Chap17

Physics 1B Solutions

Easy

1.) From the definition of current: $I = \frac{\Delta Q}{\Delta t} \Rightarrow \Delta Q = I(\Delta t)$

This represents the amount of charge that would pass during a given time.

The amount of electrons will be given by: $\Delta Q = n|e| \Rightarrow n = \frac{\Delta Q}{|e|}$

$$\Rightarrow n = \frac{I(\Delta t)}{|e|} = \frac{(80\times10^{-3}A)(10\,min)\left(\frac{60s}{1min}\right)}{(1.602\times10^{-19}\,C/electron)} = \boxed{3.00\times10^{20}\text{ electrons}}$$

3.) From the definition of current: $I = \frac{\Delta Q}{\Delta t} \Rightarrow \Delta Q = I(\Delta t)$

This represents the amount of charge that would pass during a given time.

You can find the current from Ohm's Law: $\Delta V = IR \Rightarrow I = \frac{\Delta V}{R}$

$$\Rightarrow \Delta Q = \left(\frac{\Delta V}{R}\right)(\Delta t) = \frac{(1V)}{(10\Omega)}(20s) = \boxed{2.00\,C}$$

8.) Start with the hint that each atom supplys an electron.

We want the number of electrons per cubic meter.

Start with density, $\rho \Rightarrow \rho = 2.7\frac{g}{cm^3}\cdot\frac{(100cm)^3}{1m^3}\cdot\frac{1kg}{1000g} = 2700\,kg/m^3$

$$\Rightarrow \rho = \frac{Mass}{Vol.} = \frac{(\text{Mass per atom})(\text{\# of atoms})}{1m^3} \Rightarrow \frac{\text{\# of atoms}}{m^3} = n = \frac{\rho}{(\text{Mass per atom})}$$

$$\Rightarrow n = \frac{\rho}{(\text{Atomic Mass}/N_A)} = \frac{\rho N_A}{(\text{Atomic Mass})} = \frac{(2700\,kg/m^3)(6.02\times10^{23}/mole)}{(26.98\,g/mole)\left(\frac{1kg}{1000g}\right)} = 6.02\times10^{28}/m^3$$

Current in a conductor is given by:

$$I = nqV_dA \Rightarrow V_d = \frac{I}{nqA} = \frac{I}{neA} = \frac{5A}{(6.02\times10^{28}/m^3)(1.60\times10^{-19}C)(4\times10^{-6}m^2)}$$

$$\Rightarrow V_d = \boxed{1.3\times10^{-4}\,m/s}$$

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11.) Use Ohm's Law: $\Delta V = IR \Rightarrow \Delta V_{max} = I_{max} R$

For dry skin $\Rightarrow \Delta V_{max} = (80\times10^{-6}A)(4\times10^{5}\Omega) = \boxed{32V}$

For wet skin $\Rightarrow \Delta V_{max} = (80\times10^{-6}A)(2000\Omega) = \boxed{0.16V}$

13.) Start with the equation for calculating the resistence from a conductor $\Rightarrow R = \rho\frac{L}{A}$

Assume that the wire is a cylinder $\Rightarrow$ Area is circular $\Rightarrow A = \pi r^2$

$$\Rightarrow R = \rho\frac{L}{A} = \rho\frac{L}{\pi r^2} \Rightarrow r^2 = \frac{\rho L}{\pi R} \Rightarrow r = \sqrt{\frac{\rho L}{\pi R}}$$

To find diameter $\Rightarrow d = 2r$ and we can find the ρ of tungsten $= 5.6\times10^{-8}\Omega m$

$$\Rightarrow d = 2r = 2\sqrt{\frac{\rho L}{\pi R}} = 2\sqrt{\frac{(5.6\times10^{-8}\Omega m)(0.02m)}{\pi\,(0.050\Omega)}} = \boxed{1.7\times10^{-4}m}$$

20.) As the question suggests use: $R = R_o[1+\alpha(T-T_o)]$

For tungsten, $\alpha = 4.5\times10^{-3}\,(C^\circ)^{-1}$

$$\Rightarrow \frac{R}{R_o} = 1+\alpha(T-T_o) \Rightarrow \frac{R}{R_o}-1 = \alpha(T-T_o) \Rightarrow \frac{1}{\alpha}\left(\frac{R}{R_o}-1\right) = T-T_o$$

$$\Rightarrow T = T_o + \frac{1}{\alpha}\left(\frac{R}{R_o}-1\right) = 20^\circ C + \frac{1}{4.5\times10^{-3}(C^\circ)^{-1}}\left(\frac{140\Omega}{19\Omega}-1\right) = 20^\circ C + 1400^\circ C$$

$\Rightarrow T = \boxed{1400^\circ C}$ ← two significant figures

23.) First, we need to find the resistance at $80^\circ C$.

Use $R = R_o[1+\alpha(T-T_o)]$; For carbon, $\alpha = -0.5\times10^{-3}(C^\circ)^{-1}$

$$\Rightarrow R = 200\Omega[1+(-0.5\times10^{-3}(C^\circ)^{-1})(80^\circ C - 20^\circ C)] = 200\Omega(0.97)$$

$\Rightarrow R = 194\Omega$

To find current use Ohm's Law: $I = \frac{\Delta V}{R} = \frac{5V}{194\Omega} = \boxed{0.026A}$

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31.) Use the equations for power delivered to an element

$$P = I(\Delta V) \Rightarrow I = \frac{P}{\Delta V} = \frac{600W}{120V} = \boxed{5.0A}$$

Use Ohm's Law to find resistence: $R = \frac{\Delta V}{I} = \frac{120V}{5A} = \boxed{24\Omega}$

33.) We need to calculate the maximum power that can be dissipated in the circuit is: $P_{max} = (\Delta V) I_{max}$

$$\Rightarrow P_{max} = (120V)(15A) = 1.8 \times 10^3 W$$

Since each light bulb consumes 100W

$$\Rightarrow \#\text{ of lightbulbs} = \frac{1.8 \times 10^3 W}{100W} = 18. \Rightarrow$$

At most $\boxed{\text{18 lightbulbs}}$ can be operated.

45.) Turning to the definition of power: $P = \frac{\Delta E}{\Delta t}$

How much energy can we save by using the 11 W lamp?

$$\Delta E = (P_{saved}) \cdot \Delta t = (P_{high} - P_{low}) \Delta t = (40W - 11W)(100 hrs)$$

$$\Rightarrow \Delta E = 2.9 \text{ kW(hrs)}$$

Money saved $= (\Delta E) \cdot rate = 2.9 \text{ kW(hrs)} \cdot \$0.080/\text{kW(hrs)} = \boxed{\$0.23} = 23 \text{cents}$

52.) The bird is basically standing between a resistor. A cylindrical wire. We need to find the resistance between its legs: $\rho_{copper} = 1.7 \times 10^{-8} \Omega \cdot m$

$$\Rightarrow R = \rho \frac{L}{A} = (1.7 \times 10^{-8} \Omega \cdot m) \frac{0.04m}{\pi (0.011m)^2} = 1.79 \times 10^{-6} \Omega \qquad r_{wire} = \frac{0.022m}{2}$$

Use Ohm's Law to find ΔV: $\Delta V = IR = (50A)(1.79 \times 10^{-6} \Omega) = \boxed{8.9 \times 10^{-5} V}$

Chap 17

Medium

12.) First, let's find the total of volume of copper that we have:

(a.) density $\rightarrow \rho_{cu} = \frac{M}{Vol.} \Rightarrow Vol. = \frac{M}{\rho_{cu}} = \frac{1\times10^{-3}kg}{8.92\times10^{3}kg/m^3} = 1.12\times10^{-7}m^3$

density $\rightarrow \rho_{cu}$

With the wire we will make a long, thin cylinder with length L and area A

$\Rightarrow Vol. = L*A = 1.12\times10^{-7}m^3$

But we also know the resistance of the wire

$\Rightarrow R = \rho\frac{L}{A} = 0.5\Omega \Rightarrow A = \rho\frac{L}{0.5\Omega} = (1.7\times10^{-8}\Omega\cdot m)\frac{L}{0.5\Omega} = (3.4\times10^{-8}m)L$

Putting this back into the volume equation

$\Rightarrow L(3.4\times10^{-8}m)L = 1.12\times10^{-7}m^3 \Rightarrow L^2 = \frac{1.12\times10^{-7}m^3}{3.4\times10^{-8}m} = 3.29m^2$

$\Rightarrow L = \boxed{1.82m}$

(b.) $\Rightarrow L*A = 1.12\times10^{-7}m^3 \Rightarrow A = \frac{1.12\times10^{-7}m^3}{1.82m} = 6.15\times10^{-8}m^2$

$\Rightarrow \pi r^2 = 6.15\times10^{-8}m^2 \Rightarrow r^2 = \frac{6.15\times10^{-8}m^2}{\pi} \Rightarrow r = \sqrt{\frac{6.15\times10^{-8}m^2}{\pi}}$

$\Rightarrow r = 1.4\times10^{-4}m \Rightarrow$ diameter $= 2r = 2(1.4\times10^{-4}m) = \boxed{2.8\times10^{-4}m}$

19.) When the wire is re-made its volume remains constant ($r_f = 0.25r_0$)

$\Rightarrow Vol_0 = Vol_f \Rightarrow A_0L_0 = A_fL_f \Rightarrow \pi r_0^2L_0 = \pi r_f^2L_f$

$\Rightarrow L_f = \frac{r_0^2}{r_f^2}L_0 = \frac{r_0^2}{(0.25r_0)^2}L_0 = \frac{r_0^2}{(0.0625)r_0^2}L_0 = 16L_0$

With these new values we can calculate the new resistance:

$R_f = \rho\frac{L_f}{A_f} = \rho\frac{16L_0}{\pi r_f^2} = \rho\frac{16L_0}{\pi(0.25r_0)^2} = \frac{16}{(0.0625)}\rho\frac{L_0}{\pi r_0^2} = 256\left(\rho\frac{L_0}{A_0}\right)$

original resistance R_0

$\Rightarrow R_f = 256(R_0) = 256(1\Omega) = \boxed{256\Omega}$

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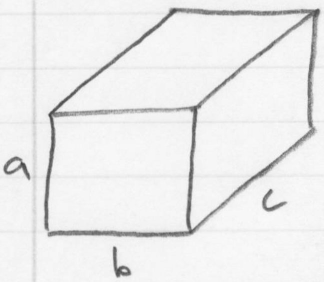
Medium

18 Rectangular block of copper $\left(\rho = 1.7\times10^{-8}\ \Omega\cdot m\right.$ page 576$\left.\right)$



$a = 10$ cm
$b = 20$ cm
$c = 40$ cm

Powered by 6V source

ⓐ max current? Using Ohm's law $(V=IR)$

we have $I = \frac{V}{R}$; since V is constant,

we will get I_{max} when R is minimum.

Recall $R=\rho l/A \rightarrow$ minimize it $\rightarrow R=\rho l_{min}/A_{max}$

Thus we let $l=a=.1m$ & $A=bc=.08\ m^2$

Finally $I = V/R_{min} = V/(\rho l_{min}/A_{max}) = VA_{max}/\rho l_{min} = \boxed{2.82\times10^{8}\ A}$

ⓑ likewise $I_{min} = V/R_{max} = V/(\rho l_{max}/A_{min})$

$= (6V)/[\rho(.4m)/(.1m)(.2m)] = \boxed{1.76\times10^{7}\ A = I_{min}}$

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$P = 1050$ W

$V = 120$ V

$l = 4.00$ m

$T = 320°C$

$A = ?$

material = nichrome

$\rho = 150 \times 10^{-8}$ Ωm

$\alpha = 0.4 \times 10^{-3}$ ($°C^{-1}$)

Formulas to use: $P = IV = V^2/R$ (1)

$R_0 = \rho_0 l / A$ (2) $\quad R = R_0 [1 + \alpha(T - 20°C)]$ (3)

We must combine the equations and solve for A

$$(1) + (3) \rightarrow R = \frac{V^2}{P} = R_0 [1 + \alpha(T - 20°C)] \quad (4)$$

$$(2) + (4) \rightarrow \frac{V^2}{P} = \rho_0 \frac{l}{A} [1 + \alpha(T - 20°C)]$$

solve for A

$$A = \frac{P}{V^2} \rho_0 l [1 + \alpha(T - 20°C)] \quad \text{Now plug in}$$

$$A = \frac{(1050\,W)}{(120\,V)^2} (150 \times 10^{-8}\ \Omega m)(4\,m)[1 + .4 \times 10^{-3}(300)]$$

$$\boxed{A = 4.9 \times 10^{-7}\ m^2}$$

Chap 17 Physics 1B Solutions

Medium

38 $V = 120\,V$ nichrome

$T_i = 20°C$ $\rho = 1.50 \times 10^{-8}\ \Omega m$

$I_i = 1.8\,A$ $\alpha = 0.4 \times 10^{-3}\ (°C^{-1})$

$T_f = ?$

$I_f = 1.53\,A$

(a) Find power converted at operating temp (T_f)

$$P = IV = (1.53\,A)(120\,V) = \boxed{184 \text{ watts}}$$

(b) Find T_f; we know voltage stays constant so

$$V = I_i R_i = I_f R_f \rightarrow \frac{I_i}{I_f} = \frac{R_f}{R_i} = 1.18$$

$$R_f = R_i\,[1 + \alpha(T_f - T_i)]$$ This works b/c $T_i = 20°C$

$$\frac{R_f}{R_i} = 1.18 = 1 + \alpha(T_f - 20)$$

$$\frac{(1.18 - 1)}{\alpha} + 20°C = T_f = \boxed{461°C = T_f}$$

Chap 17

Medium

35.) How much energy did it take to boil the water?

$$\Delta E = Q = m c_{H_2O} \Delta T = (0.5 kg)(4186 \tfrac{J}{kg\cdot °C})(100°C - 23°C)$$

$$\Rightarrow \Delta E = 1.61 \times 10^5 J$$

How much power does the heating element deliver?

$$P_{del.} = (\Delta V) I = (120V)(2A) = 240W = 240 \tfrac{Joules}{sec.}$$

Going back to the definition of power: $P = \frac{\Delta E}{\Delta t} \Rightarrow \Delta t = \frac{\Delta E}{P}$

$$\Rightarrow \Delta t = \frac{(1.61 \times 10^5 J)}{240\ J/s} = \boxed{671 sec} \text{ or } 11 min \text{ and } 11 sec.$$

39.) When measuring the total power loss through the cable use:

$P = I^2 R$ but here we have a power loss per unit length

$$\Rightarrow P/L = I^2 R/L \Rightarrow R/L = \frac{P/L}{I^2} = \frac{2\ W/m}{(300A)^2} = 2.22 \times 10^{-5}\ \Omega/m$$

We can turn to the resistivity equation to find: $\rho_{copper} = 1.7 \times 10^{-8} \Omega\text{-}m$

$$R = \rho L/A \Rightarrow R/L = \frac{\rho}{A} \Rightarrow A = \rho/_{R/L} = \frac{1.7 \times 10^{-8} \Omega m}{2.22 \times 10^{-5} \Omega/m} = 7.66 \times 10^{-4} m^2$$

$$\Rightarrow \pi r^2 = 7.66 \times 10^{-4} m^2 \Rightarrow r = \sqrt{\frac{7.66 \times 10^{-4} m^2}{\pi}} = \boxed{0.016m} = 1.6 cm$$

41.) How much total power is converted by the clocks?

$$P_{tot.} = (\#\text{ of clocks})(\text{Power}/\text{clock}) = (270 \times 10^6)(2.5W) = 6.75 \times 10^8 W$$

This means that in one hour: $P = \frac{\Delta E}{\Delta t} \Rightarrow \Delta E = P(\Delta t)$

$$\Rightarrow \Delta E = (6.75 \times 10^8 W)(3600s) = 2.43 \times 10^{12} J$$

Since coal plants are only 25% efficient, must make 4 time energy

$$\Rightarrow E_{coal} = 4(2.43 \times 10^{12} J) = 9.72 \times 10^{12} J$$

Chap 17

Medium

41.) It is given that it takes 1 kg of coal to produce 33×10^{6} J

(conti.) So, to produce 9.72×10^{12} J $\Rightarrow$ mass $= \dfrac{9.72\times10^{12}\,J}{33\times10^{6}\,J/kg} = 2.95\times10^{5}\,kg$

One metric ton is defined to be 1,000 kg

$\Rightarrow$ mass in metric tons $= \dfrac{2.95\times10^{5}\,kg}{1000\,kg/\text{metric ton}} = \boxed{295 \text{ metric tons}}$

55.) Use the equation for the power delivered to an element:

a. $P = I(\Delta V) \Rightarrow I = \dfrac{P}{\Delta V} = \dfrac{8\times10^{3}\,W}{12\,V} = \boxed{667\,A}$

b. Using the definition of power: $P = \dfrac{\Delta E}{\Delta t} \Rightarrow \Delta E = P(\Delta t)$

$\Rightarrow \Delta t = \dfrac{\Delta E}{P} = \dfrac{2\times10^{7}\,J}{8\times10^{3}\,W} = 2.50\times10^{3}\,s$

Since the car moves at a steady $20\,m/s \Rightarrow a = 0 \Rightarrow V = \dfrac{d}{t}$

$\Rightarrow d = V * t = (20\,m/s)(2.50\times10^{3}\,s) = 5.0\times10^{4}\,m = \boxed{50\,km}$

56.) The amount of volume available to make a resistor is:

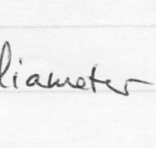
a. $\rho = \dfrac{Mass}{Vol.} \Rightarrow Vol. = \dfrac{Mass}{\rho} = \dfrac{115\times10^{-3}\,kg}{2.70\times10^{3}\,kg/m^{3}} = 4.26\times10^{-5}\,m^{3}$

Density

We are making a cylinder whose height equals the diameter

$\Rightarrow Vol. = \pi r^{2} h = \pi\left(\dfrac{d}{2}\right)^{2} d = \pi \dfrac{d^{2}}{4} d = \dfrac{\pi d^{3}}{4}$

$\Rightarrow d = \sqrt[3]{\dfrac{4(Vol.)}{\pi}} = \sqrt[3]{\dfrac{(4)(4.26\times10^{-5}\,m^{3})}{\pi}} = 0.03785\,m = L$



$\rho_{Al} = 2.82\times10^{-8}\,\Omega m$

The resistance between the ends will be given by:

$R = \rho_{al}\dfrac{L}{A} = (2.82\times10^{-8}\,\Omega\cdot m)\dfrac{d}{\pi d^{2}/4} = \dfrac{(2.82\times10^{-8}\,\Omega m)4}{\pi d} = \dfrac{(2.82\times10^{-8}\,\Omega m)4}{\pi(0.03785\,m)}$

$\Rightarrow R = \boxed{9.49\times10^{-7}\,\Omega}$

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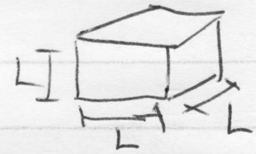
Medium



56.) If we now make the aluminum into a cube

(b) $\Rightarrow Vol = L^3 \Rightarrow L = (Vol.)^{1/3} = (4.26\times10^{-5} m^3)^{1/3} = 0.0349 m$

$$\Rightarrow R = \rho_{al}\frac{L}{A} = \frac{\rho_{al} L}{L^2} = \frac{(2.82\times10^{-8}\Omega m)}{(0.0349 m)} = \boxed{8.08\times10^{-7}\Omega}$$

60.) We want to calculate the maximum safe current:

Use the power loss equation, $P_{loss} = I^2 R$

$$\Rightarrow I^2 = \frac{P_{loss}}{R} \Rightarrow I = \sqrt{\frac{P_{loss}}{R}} = \sqrt{\frac{60W}{4\Omega}} = 3.87A$$

If the current goes above this value it will break the speaker. A 4 A fuse is included, but if the current reaches 3.95 A it will break the speaker before the fuse can protect it. Thus, the system $\boxed{\text{is not adequately protected.}}$ The recommendation is to switch to a 3.75 A fuse.

Hard

30.) Use the given hint and find R_o.

$\alpha_{plat.} = 3.92\times10^{-3}(°C^{-1})$

$\rho_{plat.} = 11\times10^{-8}\,\Omega\cdot m$ with $T = 0°C$

Use the equation: $R = R_o[1+\alpha(T-T_o)]$

$$\Rightarrow R_o = \frac{R}{[1+\alpha(T-T_o)]} = \frac{200\Omega}{(1+3.92\times10^{-3}(°C^{-1})(0°C-20°C)}$$

$$\Rightarrow R_o = \frac{200\Omega}{[1+(-0.0784)]} = 217\Omega$$

Now, apply this equation again but now with T = melting point

$$\Rightarrow R = R_o[1+\alpha(T-T_o)] \Rightarrow \frac{R}{R_o} = 1+\alpha(T-T_o) \Rightarrow \alpha(T-T_o) = \frac{R}{R_o} - 1$$

$$\Rightarrow T - T_o = \frac{\frac{R}{R_o}-1}{\alpha} \Rightarrow T = T_o + \frac{R/R_o - 1}{\alpha}$$

Chap 17
Hard

30.) Plugging in the values gives us:
(cont.)

$$T = 20^\circ C + \frac{253.8\Omega / 217\Omega - 1}{3.92\times 10^{-3}(^\circ C^{-1})} = 20^\circ C + 43.3^\circ C = \boxed{63.3^\circ C}$$

64.) The amount of volume available to make a resister is:

a. $\text{density} = \rho = \frac{\text{Mass}}{\text{Vol.}} \Rightarrow \text{Vol.} = \frac{\text{Mass}}{\rho} = \frac{50\times 10^{-3}\text{kg}}{(7.86\text{g}/\text{cm}^3)\left(\frac{1\text{kg}}{1000\text{g}}\right)\left(\frac{100\text{cm}}{1\text{m}}\right)^3} = 6.36\times 10^{-6}\text{m}^3$

For this cylindrical wire, $\text{Vol.} = AL = \pi r^2 L$

$$\Rightarrow A = \frac{\text{Vol.}}{L}$$

Use the resistivity equation for a resistor: $R = \rho \frac{L}{A}$

$$\Rightarrow R = \rho \frac{L}{\text{Vol.}/L} = \frac{\rho L^2}{\text{Vol.}} \Rightarrow L^2 = \frac{R(\text{Vol.})}{\rho} \Rightarrow L = \sqrt{\frac{R(\text{Vol.})}{\rho}}$$

$$\Rightarrow L = \sqrt{\frac{(1.5\Omega)(6.36\times 10^{-6}\text{m}^3)}{11\times 10^{-8}\,\Omega\cdot\text{m}}} = \boxed{9.3\text{m}}$$

b. We also know that: $A = \pi r^2 = \frac{\text{Vol.}}{L} \Rightarrow r^2 = \frac{\text{Vol}}{\pi L} \Rightarrow r = \sqrt{\frac{\text{Vol.}}{\pi L}}$

$$\Rightarrow r = \sqrt{\frac{6.36\times 10^{-6}\text{m}^3}{\pi(9.3\text{m})}} = 4.66\times 10^{-4}\text{m}$$

$$\text{diameter} = 2r = \boxed{9.3\times 10^{-4}\text{m}} = 0.93\text{mm}$$