Example 2.11 Calculate the electron and hole densities in an n-type silicon wafer ($N_d = 10^{17}$ cm$^{-3}$) illuminated uniformly with 10 mW/cm$^2$ of red light ($E_{ph} = 1.8$ eV). The absorption coefficient of red light in silicon is $10^3$ cm$^{-1}$. The minority carrier lifetime is 10 µs.

Solution

The generation rate of electrons and holes equals:

$$G_n = G_p = \alpha \frac{P_{opt}}{E_{ph}A} = 10^{-3} \frac{10^{-2}}{1.8 \times 1.6 \times 10^{-19}} = 3.5 \times 10^{13} \text{ cm}^{-3} \text{s}^{-1}$$

where the photon energy was converted into Joules. The excess carrier densities are then obtained from:

$$\delta n = \delta p = \tau_p G_p = 10 \times 10^{-6} \times 3.5 \times 10^{13} = 3.5 \times 10^8 \text{ cm}^{-3}$$

So that the electron and hole densities equal:

$$n = n_o + \delta n = 10^{17} + 3.5 \times 10^8 = 10^{17} \text{ cm}^{-3}$$

$$p = \frac{n^2}{n_o} + \delta p = \frac{(10^{10})^2}{10^{17}} + 3.5 \times 10^8 = 3.5 \times 10^8 \text{ cm}^{-3}$$