Practice Problem 1

$$n_p(-x_p) = n_{po} \exp\left(\frac{eV_a}{kT}\right) \qquad \text{and} \qquad p_n(x_n) = p_{no} \exp\left(\frac{eV_a}{kT}\right)$$

The thermal-equilibrium minority carrier concentrations are

$$n_{po} = \frac{n_i^2}{N_a} = \frac{(1.5 \times 10^{10})^2}{6 \times 10^{15}} = 3.75 \times 10^4 \text{ cm}^{-3}$$

and

$$p_{no} = \frac{n_i^2}{N_d} = \frac{(1.5 \times 10^{10})^2}{10^{16}} = 2.25 \times 10^4 \text{ cm}^{-3}$$

We then have

$$n_p(-x_p) = 3.75 \times 10^4 \exp\left(\frac{0.60}{0.0259}\right) = 4.31 \times 10^{14} \text{ cm}^{-3}$$

and

$$p_n(x_n) = 2.25 \times 10^4 \exp\left(\frac{0.60}{0.0259}\right) = 2.59 \times 10^{14} \text{ cm}^{-3}$$

Practice Problem 2

The ideal reverse-saturation current density is given by

$$J_s = \frac{eD_n n_{p0}}{L_n} + \frac{eD_p p_{n0}}{L_p}$$

which may be rewritten as

$$J_s = en_i^2 \left(\frac{1}{N_a}\sqrt{\frac{D_n}{\tau_{n0}}} + \frac{1}{N_d}\sqrt{\frac{D_p}{\tau_{p0}}}\right)$$

Then

$$J_s = (1.6 \times 10^{-19})(1.5 \times 10^{10})^2 \left(\frac{1}{10^{16}}\sqrt{\frac{25}{5 \times 10^{-7}}} + \frac{1}{10^{16}}\sqrt{\frac{10}{5 \times 10^{-7}}}\right)$$

or $\qquad J_s = 4.16 \times 10^{-11} \text{ A/cm}^2$

Practice Problem 3

$$J_n = \frac{eD_n n_{p0}}{L_n}\left[\exp\left(\frac{eV_a}{kT}\right) - 1\right] = e\sqrt{\frac{D_n}{\tau_{n0}}} \cdot \frac{n_i^2}{N_a}\left[\exp\left(\frac{eV_a}{kT}\right) - 1\right]$$

Substituting the numbers, we have

$$20 = (1.6 \times 10^{-19})\sqrt{\frac{25}{5 \times 10^{-7}}} \cdot \frac{(1.5 \times 10^{10})^2}{N_a}\left[\exp\left(\frac{0.65}{0.0259}\right) - 1\right]$$

which yields

$$N_a = 1.01 \times 10^{15}\ \text{cm}^{-3}$$

$$J_p = \frac{eD_p p_{n0}}{L_p}\left[\exp\left(\frac{eV_a}{kT}\right) - 1\right] = e\sqrt{\frac{D_p}{\tau_{p0}}} \cdot \frac{n_i^2}{N_d}\left[\exp\left(\frac{eV_a}{kT}\right) - 1\right]$$

Substituting the numbers, we have

$$5 = (1.6 \times 10^{-19})\sqrt{\frac{10}{5 \times 10^{-7}}} \cdot \frac{(1.5 \times 10^{10})^2}{N_d}\left[\exp\left(\frac{0.65}{0.0259}\right) - 1\right]$$

which yields

$$N_d = 2.55 \times 10^{15}\ \text{cm}^{-3}$$

Practice Problem 4

The total forward-bias current density is given by

$$J = J_s\left[\exp\left(\frac{eV}{kT}\right) - 1\right]$$

$$J = (4.155 \times 10^{-11})\left[\exp\left(\frac{0.65}{0.0259}\right) - 1\right] = 3.295\ \text{A/cm}^2$$

The total current far from the junction in the n region will be majority carrier electron drift current, so we can write

$$J = J_n \approx e\mu_n N_d \mathrm{E}$$

The doping concentration is $N_d = 10^{16}$ cm^{-3}, and, if we assume $\mu_n = 1350$ cm^2/V-s, then the electric field must be

$$\mathrm{E} = \frac{J_n}{e\mu_n N_d} = \frac{3.295}{(1.6 \times 10^{-19})(1350)(10^{16})} = 1.525\ \text{V/cm}$$