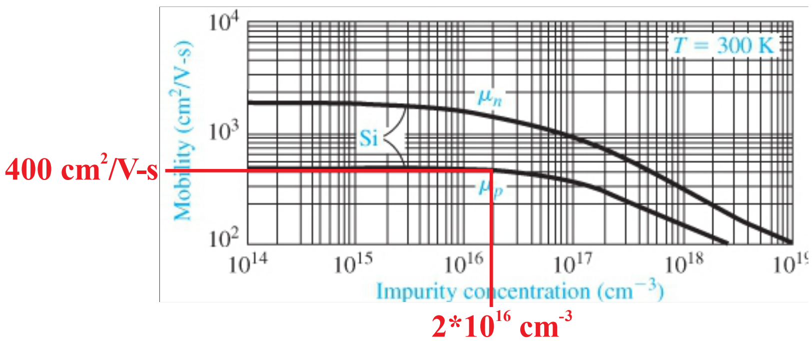
5.8 (*a*) A silicon semiconductor resistor is in the shape of a rectangular bar with a cross-sectional area of 8.5×10^{-4} cm^2, a length of 0.075 cm, and is doped with a concentration of 2×10^{16} cm^{-3} boron atoms. Let $T = 300$ K. A bias of 2 volts is applied across the length of the silicon device. Calculate the current in the resistor. (*b*) Repeat part (*a*) if the length is increased by a factor of three. (*c*) Determine the average drift velocity of holes in parts (*a*) and (*b*).

a) From Table 4.3, boron is an acceptor impurity for silicon. Going to Figure 5.3 (middle graph for Si), we read the hole mobility to be **$\mu_p \approx 400$ cm^2/V-s**.



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

Using Table B.4 for silicon @ 300 K, $n_i = 1.5\times10^{10}$ cm^{-3} which means $p \approx N_a$. Assume $N_d = 0$. From (5.23) $\sigma = e(\mu_n N_d + \mu_p N_a) \cong e\,\mu_p N_a$. Per (5.22b),

$$R = \frac{L}{\sigma A} = \frac{L}{(e\mu_p N_a)A} = \frac{0.075}{1.6022\times10^{-19}(400)2\times10^{-16}(8.5\times10^{-4})} \Rightarrow R = 68.84\ \Omega.$$

By Ohm's Law, $I = \dfrac{V}{R} = \dfrac{2}{68.84} \quad \Rightarrow$ **$I = 0.02905$ A $= 29.05$ mA**.

b) If the length is tripled, then $R = 3(68.84) = 206.52\ \Omega$ and $I = 29.05/3 \Rightarrow$ **$I = 9.68$ mA**.

c) The current density is $J = I/A$. Per (5.5), $J_{p|drf} = epv_{dp} \simeq eN_a v_{dp} \Rightarrow v_{dp} = J_{p|drf}/(eN_a)$. This gives $v_{dp} = I/(eN_a A)$.

For a), $$v_{dp,a} = \frac{I}{eN_a A} = \frac{0.02905}{1.6022\times10^{-19}(2\times10^{16})8.5\times10^{-4}} \Rightarrow v_{dp,a} = 10665.5\ \text{cm/s} = 106.65\ \text{m/s}.$$

For b), $$v_{dp,b} = \frac{I}{eN_a A} = \frac{0.02905/3}{1.6022\times10^{-19}(2\times10^{16})8.5\times10^{-4}} \Rightarrow v_{dp,b} = 3555.2\ \text{cm/s} = 35.55\ \text{m/s}.$$