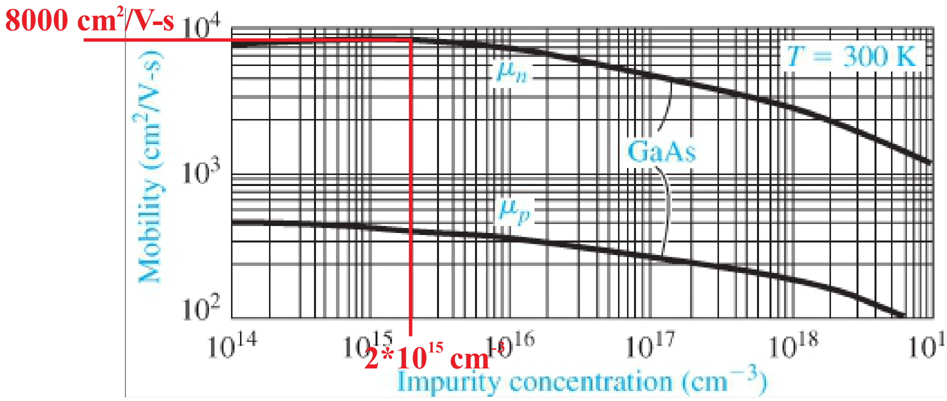
5.9 (*a*) A GaAs semiconductor resistor is doped with donor impurities at a concentration of $N_d = 2 \times 10^{15}$ cm^{-3} and has a cross-sectional area of 5×10^{-5} cm^2. A current of $I = 25$ mA is induced in the resistor with an applied bias of 5 V. Determine the length of the resistor. (*b*) Using the results of part (*a*), calculate the drift velocity of the electrons. (*c*) If the bias applied to the resistor in part (*a*) increases to 20 V, determine the resulting current if the electrons are traveling at their saturation velocity of 5×10^6 cm/s.

a) Going to Figure 5.3 (bottom graph for GaAs), we can read electron mobility for this impurity concentration to be $\mu_n \approx$ **8000 cm²/V-s**.



From Semiconductor Physics and Devices: Basic Principles (4th Edition), Donald A. Neamen, McGraw Hill, 2012, ISBN 978-0-07-352958-5.

By Ohm's Law, $R = \dfrac{V}{I} = \dfrac{5}{25 \times 10^{-3}} = 200\,\Omega$.

From (5.22b), $R = \dfrac{L}{\sigma A}$ where $\sigma = e(\mu_n n + \mu_p p)$ (5.23). Using Table B.4 for GaAs @ 300 K, $n_i = 1.8\times10^6$ cm^{-3} which means $n \approx N_d$ and $\sigma \approx e\mu_n N_d$. Therefore,

$$R = 200\,\Omega = \frac{L}{\sigma A} = \frac{L}{(e\mu_n N_d)A} \quad \Rightarrow \quad L = 200(e\mu_n N_d)A.$$

Plugging in the known values yields

$$L = 200(1.6022\times10^{-19})8000(2\times10^{15})5\times10^{-5} = 0.025635 \quad \Rightarrow \quad \underline{\mathbf{L = 0.0256\ cm}}$$

b) Using (5.6), $J_{n|drf} = (-en)v_{dn} \simeq -eN_d v_{dn}$ (ignore sign), and (5.21a), $J = I/A$, we get

$$\frac{I}{A} = eN_d v_{dn} \quad \Rightarrow \quad v_{dn} = \frac{I}{eN_d A} = \frac{25\cdot10^{-3}}{1.6022\cdot10^{-19}(2\cdot10^{15})5\cdot10^{-5}} \quad \Rightarrow \quad \underline{\mathbf{v_{dn} = 1.56\times10^6\ cm/s}}$$

c) Using (5.6), $J_{n|drf} = (-en)v_{dn} \simeq -eN_d v_{dn}$ (ignore sign), and $I = J(A)$, we get

$$I = J_{n|drf}A = eN_d v_{dn} A \simeq 1.6022\cdot10^{-19}(2\cdot10^{15})\,5\cdot10^{6}(5\cdot10^{-5}) = 0.08011\text{ A} \quad \Rightarrow \quad \underline{\mathbf{I = 80\ mA}}$$