**Example 4.4** An abrupt silicon p-n junction ($N_a = 10^{16}$ cm$^{-3}$ and $N_d = 4 \times 10^{16}$ cm$^{-3}$) is biased at $V_a$ = 0.6 V. Calculate the ideal diode current assuming that the *n*-type region is much smaller than the diffusion length with $w_n' = 1$ µm and assuming a "long" *p*-type region. Use $\mu_n$ = 1000 cm$^2$/V-s and $\mu_p$ = 300 cm$^2$/V-s. The minority carrier lifetime is 10 µs and the diode area is 100 µm by 100 µm.

Solution The current is calculated from:

$$I = qA[\frac{D_n n_{p0}}{L_n} + \frac{D_p p_{n0}}{w_n'}](e^{V_a/V_t} - 1)$$

with

$$D_n = \mu_n V_t = 1000 \text{ x } 0.0258 = 25.8 \text{ cm}^2/\text{s}$$
$$D_P = \mu_P V_t = 300 \text{ x } 0.0258 = 7.75 \text{ cm}^2/\text{s}$$
$$n_{p0} = n_i^2/N_a = 10^{20}/10^{16} = 10^4 \text{ cm}^{-3}$$
$$p_{n0} = n_i^2/N_d = 10^{20}/4 \text{ x } 10^{16} = 2.5 \text{ x } 10^3 \text{ cm}^{-3}$$
$$L_n = \sqrt{D_n \tau_n} = \sqrt{25.8 \times 10^{-5}} = 161\, \mu\text{m}$$

yielding $I$ = 40.7 µA

Note that the hole diffusion current occurs in the "short" *n*-type region and therefore depends on the quasi-neutral width in that region. The electron diffusion current occurs in the "long" *p*-type region and therefore depends on the electron diffusion length in that region.