PHYSICS 4C: QUIZ 4 SOLUTIONS

Problem 1

First, find the number of electrons per unit volume, which, with one electron donated per atom, is the same as the number of atoms per unit volume:

$$n = \frac{\text{mass}}{\text{volume}} \times \frac{\#\text{ atoms}}{\text{mass}} = \frac{\text{mass}}{\text{volume}} \times \frac{\#\text{ atoms}}{\text{mol}} \times \frac{\text{mol}}{\text{mass}} \tag{1}$$

$$n = \left(10500\ \text{kg/m}^3\right)\left(6 \times 10^{23}/\text{mol}\right)\left(\frac{1}{0.108\ \text{kg/mol}}\right) = 5.8 \times 10^{28}/\text{m}^3. \tag{2}$$

$$j = nev_d = \left(5.8 \times 10^{28}/\text{m}^3\right)\left(1.6 \times 10^{-19}\text{C}\right)\left(0.13 \times 10^{-3}\text{m/s}\right) = 1.2 \times 10^6\,\text{A/m}^2 \tag{3}$$

$$I = jA = \left(1.2 \times 10^6\,\text{A/m}^2\right)\left(\pi(1 \times 10^{-3}\text{m})^2\right) = 4\text{A}. \tag{4}$$

Problem 2

Initially, $T_0 = 30°\text{C}$, $V_0 = 17\text{V}$. When temperature is changed, T is unknown, $V = 12.2\text{V}$.

$$\rho = \rho_0\left[1 + \alpha(T - T_0)\right] \tag{5}$$

$$\frac{RA}{L} = \frac{R_0 A}{L}\left[1 + \alpha(T - T_0)\right] \tag{6}$$

Since the dimensions of the wire don't change, they cancel. Using Ohm's law,

$$\frac{V}{I} = \frac{V_0}{I}\left[1 + \alpha(T - T_0)\right] \tag{7}$$

Canceling the current and solving for T,

$$T = \frac{V - V_0}{\alpha V_0} + T_0 = \frac{12.2\text{V} - 17\text{V}}{(0.0045/°\text{C})(17\text{V})} + 30°\text{C} = -33°\text{C}. \tag{8}$$

Problem 3

Using $I = \frac{P}{V}$, we can find the currents through both circuits:

$$I_1 = 0.67\text{A};\ I_2 = 0.25\text{A}. \tag{9}$$

Defining R_0 as the resistance of the wire and using $P = I^2 R_0$, we can write down the following relationship:

$$I_1^2 R_0 = I_2^2 R_0 + 0.15\text{W} \tag{10}$$

$$R_0 = \frac{0.15\text{W}}{I_1^2 - I_2^2} = 0.4\Omega. \tag{11}$$

Problem 4

$$j = \frac{E}{\rho} = 1.1 \times 10^7 \text{A/m}^2 \tag{12}$$

$$I = jA = 45\text{A} \tag{13}$$

$$R = \frac{\rho L}{A} = 0.01\Omega \tag{14}$$

$$P = I^2 R = 20\text{W} \tag{15}$$