

Chapter 5

5.1.6) Calculate the resistance of a silver 6.15 mm in diameter and 1.1 m long.

Answer

$$\sigma_{\text{silver}} = 6.3 * 10^7 (\Omega m)^{-1}$$

$$L = 1.1m$$

$$d = 6.15mm = 6.15 * 10^{-3} m$$

$$A = \pi r^2 = \frac{\pi d^2}{4} = \frac{\pi(6.15 * 10^{-3})^2}{4} = 2.97 * 10^{-5} m^2$$

$$R = \frac{\rho L}{A} = \frac{L}{\sigma A} = \frac{1.1}{6.3 * 10^7 * 2.97 * 10^{-5}} = 5.88 * 10^{-4} \Omega$$

5.1.7) A nichrome wire must have a resistance of 110 Ω . How long must it be (in meters), if it is 0.003in in diameter. ($\sigma_e(\text{nichrome}) = 9.3 * 10^5 (\Omega m)^{-1}$)

Answer

$$\sigma = 9.3 * 10^5 (\Omega m)^{-1}$$

$$R = 110\Omega$$

$$d = 0.003in = 0.003 * 2.54 * 10^{-2} m = 7.62 * 10^{-5} m$$

$$A = \pi r^2 = \frac{\pi d^2}{4} = \frac{\pi(7.62 * 10^{-5})^2}{4} = 4.56 * 10^{-9} m^2$$

$$R = \frac{\rho L}{A} = \frac{L}{\sigma A}$$

$$L = R \sigma A = 110 * 9.3 * 10^5 * 4.56 * 10^{-9} = .4665m$$

5.1.8) A wire .35 in diameter must carry 35A current.

a) If the maximum power dissipation along the wire is .035W/cm. What is the minimum allowable electrical conductivity of the wire (give the answer in SI units)?

b)What is the current density in the wire.

Answer

a)

$$d = 0.35in = 0.35 * 2.54 * 10^{-2} m = 8.89 * 10^{-3} m$$

$$A = \pi r^2 = \frac{\pi d^2}{4} = \frac{\pi(8.89 * 10^{-3})^2}{4} = 6.2 * 10^{-5} m^2$$

$$I = 35A$$

$$P = .035W$$

$$L = 1cm = 10^{-2} m$$

$$R = \frac{P}{I^2} = \frac{.035}{35^2} = 2.857 * 10^{-5} \Omega$$

$$R = \frac{\rho L}{A} = \frac{L}{\sigma A}$$

$$\sigma = \frac{L}{R A} = \frac{10^{-2}}{2.857 * 10^{-5} * 6.2 * 10^{-5}} = 5.65 * 10^6 (\Omega m)^{-1}$$

b)

$$J = \frac{I}{A} = \frac{35}{6.2 * 10^{-5}} = 5.645 * 10^5 \text{ A / m}^2$$

5.1.9) A gold wire is to conduct a 6A current with a maximum voltage drop of 0.003V/cm. What must be the minimum diameter of the wire in meters?

Answer

$$I = 6A$$

$$V = .003V$$

$$L = 1cm = 10^{-2}m$$

$$\sigma_{gold} = 4.2 * 10^7$$

$$R = \frac{V}{I} = \frac{.003}{6} = .5 * 10^{-3} \Omega$$

$$R = \frac{\rho L}{A} = \frac{L}{\sigma A}$$

$$A = \frac{L}{R \sigma} = \frac{10^{-2}}{.5 * 10^{-3} * 4.2 * 10^7} = 4.76 * 10^{-7} m^2$$

$$A = \frac{\pi d^2}{4}$$

$$d = \sqrt{\frac{4A}{\pi}} = \sqrt{\frac{4 * 4.76 * 10^{-7}}{\pi}} = 7.785m$$

5.1.14) Calculate the electrical resistivity (in ohm-meters) of a copper wire 70ft long and 0.025in in a diameter at 180°C .

Answer

$$\rho_{0cu} = 1.6 \mu \Omega cm = 1.6 * 10^{-8} \Omega m$$

$$\alpha_{0cu} = 0.0039^\circ C^{-1}$$

$$\begin{aligned} \rho_{180cu} &= \rho_{0cu} (1 + \alpha_{0cu} t) \\ &= 1.6 * 10^{-8} (1 + 0.0039 * 180) = 2.72 * 10^{-8} \Omega m \end{aligned}$$

5.1.15) At what temperature will a silver wire have the same electrical resistivity as an aluminum one at 40°C ?

Answer

$$\rho_{0Al} = 2.7 \mu \Omega cm = 2.7 * 10^{-8} \Omega m$$

$$\alpha_{0Al} = 0.0039^\circ C^{-1}$$

$$\begin{aligned} \rho_{40Al} &= \rho_{0Al} (1 + \alpha_{0Al} t) \\ &= 2.7 * 10^{-8} (1 + 0.0039 * 40) = 3.1 * 10^{-8} \Omega m \end{aligned}$$

$$\rho_{0silver} = 1.47 \mu\Omega cm = 1.47 * 10^{-8} \Omega m$$

$$\alpha_{0silver} = 0.0038^{\circ}C^{-1}$$

$$p_{silver} = \rho_{0silver} (1 + \alpha_{0silver} t) = 3.1 * 10^{-8} \Omega m$$

$$t = \frac{(p_{silver} / \rho_{0silver}) - 1}{\alpha_{0silver}} = \frac{(3.1 * 10^{-8} / 1.47 * 10^{-8}) - 1}{0.0038} = 292^{\circ}C$$

5.1.16) At what temperature will the electrical resistivity of a gold wire be $6.55 * 10^{-8} \Omega m$.

Answer

$$\rho_{0gold} = 2.3 \mu\Omega cm = 2.3 * 10^{-8} \Omega m$$

$$\alpha_{0gold} = 0.0034^{\circ}C^{-1}$$

$$p_{gold} = \rho_{0gold} (1 + \alpha_{0gold} t) = 6.55 * 10^{-8} \Omega m$$

$$t = \frac{(p_{gold} / \rho_{0gold}) - 1}{\alpha_{0gold}} = \frac{(6.55 * 10^{-8} / 2.3 * 10^{-8}) - 1}{0.0034} = 543^{\circ}C$$