8.5 Consider a GaAs pn junction with doping concentrations $N_a = 5 \times 10^{16}$ cm^{-3} and $N_d = 10^{16}$ cm^{-3}. The junction cross-sectional area is $A = 10^{-3}$ cm^2 and the applied forward-bias voltage is $V_a = 1.10$ V. Calculate the (*a*) minority electron diffusion current at the edge of the space charge region, (*b*) minority hole diffusion current at the edge of the space charge region, and (*c*) total current in the pn junction diode.

From Table B.4, $n_i = 1.8 \times 10^6$ cm^{-3} for GaAs at 300 K.

From page 323 'Note', $D_n = 205$ cm^2/s, $D_p = 9.8$ cm^2/s, $\tau_{n0} = 5 \times 10^{-8}$ s, & $\tau_{p0} = 10^{-8}$ s.

a) Per (8.24), $J_n(-x_p) = \dfrac{eD_n n_{p0}}{L_n}\left(e^{V_a/V_t} - 1\right)$.

From p. 283, $L_n = \sqrt{D_n \tau_{n0}} = \sqrt{205\,(5\times10^{-8})} = 0.003201562$ cm.

Since $N_a >> n_i$, $p_{p0} \cong N_a = 5 \times 10^{16}$ cm^{-3}.

Per (4.43), $n_{p0} = n_i^2 / p_{p0} = (1.8\times10^6)^2 / 5\times10^{16} = 6.48 \times 10^{-5}$ cm^{-3}.

Per (7.10), $V_t = \dfrac{k_B T}{e} = \dfrac{8.617333\times10^{-5}\ \text{eV/K}\,(300\,\text{K})}{e} = 0.025852$ V.

$$J_n(-x_p) = \frac{1.602176634\times10^{-19}(205)\ 6.48\times10^{-5}}{0.003201562}\left(e^{1.1/0.025852} - 1\right) = 2.003844\ \text{A/cm}^2.$$

$I_n(-x_p) = J_n(-x_p)\,A = 2.003844\,(10^{-3})$ $\Rightarrow$ <u>$I_n(-x_p) = 2.00384$ **mA**</u>.

b) Per (8.22), $J_p(x_n) = \dfrac{eD_p p_{n0}}{L_p}\left(e^{V_a/V_t} - 1\right)$.

From p. 283, $L_p = \sqrt{D_p \tau_{p0}} = \sqrt{9.8\,(10^{-8})} = 0.00031305$ cm.

Since $N_d >> n_i$, $n_{n0} \cong N_d = 10^{16}$ cm^{-3}.

Per (4.43), $p_{n0} = n_i^2 / n_{n0} = (1.8\times10^6)^2 / 10^{16} = 3.24 \times 10^{-4}$ cm^{-3}.

$$J_p(x_n) = \frac{1.602176634\times10^{-19}(9.8)\ 3.24\times10^{-4}}{0.00031305}\left(e^{1.1/0.025852} - 1\right) = 4.89841\ \text{A/cm}^2.$$

$I_p(x_n) = J_p(x_n)\,A = 4.89841\,(10^{-3})$ $\Rightarrow$ <u>$I_p(x_n) = 4.89841$ **mA**</u>.

c) The total current is $I = I_n(-x_p) + I_p(x_n) = 2.00384 + 4.89841$ $\Rightarrow$ <u>$I = 6.90225$ **mA**</u>.