KING FHAD UNIVERSITY OF PETROLEUM & MINERALS
DEPARTMENT OF PHYSICS

PHYSICS 102 (992)
SOLUTIONS (CHAPTER 27)

Q.1 Near Earth, the density of protons in the solar wind is 8.70 cm^{-3} and their speed is 470 km/s. (a) Find the current density of these protons. (b) If Earth's magnetic field did not deflect them, the protons would strike the planet. What total current would Earth then receive?

(a) $\Delta q = n e v \Delta t \, A$

$$I = \frac{\Delta q}{\Delta t} = n e v A$$

$$J = \frac{I}{A} = n e v = (8.70 \times 10^{6})(1.6 \times 10^{-19})(470 \times 10^{3})$$

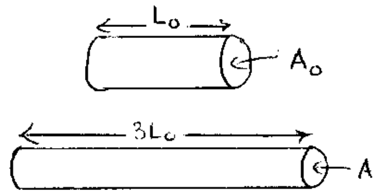
$$J = 6.54 \times 10^{-7} \ A/m^2 = \boxed{0.654 \ \mu A/m^2}$$

(b) $I = JA = (0.654 \times 10^{-6})(4\pi R_E^2)$

$$= (0.654 \times 10^{-6})(4 * \pi * (6.37 \times 10^{6})^2)$$

$$= \boxed{3.33 \times 10^{8} \ A}$$

Q.2 A wire with a resistance of 6.0 Ω is drawn out through a die so that its new length is three times its original length. Find the resistance of the longer wire, assuming that the resistivity and the density of the material are unchanged.



$$R_o = 6.0\,\Omega = \rho \frac{L_o}{A_o}$$

$$R = \rho \frac{3L_o}{A_o/3} = 9\left(\rho \frac{L_o}{A_o}\right)$$

$$3L_o A = L_o A_o$$

$$A = A_o/3$$

$$R = 9 R_o = 9 \times 6 = \boxed{54\ \Omega}$$

Q.3 A common flashlight bulb is rated at 0.30 A and 2.9 V (the values of the current and voltage under operating conditions). If the resistance of the bulb filament at room temperature (20°) is 1.1 Ω, what is the temperature of the filament when the bulb is on? The filament is made of tungsten.

$I = 0.30\ A$, $V = 2.9$ volts ; at room temp. $R = 1.1\,\Omega$

$$R_{operting} = \frac{V}{I} = \frac{2.9}{0.3} = 9.67\ \Omega$$

$$R_{operting} = R_o\left(1 + \alpha_W (T - T_o)\right)$$

$$\frac{9.67}{1.1} = 1 + 4.5\times10^{-3}(T - T_o)$$

$$T - T_o = \frac{8.79 - 1}{4.5\times10^{-3}} = \frac{7.79}{4.5\times10^{-3}}$$

$$T = T_o + \frac{7.79}{4.5\times10^{-3}} = 20 + \frac{7.79}{4.5\times10^{-3}} = \boxed{1750\ °C}$$

Q.4 A cylindrical resistor of radius 5.0 mm and length 2.0 cm is made of material that has a resistivity of 3.5×10^{-5} Ωm. What are (a) the current density and (b) the potential difference when the energy dissipation rate in the resistor is 1.0 W?

$$R = \rho \frac{L}{A} = 3.5\times10^{-5} \frac{2\times10^{-2}}{\pi(5\times10^{-3})^2} = 8.91\times10^{-3}\ \Omega$$

$$P = I^2 R \quad , \quad I = \sqrt{\frac{P}{R}}$$

$$I = \sqrt{\frac{1}{8.91\times10^{-3}}} = 10.6\ \text{A}$$

(a) $$J = \frac{I}{A} = \frac{10.6}{\pi(5\times10^{-3})^2} = \boxed{1.3\times10^{5}\ \text{A/m}^2}$$

(b) $$V = IR = (10.6)(8.91\times10^{-3}) = \boxed{0.094\ \text{volts or } 94\ \text{mV}}$$

Q.5 A 100 W lightbulb is plugged into a standard 120 V outlet. (a) How much does it cost per month to leave the light turned on continuously? Assume electrical energy costs 6 c/kWh. (b) What is the resistance of the bulb? (c) What is the current in the bulb? (d) Is the resistance different when the bulb is turned off?

$$100 \text{ W} \times 30 \times 24 = 7200 \text{ W.h} = 72 \text{ kWh. (per month)}$$

(a) $$72 \text{ kWh} \times \frac{6\text{C}}{\text{kWh}} = \boxed{432 \text{ C} = \$ 4.32}$$

(b) $$R = \frac{V}{I}$$

$$IV = 100, \; I = \frac{100}{120} = 0.83 \text{ A}$$

$$R = \frac{120}{0.83} = \boxed{144 \, \Omega}$$

(c) $$I = \boxed{0.83 \text{ A}}$$