Chapter 27 · Homework # 1

2. The quantity of charge q (in C) passing through a surface of area 1 cm^2 varies with time as $q = 3t^2 - 4t + 2$, where t is in s. (a) What is the instantaneous current through the surface at $t = 0.5$ s? (b) What is the value of the current density?
3. The current I (in A) in a conductor depends on time as $I = t^2 - 0.5t + 6$, where t is in s. What quantity of charge moves across a section through the conductor during the interval $t = 1$ s to $t = 3$ s?

7E. A fuse in an electrical 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 composing the fuse melts once the current density rises to 440 A/cm^2. What diameter of cylindrical wire should be used to limit the current to 0.50 A?

14P. A steady beam of alpha particles ($q = 2e$) traveling with constant kinetic energy 20 MeV carries a current 0.25 μA. (*a*) If the beam is directed perpendicular to a plane surface, how many alpha particles strike the surface in 3.0 s? (*b*) At any instant, how many alpha particles are there in a given 20-cm length of the beam? (*c*) Through what potential difference was it necessary to accelerate each alpha particle from rest to bring it to an energy of 20 MeV?

alpha particle nucleus of He atom
mass $= 4(1.67 \times 10^{-27}$ kg$)$

18E. A human being can be electrocuted if a current as small as 50 mA passes near the heart. An electrician working with sweaty hands makes good contact with the two conductors he is holding. If his resistance is 2000 Ω, what might the fatal voltage be?

27E. 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 not changed during the drawing process.

Volume remains the same

30P. Two conductors are made of the same material and have the same length. Conductor A is a solid wire of diameter 1.0 mm. Conductor B is a hollow tube of outside diameter 2.0 mm and inside diameter 1.0 mm. What is the resistance ratio, R_A/R_B, measured between their ends?

37P. When 115 V is applied across a 0.30-mm radius, 10-m-long wire, the current density is 1.4×10^4 A/m^2. Find the resistivity of the wire.

42P. When a metal rod is heated, not only its resistance but also its length and its cross-sectional area change. The relation $R = \rho L/A$ suggests that all three factors should be taken into account in measuring ρ at various temperatures. (*a*) If the temperature changes by 1.0°C, what percentage changes in R, L, and A occur for a copper conductor? (*b*) What conclusion do you draw? The coefficient of linear expansion is 1.7×10^{-5}/°C.

Chapter 27 Homework #1

2). A) $I = \frac{dq}{dt} = 6t - 4$ amps $\Big|_{\frac{1}{2}} = -1$ Amps

B) $J = \frac{I}{A} = \frac{1}{10^{-4}} = 10^4$ amps/ m^2

3) $Q = \int I\,dt = \int_1^3 (t^2 - \frac{1}{2}t + 6)\,dt$

$= \frac{t^3}{3} - \frac{t^2}{4} + 6t \Big|_1^3 = (9 - \frac{9}{4} + 18) - (\frac{1}{3} - \frac{1}{4} + 6)$

$= \cancel{27 - 2 + 12} = \cancel{37}$ C $18\frac{2}{3}$ C

7E) $J = \frac{I}{A}$

$440 = \frac{.50}{\pi r^2}$

$r^2 = \frac{.50}{440\pi} = 3.16 \times 10^{-4}$ cm

$r = 1.90 \times 10^{-2}$ cm diameter = .380 mm

14P) $I = \frac{dQ}{dt}$ $dQ = I\,dt = (.25)(10^{-6})(3) = .75 \times 10^{-6}$ C

A) $\frac{.75 \times 10^{-6}}{1.6 \times 10^{-19}} = 4.69 \times 10^{12}$ electrons = 2.34×10^{12} alpha particles

B) $K = \frac{1}{2}mv^2$

$4 \cdot \frac{1}{2}(1.67 \times 10^{-27}) v^2 = 20(10^6)(1.6 \times 10^{-19})$

$V = 3.093 \times 10^7$ m/sec

$T = \frac{.2}{3.093 \times 10^7} = 6.47 \times 10^{-9}$ sec

$(6.47 \times 10^{-9})(.78 \times 10^{12}) = 5.05 \times 10^3$ alpha particles

In one second

c) $K = qV$

$20 MeV = (2eV)$

$\boxed{V = 10 \text{ M volts}}$

18E)

$V = iR = (50 \times 10^{-3} \text{ amps})(2 \times 10^{3}\ \Omega) = \underline{100 \text{ volts}}$

27E) $R = \frac{\rho l}{A}$

$V = Al$

If $l_f = 3l$

$A_f = \frac{1}{3}A$

$R_f = \frac{\rho(3l)}{\frac{1}{3}A} = 9\frac{\rho l}{A} = 9(6) = \boxed{54\ \Omega}$

30P) $\frac{R_A}{R_B} = \frac{\frac{\rho l}{A_A}}{\frac{\rho l}{A_B}} = \frac{A_B}{A_A} = \frac{\pi(d_o^2 - d_i^2)/4}{\pi d^2/4} = \frac{d_o^2 - d_i^2}{d^2} = \frac{2^2 - 1^2}{1^2} = 3.$

37P) $V = El$

$V = \rho J l$

$\rho = \frac{V}{Jl} = \frac{115}{(1.4 \times 10^{4})(10)} = \boxed{8.21 \times 10^{-4}\ \Omega m}$

Chapter 27 Homework # 2

43P. A resistor is in the shape of a truncated right circular cone (Fig. 20). The end radii are a and b, the altitude is L. If the taper is small, we may assume that the current density is uniform across any cross section. (*a*) Calculate the resistance of this object. (*b*) Show that your answer reduces to $\rho(L/A)$ for the special case of zero taper ($a = b$).

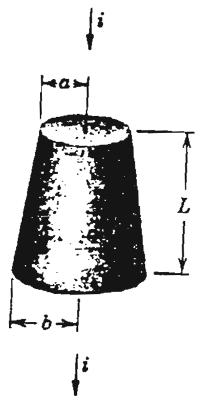


Figure 20 Problem 43.

46E. An x-ray tube takes a current of 7.0 mA and operates at a potential difference of 80 kV. What power in watts is dissipated?

49E. A space heater, operating from a 120-V line, has a hot resistance of 14 Ω. (*a*) At what rate is electrical energy transferred into heat? (*b*) At 5.0¢/kW·h, what does it cost to operate the device for 5.0 h?

56P. A 1250-W radiant heater is constructed to operate at 115 V. (*a*) What will be the current in the heater? (*b*) What is the resistance of the heating coil? (*c*) How much thermal energy is generated in one hour by the heater?

58P. A Nichrome heater dissipates 500 W when the applied potential difference is 110 V and the wire temperature is 800°C. How much power would it dissipate if the wire temperature were held at 200°C by immersion in a bath of cooling oil? The applied potential difference remains the same; α for Nichrome at 800°C is 4.0×10^{-4}/°C.

60P. An electron linear accelerator produces a pulsed beam of electrons. The pulse current is 0.50 A and the pulse duration 0.10 μs. (*a*) How many electrons are accelerated per pulse? (*b*) What is the average current for a machine operating at 500 pulses/s? (*c*) If the electrons are accelerated to an energy of 50 MeV, what are the average and peak power outputs of the accelerator?

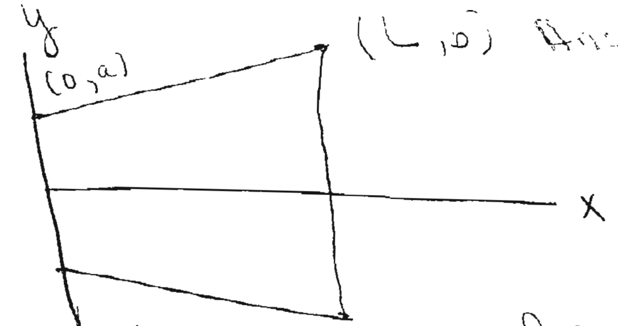
over 1 sec

15. (II) (*a*) Show that if a straight wire of cross-sectional area A lies along the x axis, the rate at which charge flows is given by

$$\frac{dq}{dt} = -\sigma A \frac{dV}{dx},$$

where dV/dx is the potential gradient, and σ is the conductivity. (*b*) Make an analogy to heat conduction (Section 20–7 and Eq. 20–2). Would you expect σ and k (thermal conductivity) to be related?

+3.



Put a coordinate axis on the resistor

$r(x) \equiv$ radius of resistor at x

$\pi (r(x))^2 =$ cross sectional area at x

$$m = \frac{b-a}{L-0}$$

$$y - a = \frac{b-a}{L}(x-0)$$

$$r(x) = y = \frac{b-a}{L}x + a$$

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

$$dR = \rho \frac{dL}{A}$$

$$R = \rho \int_0^L \frac{dx}{\pi\left(\frac{b-a}{L}x + a\right)^2} = \frac{\rho}{\pi}\int_0^L \frac{dx}{(Kx+a)^2}$$

$$= -\frac{\rho}{\pi K}\left(\frac{1}{Kx+a}\right)\Bigg|_0^L$$

$$= -\frac{\rho}{\pi\left(\frac{b-a}{L}\right)}\left[\frac{1}{KL+a} - \frac{1}{a}\right]$$

$$= -\frac{\rho L}{\pi(b-a)}\left[\frac{a - KL - a}{a\left[\left(\frac{b-a}{L}L\right) + a\right]}\right]$$

$$= \frac{+\rho L\, KL}{\pi(b-a)\,a(b)} = \frac{\rho L^2\,\frac{b-a}{L}}{\pi(b-a)\,ab}$$

$$\boxed{R = \frac{\rho L}{\pi a b}}$$

If $a = b$

b) $R = \frac{\rho L}{\pi a^2} = \frac{\rho L}{A}$ same as before

46E) $P = iV = (7\times10^{-3})(80\times10^{3}) = \underline{560 \text{ WATTS}}$

49E) $P = \frac{V^2}{R} = \frac{(120)^2}{14} = 1029 \text{ WATTS}$

A)

B) $P = \frac{\Delta E}{\Delta t}$ $\Delta E = P\Delta t = (1.03\text{ kw})(5\text{h}) = 5.15 \text{ kw.h}$

Hence the cost is $(5.15\text{ kw.h})(5¢) = \underline{25.75 \text{ CENT}}$

56P)

A) $P = Vi$

$1850 = (1150)\, i$

$i = 10.7 \text{ amps}$

B) $V = IR$

$115 = 10.7 R$

$\boxed{R = 10.6\,\Omega}$

c) $\Delta E = P\Delta t = (1250\text{ J/s})(3600\text{s}) = \underline{4.5\times10^{6} \text{ joules}}$

58)

$$\rho - \rho_0 = \rho_0 \alpha (T - T_0)$$

$$\frac{\rho - \rho_0}{\rho_0} = 4 \times 10^{-4} (200 - 800)$$

$$\frac{\rho}{\rho_0} - 1 = -2400 \times 10^{-4}$$

$$\frac{\rho}{\rho_0} - 1 = -.24$$

$$\frac{\rho}{\rho_0} = .76 = \frac{R}{R_0}$$

$$P = \frac{V^2}{R}$$

$$\frac{P}{P_0} = \frac{\frac{V^2}{R}}{\frac{V^2}{R_0}} = \frac{R_0}{R} = \frac{1}{.76} = 1.316$$

$$P = (1.316)(500) = \boxed{658 \text{ watts}}$$

60) $i = \frac{dq}{dt}$ $\quad q = i\,dt = (.5)(.1)10^{-6} = 5 \times 10^{-8}\,C$

A) $$\frac{5 \times 10^{-8}}{1.6 \times 10^{-19}} = \boxed{3.13 \times 10^{11} \text{ electrons}}$$

B) $Q = (500)(5 \times 10^{-8}) = \underline{25 \times 10^{-6}\,C}$

$$\bar{i} = \frac{q}{t} = \frac{25 \times 10^{-6}}{1} = \underline{25\mu \text{ amps}}$$

c) $V = \frac{K}{e} = \frac{50 \text{ MeV}}{1e} = 5 \times 10^7$ Volts

$$P = iV = (.5)(5 \times 10^7) = \boxed{2.5 \times 10^7 \text{ watts}}$$

$$\bar{P} = \bar{i} V = (25 \times 10^{-6})(5 \times 10^7) = \boxed{1250 \text{ watts}}$$

15) $V = E\ell$

$IR = E\ell$

$\frac{I\rho\ell}{A} = E\ell$

$E = \rho I / A$ but $E = -\frac{dU}{dx}$ $\quad I = \frac{dq}{dt}$

$-\frac{dU}{dx} = \frac{\rho}{A}\frac{dq}{dt}$

$-\frac{A}{\rho}\frac{dU}{dx} = \frac{dq}{dt}$

$$\boxed{-\sigma A \frac{dU}{dx} = \frac{dq}{dt}}$$

b) $\frac{dQ}{dt} = -KA\frac{dT}{dx}$ $\quad Q$ = thermal energy

T = temperature

Yes,

most materials that have high electrical conductivity also have a high thermal conductivity, Some materials are gold, platitum, silve