8.43 A silicon pn junction diode at $T = 300$ K has a cross-sectional area of 10^{-2} cm^2. The length of the p region is 0.2 cm and the length of the n region is 0.1 cm. The doping concentrations are $N_d = 10^{15}$ cm^{-3} and $N_a = 10^{16}$ cm^{-3}. Determine (*a*) approximately the series resistance of the diode and (*b*) the current through the diode that will produce a 0.1 V drop across this series resistance.

a) $r_s \simeq r_{p\text{-region}} + r_{n\text{-region}}$

Using (5.22b), $R = \frac{L}{\sigma A} = \frac{\rho L}{A}$

Using (5.23), $\sigma = e(\mu_n n + \mu_p p)$

Per Note on page 323, $D_n = 25 \frac{cm^2}{s}$ & $D_p = 10 \frac{cm^2}{s}$

Using the Einstein relation (5.47)

$$\frac{D_n}{\mu_n} = \frac{D_p}{\mu_p} = \frac{k_B T}{e} \Rightarrow \mu_n = \frac{D_n}{\left(\frac{k_B T}{e}\right)} = \frac{25}{8.617333\times10^{-5}(300)}$$

$$= 967.04 \frac{cm^2}{V\text{-}s} = 0.096704 \frac{m^2}{V\text{-}s}$$

$$\mu_p = \frac{D_p}{\frac{k_B T}{e}} = \frac{10}{8.617333\times10^{-5}(300)}$$

$$= 386.82 \frac{cm^2}{V\text{-}s} = 0.038682 \frac{m^2}{V\text{-}s}$$

So, $\sigma_p = 1.6021766\times10^{-19}(0.038682)10^{22}$

$= 61.9754$ S/m

$\sigma_n = 1.6021766\times10^{-19}(0.096704)10^{21}$

$= 15.4937$ S/m

a) cont.

$$r_{p\text{-region}} = \frac{L_{p\text{-region}}}{\sigma_p A} = \frac{0.2\times10^{-2}}{61.9754(10^{-2})\frac{1m^2}{100^2 cm^2}}$$

$$= 21.745\,\Omega$$

$$r_{n\text{-region}} = \frac{L_{n\text{-region}}}{\sigma_n A} = \frac{0.1\times10^{-2}}{15.4937(10^{-2})\frac{1}{100^2}}$$

$$= 64.542\,\Omega$$

$$r_s \simeq 21.745 + 64.542 = \underline{\underline{86.287\,\Omega}}$$

Note: Table 5.2 gives $\mu_n = 1350\ \frac{cm^2}{V\cdot s} \rightarrow \sigma_n = 21.6\ S/m$

$\mu_p = 480\ \frac{cm^2}{V\cdot s} \rightarrow \sigma_p = 76.9\ S/m$

$N_a = 10^{16}\ cm^{-3}$, $N_d = 10^{15}\ cm^{-3}$:

Fig 5.4 gives $\rho_n = 4.8\ \Omega\text{-cm} \rightarrow \sigma_n = 20.8\ S/m$

$\rho_p = 1.6\ \Omega\text{-cm} \rightarrow \sigma_p = 62.5\ S/m$

Fig 5.3 gives $\mu_n = 1868\ \frac{cm^2}{V\cdot s} \rightarrow \sigma_n = 29.9\ S/m$

$\mu_p = 400\ \frac{cm^2}{V\cdot s} \rightarrow \sigma_p = 64.1\ S/m$

$\Rightarrow$ These will yield different r_s values.

b) Using Ohm's Law $V = IR$

$$\underline{\underline{I = \frac{0.1V}{86.287\,\Omega} = 1.159\ mA}}$$