ln\left(\frac{n_0 + \delta n}{n_i}\right)$

$$E_{Fn} - E_F = 0.00102 = 8.617333 \times 10^{-5}(300)\left[\ln\left(\frac{n_0 + \delta n}{n_i}\right) - \ln\left(\frac{5 \times 10^{15}}{1.5 \times 10^{10}}\right)\right]$$

$$\ln\left(\frac{5 \times 10^{15} + \delta n}{1.5 \times 10^{10}}\right) = \frac{0.00102}{0.025852} + \ln\left(\frac{5 \times 10^{15}}{1.5 \times 10^{10}}\right) = 12.756353$$

$$\hookrightarrow \frac{5 \times 10^{15} + \delta n}{1.5 \times 10^{10}} = e^{12.756353} \Rightarrow \delta n = 1.5 \times 10^{10} e^{12.756353} - 5 \times 10^{15}$$

$$\underline{\delta n = 2.0122 \times 10^{14} \text{ cm}^{-3}}$$

b) Per (6.85a), $n_0 + \delta n = n_i e^{(E_{Fn} - E_{Fi})/k_B T}$

$\hookrightarrow E_{Fn} - E_{Fi} = k_B T \ln\left(\frac{n_0 + \delta n}{n_i}\right)$

$= 8.617333 \times 10^{-5} (300) \ln\left(\frac{5 \times 10^{15} + 2.0122 \times 10^{14}}{1.5 \times 10^{10}}\right)$

$\underline{\underline{E_{Fn} - E_{Fi} = 0.32978 \text{ eV}}}$

c) Per (6.85b), $p_0 + \delta p = n_i e^{(E_{Fi} - E_{Fp})/k_B T}$

$\hookrightarrow E_{Fi} - E_{Fp} = k_B T \ln\left(\frac{p_0 + \delta p}{n_i}\right)$ (Note: $\delta n = \delta p$)

$= 8.617333 \times 10^{-5} (300) \ln\left(\frac{45000 + 2.0122 \times 10^{14}}{1.5 \times 10^{10}}\right)$

$\underline{\underline{E_{Fi} - E_{Fp} = 0.24570 \text{ eV}}}$