

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 $\mu_e = 0.13 \text{ (m}^2/\text{V}\cdot\text{s)}$, $\mu_h = 0.05 \text{ (m}^2/\text{V}\cdot\text{s)}$, $N_e = 1.5 \times 10^{16} \text{ electrons/m}^3$, 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),

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

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

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

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

$$\begin{aligned}\mathbf{u}_e &= -\mu_e \mathbf{E} = -(0.13) \left(\frac{5}{0.08} \right) \frac{\mathbf{E}}{|\mathbf{E}|} = -8.125 \frac{\mathbf{E}}{|\mathbf{E}|} \quad (\text{m/s}), \\ \mathbf{u}_h &= \mu_h \mathbf{E} = +(0.05) \left(\frac{5}{0.08} \right) \frac{\mathbf{E}}{|\mathbf{E}|} = 3.125 \frac{\mathbf{E}}{|\mathbf{E}|} \quad (\text{m/s}).\end{aligned}$$

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

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

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