Chapter 27

Problems

1,11,12,15,16,22,36,49

1. In a particular cathode ray tube, the measured beam current is 30.0 μA. How many electrons strike the tube screen every 40.0 s?

$$I = \frac{\Delta Q}{\Delta t} \qquad \Delta Q = I\Delta t = \left(30.0 \times 10^{-6}\ \text{A}\right)\left(40.0\ \text{s}\right) = 1.20 \times 10^{-3}\ \text{C}$$

$$N = \frac{Q}{e} = \frac{1.20 \times 10^{-3}\ \text{C}}{1.60 \times 10^{-19}\ \text{C/electron}} = \boxed{7.50 \times 10^{15}\ \text{electrons}}$$

11. An aluminum wire having a cross-sectional area of 4.00×10^{-6} m^2 carries a current of 5.00 A. Find the drift speed of the electrons in the wire. The density of aluminum is 2.70 g/cm^3. Assume that one conduction electron is supplied by each atom.

We use $I = nqAv_d$ n is the number of charge carriers per unit volume, and is identical to the number of atoms per unit volume. We assume a contribution of 1 free electron per atom in the relationship above. For aluminum, which has a molar mass of 27, we know that Avogadro's number of atoms, N_A, has a mass of 27.0 g. Thus, the mass per atom is

$$\frac{27.0\text{ g}}{N_A} = \frac{27.0\text{ g}}{6.02 \times 10^{23}} = 4.49 \times 10^{-23}\ \text{g/atom}.$$

Thus, $$n = \frac{\text{density of aluminum}}{\text{mass per atom}} = \frac{2.70\ \text{g/cm}^3}{4.49 \times 10^{-23}\ \text{g/atom}}$$

$$n = 6.02 \times 10^{22}\ \text{atoms/cm}^3 = 6.02 \times 10^{28}\ \text{atoms/m}^3.$$

Therefore, $$v_d = \frac{I}{nqA} = \frac{5.00\text{ A}}{\left(6.02 \times 10^{28}\ \text{m}^{-3}\right)\left(1.60 \times 10^{-19}\ \text{C}\right)\left(4.00 \times 10^{-6}\ \text{m}^2\right)} = 1.30 \times 10^{-4}\ \text{m/s}$$

or, $$v_d = \boxed{0.130\ \text{mm/s}}.$$

12. Calculate the current density in a gold wire at 20°C, if an electric field of 0.740 V/m exists in the wire.

$$J = \sigma E = \frac{E}{\rho} = \frac{0.740\ \text{V/m}}{2.44 \times 10^{-8}\ \Omega\cdot\text{m}}\left(\frac{1\ \Omega\cdot\text{A}}{1\ \text{V}}\right) = \boxed{3.03 \times 10^{7}\ \text{A/m}^2}$$

15. A 0.900-V potential difference is maintained across a 1.50-m length of tungsten wire that has a cross-sectional area of 0.600 mm². What is the current in the wire?

$$\Delta V = IR$$

and $\quad R = \frac{\rho \ell}{A}: \qquad A = (0.600 \text{ mm})^2 \left(\frac{1.00 \text{ m}}{1\,000 \text{ mm}} \right)^2 = 6.00 \times 10^{-7} \text{ m}^2$

$$\Delta V = \frac{I \rho \ell}{A}: \qquad I = \frac{\Delta V A}{\rho \ell} = \frac{(0.900 \text{ V})(6.00 \times 10^{-7} \text{ m}^2)}{(5.60 \times 10^{-8} \ \Omega \cdot \text{m})(1.50 \text{ m})}$$

$$I = \boxed{6.43 \text{ A}}$$

16. A conductor of uniform radius 1.20 cm carries a current of 3.00 A produced by an electric field of 120 V/m. What is the resistivity of the material?

$$J = \frac{I}{\pi r^2} = \sigma E = \frac{3.00\text{ A}}{\pi(0.0120\text{ m})^2} = \sigma(120\text{ N/C})$$

$$\sigma = 55.3(\Omega \cdot \text{m})^{-1} \qquad \rho = \frac{1}{\sigma} = \boxed{0.0181\ \Omega \cdot \text{m}}$$

36. A toaster is rated at 600 W when connected to a 120-V source. What current does the toaster carry, and what is its resistance?

$$I = \frac{\mathcal{P}}{\Delta V} = \frac{600\text{ W}}{120\text{ V}} = \boxed{5.00\text{ A}}$$

$$\text{and } R = \frac{\Delta V}{I} = \frac{120\text{ V}}{5.00\text{ A}} = \boxed{24.0\ \Omega}.$$

49. Compute the cost per day of operating a lamp that draws a current of 1.70 A from a 110-V line. Assume the cost of energy from the power company is \$0.060 0/kWh.

$$\mathcal{P} = I(\Delta V) = (1.70\text{ A})(110\text{ V}) = 187\text{ W}$$

$$\text{Energy used in a 24-hour day} = (0.187\text{ kW})(24.0\text{ h}) = 4.49\text{ kWh}$$

$$\therefore \text{cost} = 4.49\text{ kWh}\left(\frac{\$0.060\,0}{\text{kWh}}\right) = \$0.269 = \boxed{26.9¢}$$