سارجبار

Principles of physics (10th eddition)

phy 132

CH26: current and Resistance

Problems: 2, 3, 11, 15, 25, 43, 45, 53

P2: A wire 8.00 m long and 6.00 mm in diameter has a resistance of 30.0 mΩ. A potential difference of 23.0 V is applied between the ends. (a) What is the current in the wire? (b) What is the magnitude of the current density? (c) calculate the resistivity of the wire material (d) using Table 26-1, Identify the material.

Sol: $L = 8.00\,m$, $D = 6.00\,mm$, $R = 30\,m\Omega$

$V = 23.0\,V$

a) $I = \frac{V}{R} = \frac{23}{30 \times 10^{-3}} = 7.67 \times 10^{2}\,A$

b) $A = 4\pi r^2 = \pi\left(\frac{d}{2}\right)^2 = \frac{\pi d^2}{4} = \frac{3.14 \times (6 \times 10^{-3})^2}{4}$

$= 2.826 \times 10^{-5}\,m^2$

$J = \frac{I}{A} = \frac{7.67 \times 10^{2}}{2.826 \times 10^{-5}} = 2.71 \times 10^{7}\,A/m^2$

c) $R = \frac{\rho L}{A} \Rightarrow \rho = \frac{RA}{L} = \frac{30 \times 10^{-3} \times 2.826 \times 10^{-5}}{8}$

$\rho = 1.06 \times 10^{-7}\,\Omega \cdot m$

$= 10.6 \times 10^{-7}\,\Omega \cdot m$

d) The material is Platinum

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P3: An electrical cable consists of 63 strands of fine wire, each having 2.65 $\mu\Omega$ resistance. The same potential difference is applied between the ends of all the strands and results in a total current of 0.750 A (a) What is the current in each strand? (b) What is the applied potential difference? (c) What is the resistance of the cable?

Sol

a) * The given electrical cable consists of 63 strands of wire.

* Resistance (r) of each strand is

$$r = 2.65\ \mu\Omega = 2.65 \times 10^{-6}\ \Omega$$

* The total current flowing through the cable is

$$I = 0.750\ A$$

* the current flowing in each strand of wire will be $i = \frac{0.750}{63} = 0.0119 \simeq 11.9\ mA$

b) The potential difference across each strand will be

$$V = ir = 0.0119 \times 2.65 \times 10^{-6}$$
$$= 3.1535 \times 10^{-8}\ volt$$
$$= 31.535\ nV$$
$$= 31.5\ nV$$

c) $R = \frac{V}{I} = \frac{31.5 \times 10^{-9}}{0.750} = 4.2 \times 10^{-8}\ \Omega$

$$= 42\ n\Omega$$

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P_{11}: When 230 V is applied across a wire that is 14.1 m Long and has a 0.30 mm radius, the magnitude of the current density is 1.98×10^8 A/m². Find the resistivity of the wire.

المعطيات: $V = 230$ volt, $l = 14.1$ m, $r = 0.3$ mm, $J = 1.98 \times 10^8$ A/m²

sol: $J = \frac{E}{\rho}$ — E: electric field, ρ: the resistivity of the material

$E = \frac{V}{L}$ — V: the potential difference, L: the length of the wire

$\Rightarrow E = \frac{230}{14.1} = 16.3$ volt/m

$\rho = \frac{E}{J} \Rightarrow \rho = \frac{16.3}{1.98 \times 10^8} = 8.23 \times 10^{-8}$ Ω.m

P15: A heater contains a Nichrome wire (resistivity 5.0×10^{-7} Ω.m) of length 5.85 m with an end-to-end potential difference of 112 V and with a dissipation power 4000 W (a) what is the wire's cross-sectional area? (b) if 100 V is used to obtain the same dissipation rate, what should the length be?

sol: $\rho = 5.0 \times 10^{7}$ Ω.m

$L = 5.85$ m $V = 112$ volt $P = 4000$ W

a) $R = \frac{\rho L}{A}$, R = ? A = ?

to Find R we use the Power value

$P = IV = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{(112)^2}{4000} = 3.136$ Ω

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$$R = \frac{\rho L}{A} \Rightarrow A = \frac{\rho L}{R} = \frac{5 \times 10^{-7} \times 5.85}{3.136}$$

$$A = 9.327 \times 10^{-7}\ m^2$$

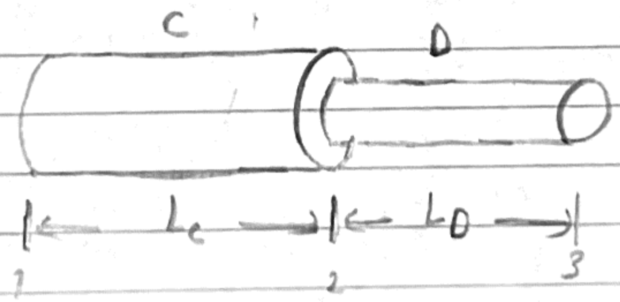
$$\boxed{A = 9.33 \times 10^{-7}\ m^2}$$

b) $P = \frac{V^2}{R} \Rightarrow R = \frac{V^2}{P} = \frac{(100)^2}{4000} = 2.5\ \Omega$

$$R = \frac{\rho L}{A} \Rightarrow L = \frac{RA}{\rho} = \frac{2.5 \times 9.33 \times 10^{-7}}{5 \times 10^{-7}}$$

$$\boxed{L = 4.665\ m}$$

P25: wire C and wire D are made from different materials and have length $L_C = L_D = 1.0\ m$. The resistivity and radius of wire C are $2.0 \times 10^{-6}\ \Omega.m$ and 1.00 mm, and those of wire D are $1.0 \times 10^{-6}\ \Omega.m$ and 0.5 mm. The wires are joined as shown in Fig 26.23 and a current of 2.0 A is set up in them. What is the electric potential difference between (a) points 1 and 2 (b) points 2 and 3? What is the rate at which energy is dissipated between (c) points 1 and 2 (d) point 2 and 3?



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Sol : $L_c = 1\ m$ $\quad$ $L_D = 1m$

$\rho_c = 2.0 \times 10^{-6}\ \Omega m$ $\quad$ $\rho_D = 1 \times 10^{-6}\ \Omega.m$

$r_c = 1\ mm = 1 \times 10^{-3}\ m$ $\quad$ $r_D = 0.5 mm = 0.5 \times 10^{-3} m$

$I = 2\ A$

$V = IR \quad , R = \frac{\rho L}{A}$

a) between 1 and 2 (for R_c)

$$R_c = \frac{\rho_c L_c}{A_c} = \frac{2 \times 10^{-6} \times 1}{\pi (1 \times 10^{-3})^2} = 0.6369 \simeq 0.64\ \Omega$$

$$V_c = IR_c = 2 \times 0.6369 = 1.27 \simeq 1.3\ volt$$

b) between 2 and 3 (for R_D)

$$R_D = \frac{\rho_D L_D}{A_D} = \frac{1 \times 10^{-6} \times 1}{\pi (0.5 \times 10^{-3})^2} = 1.273\ \Omega$$

$$V_D = IR_D = 2 \times 1.273 = 2.547 \simeq 2.5\ volt$$

c) $P = IV$

$P_c = IV_c$

$= 2 \times 1.27$

$= 2.54$ watt

$\simeq 2.5$

d) $P_D = IV_D$

$= 2 \times 2.547$

$= 5.094$ watt

$\simeq 5.1$ watt

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P43: How long does it takes electron to get from a car battery to the starting motor? Assume the current is 285 A and the electrons travel through a copper wire with cross sectional area 0.17 cm^2 and length 0.43 m the number of charge carriers per unit volume is $8.49 \times 10^{28}\ m^{-3}$

Sol: I or $i = 285\ A$, $A = 0.17\ cm^2 = 0.17 \times 10^{-4}\ m^2$

$L = 0.43\ m$ $\quad n = 8.49 \times 10^{28}\ m^{-3}$

$$V_d = \frac{I}{ne} = \frac{i}{Ane}$$

$$t = \frac{L}{V_d} = \frac{L}{i/Ane} = \frac{LAne}{i}$$

$$t = \frac{(0.43)(0.17 \times 10^{-4})(8.49 \times 10^{28})(1.6 \times 10^{-19})}{285}$$

$$t = 348.4\ sec$$

$$t = \frac{348.4}{60} = 5.8\ min$$

P45: What is the current in a wire of radius $R = 2.67$ mm. If the magnitude of the current density is given by a) $J_a = J_0 r/R$ and (b) $J_b = J_0(1 - r/R)$ in which r is the radial distance and $J_0 = 5.50 \times 10^4\ A/m^2$? (c) Which function maximizes the current density near the wire surface?

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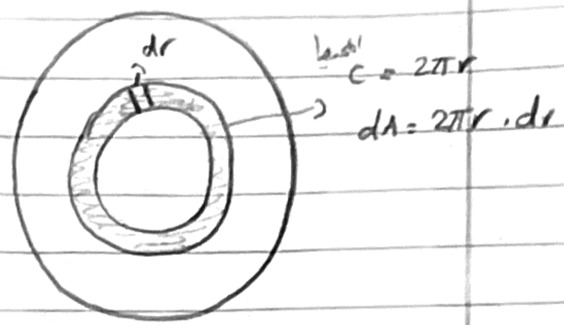
a) $i = \int J_a \cdot dA$



$$i = \int_0^R \frac{J_o r}{R} \cdot 2\pi r dr$$

$$i = \frac{2\pi J_o}{R} \int_0^R r^2 dr$$

$$= \frac{2\pi J_o}{R} \cdot \frac{r^3}{3} \Big]_0^R$$

$$= \frac{2\pi J_o}{R} \left[\frac{R^3}{3} - 0\right]$$

$$= \frac{2\pi J_o}{R} \frac{R^3}{3}$$

$$i = \frac{2}{3} \pi J_o R^2 \Rightarrow i = \frac{2}{3} (3.14)(5.5\times10^4)(2.67\times10^{-3})^2$$

$$i_a = 0.821\ A$$

b) $i = \int J_b \cdot dA$

$$= \int_0^R J_o\left(1 - \frac{r}{R}\right) 2\pi r dr$$

$$= 2\pi J_o \int_0^R \left(1 - \frac{r}{R}\right) r dr$$

$$= 2\pi J_o \int_0^R \left(r - \frac{r^2}{R}\right) dr$$

$$2\pi J_o \left[\frac{r^2}{2} - \frac{r^3}{3R}\right]_0^R$$

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$$i_b = 2\pi J_0 \left(\left[\frac{R^2}{2} - \frac{R^3}{3R} \right] - [0 - 0] \right)$$

$$= 2\pi J_0 \left[\frac{R^2}{2} - \frac{R^2}{3} \right]$$

$$= 2\pi J_0 \left[\frac{3R^2}{6} - \frac{2R^2}{6} \right]$$

$$= 2\pi J_0 \frac{R^2}{6}$$

$$= \pi J_0 \left[\frac{R^2}{3} \right]$$

$$= 3.14\ (5.5\times10^{4})\ \frac{(2.67\times10^{-3})^2}{3}$$

$$= 0.41\ A$$

c) $i_a = 0.821\,A$, $i_b = 0.41\,A$

$\Rightarrow$ $i_a > i_b$ so J_a the function that maximizes the current density

P53: A beam contains 4.5×10^{8} doubly charged negative ions per cubic centimeter, all of which are moving north with a speed of 300 m/s. What are (a) the magnitude (b) direction of the current density $\vec{J}$? (c) If the particle distribution is uniform across a cross-sectional area of $2.5\,\mu m^2$ What is the current?

sol $n = 4.5\times10^{8}/cm^3 = 4.5\times10^{8}\times^{6}/m^3 = 4.5\times10^{14}/m^3$

$q = 2e = 2(1.6\times10^{-19}) = 3.2\times10^{-19}\,C$

$V_d = 300\ m/s$

a) $J = nqV_d = (4.5\times10^{14})(3.2\times10^{-19})(300)$

$= 0.0432\ A/m^2$

$= 43.2\ mA/m^2$

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b) since the particles are negatively charged, the current density is in the opposite direction of their motion to the south

c) $i = JA = 0.0432 \times 25 \times 10^{-6}$
$= 1.08 \times 10^{-7}$ m²
$\simeq 11 \mu$ m²