4.41 A cylindrical bar of silicon has a radius of 4 mm and a length of 8 cm. If a voltage of 5 V is applied between the ends of the bar and $\mu_e = 0.13$ (m^2/V·s), $\mu_h = 0.05$ (m^2/V·s), $N_e = 1.5 \times 10^{16}$ electrons/m^3, and $N_h = N_e$, find the following:

(a) The conductivity of silicon.

(b) The current I flowing in the bar.

(c) The drift velocities $\mathbf{u}_e$ and $\mathbf{u}_h$.

(d) The resistance of the bar.

(e) The power dissipated in the bar.

Solution:

(a) Conductivity is given in Eq. (4.65),

$$\begin{aligned}\sigma &= (N_e\mu_e + N_h\mu_h)e \\ &= (1.5\times 10^{16})(0.13+0.05)(1.6\times 10^{-19}) = 4.32\times 10^{-4} \qquad \text{(S/m)}.\end{aligned}$$

(b) Similarly to Example 4.8, parts b and c,

$$I = JA = \sigma EA = (4.32\times 10^{-4})\left(\frac{5\text{V}}{0.08}\right)(\pi(4\times 10^{-3})^2) = 1.36 \qquad (\mu\text{A}).$$

(c) From Eqs. (4.62a) and (4.62b),

$$\mathbf{u}_e = -\mu_e\mathbf{E} = -(0.13)\left(\frac{5}{0.08}\right)\frac{\mathbf{E}}{|\mathbf{E}|} = -8.125\frac{\mathbf{E}}{|\mathbf{E}|} \qquad \text{(m/s)},$$

$$\mathbf{u}_h = \mu_h\mathbf{E} = +(0.05)\left(\frac{5}{0.08}\right)\frac{\mathbf{E}}{|\mathbf{E}|} = 3.125\frac{\mathbf{E}}{|\mathbf{E}|} \qquad \text{(m/s)}.$$

(d) To find the resistance, we use what we calculated above,

$$R = \frac{V}{I} = \frac{5\text{V}}{1.36\ \mu\text{A}} = 3.68 \qquad (\text{M}\Omega).$$

(e) Power dissipated in the bar is $P = IV = (5\text{V})(1.36\ \mu\text{A}) = 6.8\ (\mu\text{W})$.