Example 4.1 An abrupt silicon p-n junction consists of a p-type region containing 2 x 10^{16} cm^{-3} acceptors and an n-type region containing also 10^{16} cm^{-3} acceptors in addition to 10^{17} cm^{-3} donors.

a. Calculate the thermal equilibrium density of electrons and holes in the p-type region as well as both densities in the n-type region.
b. Calculate the built-in potential of the p-n junction.
c. Calculate the built-in potential of the p-n junction at 400 K.

Solution

a. The thermal equilibrium densities are:

In the p-type region:

$p = N_a = 2 \times 10^{16}$ cm^{-3}

$n = n_i^2/p = 10^{20}/2 \times 10^{16} = 5 \times 10^3$ cm^{-3}

In the n-type region

$n = N_d - N_a = 9 \times 10^{16}$ cm^{-3}

$p = n_i^2/n = 10^{20}/1 \times 10^{16} = 1.11 \times 10^3$ cm^{-3}

b. The built-in potential is obtained from

$$f_i = V_t \ln \frac{p_p n_n}{n_i^2} = 0.0259 \ln \frac{2\times10^{16} \times 9\times10^{16}}{10^{20}} = 0.79 \text{ V}$$

c. Similarly, the built-in potential at 400 K equals

$$f_i = V_t \ln \frac{p_p n_n}{n_i^2} = 0.0345 \ln \frac{2\times10^{16} \times 9\times10^{16}}{(4.52\times10^{12})^2} = 0.63 \text{ V}$$

where the intrinsic carrier density at 400 K was obtained from Example 2.4 b.