**4.45** A particular semiconductor material is doped at $N_d = 2 \times 10^{14}$ cm$^{-3}$ and $N_a = 1.2 \times 10^{14}$ cm$^{-3}$. The thermal equilibrium electron concentration is found to be $n_0 = 1.1 \times 10^{14}$ cm$^{-3}$. Assuming complete ionization, determine the intrinsic carrier concentration and the thermal equilibrium hole concentration.

Since $N_d > N_a$, use (4.60)

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

$$1.1\times10^{14} = \frac{(2\times10^{14} - 1.2\times10^{14})}{2} + \sqrt{\left(\frac{2\times10^{14} - 1.2\times10^{14}}{2}\right)^2 + n_i^2}$$

$$1.1\times10^{14} = 4\times10^{13} + \sqrt{(4\times10^{13})^2 + n_i^2}$$

$$7\times10^{13} = \sqrt{(4\times10^{13})^2 + n_i^2}$$

$n_i^2 = (7 \times 10^{13})^2 - (4 \times 10^{13})^2 = 3.3\times10^{27} \Rightarrow$ **$n_i = 5.74456 \times 10^{13}$ #/cm$^3$**.

Per (4.43), $n_0 p_0 = n_i^2 \Rightarrow p_0 = n_i^2 / n_0 = 3.3\times10^{27} / 1.1\times10^{14}$

$\Rightarrow$ **$p_0 = 3 \times 10^{13}$ #/cm$^3$**.