Physics 121 Practice Problem Solutions 07
Current and Resistance

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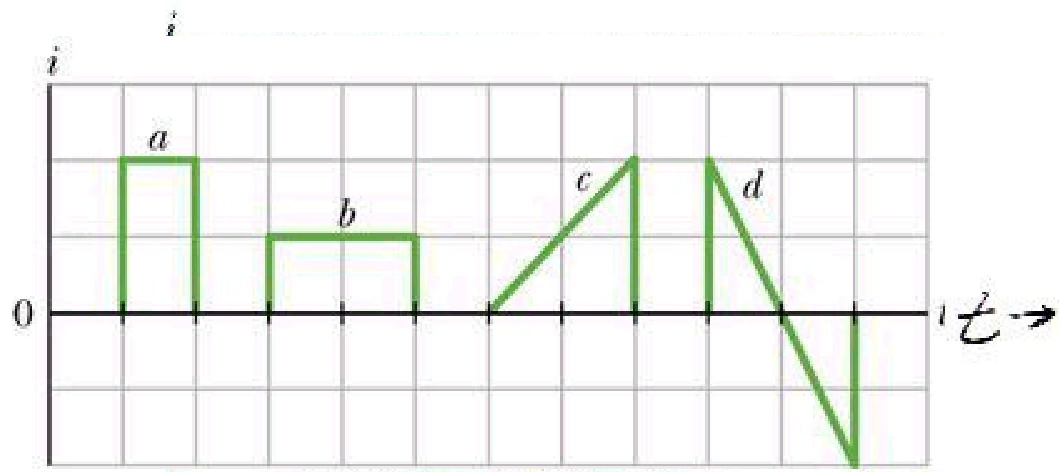
PROBLEM 121P07-1Q: The figure shows plots of the current *i* through a certain cross section of a wire over four different time periods. Rank the periods according to the net charge that passes through the cross section during each, greatest first.

$\Delta q = i \Delta t$



a) $1 \times 2 = 2$

b) $2 \times 1 = 2$

c) $\frac{1}{2} \times 2 \times 2 = 2$

d) $\frac{1}{2} 1 \times 2 - \frac{1}{2} 1 \times 2 = 0$

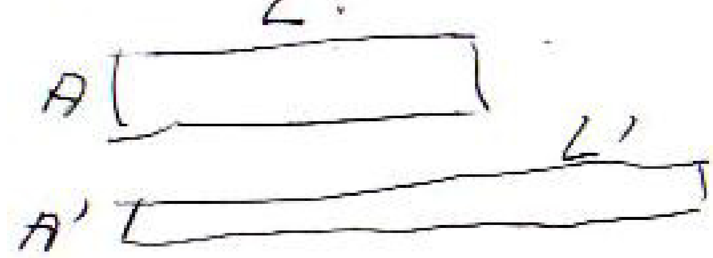
a, b, c tied
d next

Fall 2012

PROBLEM 121P07-4Q: If you stretch a cylindrical wire and it remains cylindrical, does the resistance of the wire (measured end to end along its length) increase, decrease, or remain the same?

The mass remains the same, as does the density. As L increases, A must decrease since the volume is constant.

$$R = \rho \frac{L}{A}$$ grows as L grows & A shrinks

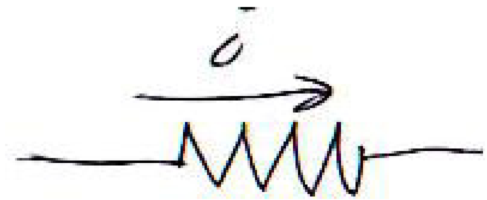


PROBLEM 121P07-1P: A current of 5.0 A exists in a 10 Ω resistor for 4.0 min. How many (a) coulombs and (b) electrons pass through any cross section of the resistor in this time?

$R = 10\,\Omega \qquad i = 5.0\,A$

$\Delta t = 4.0$ min.

$= 240$ sec



a) $\Delta Q = \int_0^T i\,dt = i\,\Delta t = 5\,\frac{\text{coul}}{\text{sec}} \times 240\,\text{sec}$

$\boxed{\Delta Q = 1200\ C.}$ Charge moved.

b) $\Delta N \equiv$ # of electrons

$= \frac{Q}{|e|} = \frac{1200 \text{ coul.}}{1.6\times10^{-19}\ \frac{\text{coul}}{\text{electron}}}$

$\boxed{\Delta N = 7.5\times10^{21}\ \text{electrons}}$

Fall 2012

PROBLEM 121P07-7P*: A fuse in an electric circuit is a wire that is designed to melt, and thereby open the circuit, if the current exceeds a predetermined value. Suppose that the material to be used in a fuse melts when the current density rises to 440 A/cm². What diameter of cylindrical wire should be used to make a fuse that will limit the current to 0.50 A?

$$J_{max} = 440\ A/cm^2.$$

$$i_{max} = \int_{\text{cross section}} \bar{J}_{max} \cdot d\vec{A} = J \times A \qquad A = \text{area}$$

$$A = \frac{i_{max}}{J_{max}} = \pi r^2.$$

$$r = \sqrt{\frac{1}{\pi}\frac{i_{max}}{J_{max}}} = \sqrt{\frac{1}{\pi}\frac{.5\ \text{amps}}{440\ \text{amps}/cm^2}}$$

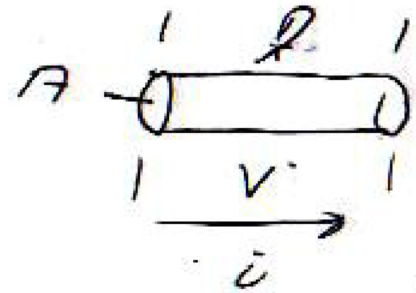
$$r = .019\ \underline{cm} = 1.9 \times 10^{-4}\ \underline{m}$$

$$\boxed{d = 3.8 \times 10^{-4}\ m}$$

Fall 2012

PROBLEM 121P07-12P: A wire of Nichrome (a nickel–chromium–iron alloy commonly used in heating elements) is 1.0 m long and 1.0 mm^2 in cross-sectional area. It carries a current of 4.0 A when a 2.0 V potential difference is applied between its ends. Calculate the conductivity σ of Nichrome.

- $V = iR$; $R = V/i$
- $R = \rho \dfrac{\ell}{A} = \dfrac{1}{\sigma}\dfrac{\ell}{A}$



$\sigma \equiv \dfrac{1}{\rho}$

ρ = resistivity

A = area

$$\Rightarrow \sigma = \frac{\ell}{RA}$$

$$= \frac{\ell i}{AV}$$

$$= \frac{1\,m \times 4.0\,amps}{1\,mm^2 \times 10^{-6}\,\frac{m^2}{mm^2} \times 2\,Volts}$$

$$\sigma = 2\times10^{6}\,(\Omega\text{-}m)^{-1} = \text{"mho"}$$

PROBLEM 121P07-19P*: 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 density of the material are unchanged.

Before. $R_0 = \rho \frac{l_0}{A_0}$ After: $R = \rho \frac{l}{A}$.

$l = 3l_0$ volume $= l_0 A_0 = lA$.

$A = \frac{l_0 A_0}{l} = \frac{l}{3}\frac{A_0}{l}$

$A = A_0/3$.

$R = \rho \times \frac{3l_0}{A_0/3} = 9\rho\frac{l_0}{A_0}$

$\boxed{R = 9R_0 = 9\times 6 = 54\,\Omega}$

Fall 2012

PROBLEM 121P07-25P: 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°C) is 1.1 Ω, what is the temperature of the filament when the bulb is on? The filament is made of tungsten.

$R_0 = 1.1\,\Omega$ at $T_0 = 20^\circ C$.

$R = V/i = \frac{2.9\,V}{.3\,A} = 9.67\,\Omega$ at operating temp T

resistivity:

$\rho = \rho_0 (1 + \alpha (T - T_0))$ at temp T

assuming shape doesn't change

$R = \rho \frac{l}{A} = R_0 (1 + \alpha (T - T_0))$

$T - T_0 = \frac{R - R_0}{\alpha R_0}$ $\quad \alpha = 4.5 \times 10^{-3}$ for Tungsten

$[\alpha] = [{}^\circ K]^{-1}$

$T = 20^\circ C + \frac{9.67 - 1.1}{1.1 \times 4.5 \times 10^{-3}}$

$\boxed{T = 1750^\circ C}$ or. $\boxed{T = 2020\,{}^\circ K}$

PROBLEM 121P07-31P: A certain x-ray tube operates at a current of 7.0 mA and a potential difference of 80 kV. What is its power in watts?

$$P = iV = 7 \times \cancel{10^{-3}}\,A \times 80 \times \cancel{10^{3}}\,V$$

$$= 7 \times 80 \text{ watts}$$

$$\boxed{P = 560 \text{ Watts}}$$

PROBLEM 121P07-35P*: An unknown resistor is connected between the terminals of a 3.00 V battery. Energy is dissipated in the resistor at the rate of 0.540 W. The same resistor is then connected between the terminals of a 1.50 V battery. At what rate is energy now dissipated?

$$P_0 = .54\,W = V_0^2/R = \frac{(3.0)^2}{R}$$

Before

$$R = \frac{V_0^2}{P_0} = \frac{9}{.54} = 16.7\,\Omega.$$

After

$$P = V^2/R. \quad R = V^2/P.$$

$$\frac{V^2}{P} = \frac{V_0^2}{P_0}$$

$$P = \frac{V^2}{V_0^2}P_0 = \left(\frac{1.5}{3.0}\right)^2 P_0 = \frac{1}{4} \times .54$$

$$\boxed{P = .135\ \text{Watts}}$$

Fall 2012

PROBLEM 121P07-38P: A heating element is made by maintaining a potential difference of 75.0 V across the length of a Nichrome wire that has a 2.60 x 10^{-6} m^2 cross section. Nichrome has a resistivity of 5.00 x 10^{-7} $\Omega \cdot$m. (a) If the element dissipates 5000 W, what is its length? (b) If a potential difference of 100 V is used to obtain the same dissipation rate, what should the length be?

a) P = power $= V^2/R$ $\quad R = V^2/P. = \frac{\rho \ell}{A}.$

$\ell = \frac{V^2 A}{P \rho} = \frac{(75)^2 \times 2.6 \times 10^{-6} m^2}{5 \times 10^3 \text{ watts} \times 5 \times 10^{-7} \Omega\text{-m}}$

$\boxed{\ell = 5.85 \text{ m}}$

b) V'^2/R' = new values = same power $= P.$

$\therefore R' = \frac{V'^2}{V^2} R \qquad R' = \frac{\rho \ell'}{A}.$

$\frac{R'}{R} = \frac{\ell'}{\ell} = \frac{V'^2}{V^2}$; $\ell' = \left(\frac{V'}{V}\right)^2 \ell. = \left(\frac{100}{75}\right)^2 \times 5.85 \Omega$

$\boxed{\ell' = 10.4 \text{m}}$