4.34 Determine the equilibrium electron and hole concentrations in silicon for the following conditions:

(*c*) $T = 300$ K, $N_d = N_a = 2 \times 10^{15}$ cm^{-3}

- Assume E_g, m_n^*, & m_p^* are temperature independent.

c) From Table B.4, we get $n_i = 1.5 \times 10^{10}$ #/cm^3 at 300K for silicon.

Per (4.60),

$$n_0 = \frac{(N_d - N_a)}{2} + \sqrt{\left(\frac{N_d - N_a}{2}\right)^2 + n_i^2}$$

$$= \frac{(2\times10^{15} - 2\times10^{15})}{2} + \sqrt{\left(\frac{2\times10^{15} - 2\times10^{15}}{2}\right)^2 + (1.5\times10^{10})^2}$$

$$= 0 + \sqrt{0 + (1.5\times10^{10})^2}$$

$\Rightarrow$ <u>$\boldsymbol{n_0 = n_i = 1.5 \times 10^{10}}$ **#/cm^3**</u>.

Per (4.62),

$$p_0 = \frac{(Na - N_d)}{2} + \sqrt{\left(\frac{N_a - N_d}{2}\right)^2 + n_i^2}$$

$$= \frac{(2\times10^{15} - 2\times10^{15})}{2} + \sqrt{\left(\frac{2\times10^{15} - 2\times10^{15}}{2}\right)^2 + (1.5\times10^{10})^2}$$

$$= 0 + \sqrt{0 + (1.5\times10^{10})^2}$$

$\Rightarrow$ <u>$\boldsymbol{p_0 = n_i = 1.5 \times 10^{10}}$ **#/cm^3**</u>.

4.34 Determine the equilibrium electron and hole concentrations in silicon for the following conditions:

(*e*) $T = 450$ K, $N_d = 10^{14}$ cm^{-3}, $N_a = 0$

- Assume E_g, m_n*, & m_p* are temperature independent.

e) From Table B.4, $E_g = 1.12$ eV, $n_i = 1.5 \times 10^{10}$ #/cm^3, $N_c = 2.8 \times 10^{19}$ #/cm^3, and $N_v = 1.04 \times 10^{19}$ #/cm^3 at 300K for silicon.

Per (4.10) $N_c = 2\left(\frac{2\pi m_n^* k_B T}{h^2}\right)^{3/2}$, we can scale N_c to 450 K as

$$N_c = 2.8\times10^{19}\left(\frac{450}{300}\right)^{3/2} = 5.14393\times10^{19} \text{ #/cm}^3.$$

Per (4.18) $N_v = 2\left(\frac{2\pi m_p^* k_B T}{h^2}\right)^{3/2}$, we can scale N_v to 450 K as

$$N_v = 1.04\times10^{19}\left(\frac{450}{300}\right)^{3/2} = 1.910602\times10^{19} \text{ #/cm}^3.$$

Per (4.23), $$\begin{aligned} n_i^2 &= N_c N_v e^{-E_g/k_BT} = 5.14393\times10^{19}(1.910602\times10^{19})e^{-1.12/[8.617333\times10^{-5}(450)]} \\ &= 2.81201\times10^{26} \text{ #cm}^3 \end{aligned}.$$

Per (4.60),

$$n_0 = \frac{(N_d - N_a)}{2} + \sqrt{\left(\frac{N_d - N_a}{2}\right)^2 + n_i^2}$$

$$= \frac{(10^{14} - 0)}{2} + \sqrt{\left(\frac{10^{14} - 0}{2}\right)^2 + 2.81201\times10^{26}}$$

$\Rightarrow$ <u>**$n_0 = 1.02737 \times 10^{14}$ #/cm^3 $\approx N_d$**</u>.

Per (4.43), $n_0 p_0 = n_i^2 \Rightarrow p_0 = n_i^2 / n_0 = 2.81201\times10^{26} / 1.02737\times10^{14}$

$\Rightarrow$ <u>**$p_0 = 2.73709 \times 10^{12}$ #/cm^3**</u>