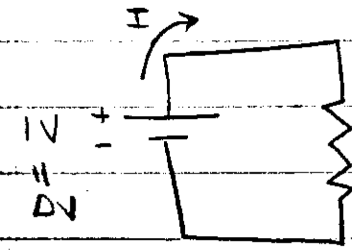
HW #3 SOL^N - ADAM COHEN

Chapter 17 - Circuits

(3)



Ohm's Law

$$\Delta V = I R$$

$$\Rightarrow I = \frac{\Delta V}{R} = \frac{1V}{10\Omega}$$

$$I = 0.1\ A$$

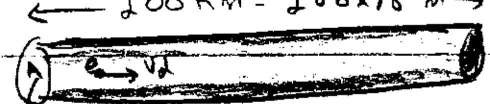
$$\text{current} = I = \frac{\text{charge}}{\text{time}} = \frac{Q}{t}$$

$$\Rightarrow Q = It = (0.1\ A)(20\ s)$$

$$\boxed{Q = 2\ C}$$

(7)

$L = 200\ Km = 200 \times 10^3\ m$



$2cm = 0.02\ m = d$

$\Rightarrow r = 0.01 m$

$I = 1000\ A$

n = charge density = $8.5 \times 10^{28}\ e^-/m^3$

current is related to:

$$I = (\text{number density})\left(\frac{\text{charge}}{\text{electron}}\right)(\text{drift speed})(\text{Area})$$

$$I = n q v_d A$$

→ A = cross sectional area $= \pi r^2 = \pi\left(\frac{d}{2}\right)^2$

$$\Rightarrow v_d = \frac{I}{nqA} = \frac{(1000A)}{(8.5\times10^{28}/m^3)(1.6\times10^{-19}C)[\pi(0.01m)^2]}$$

$$= 2.3\times10^{-4}\ m/s$$

recall : $\text{Speed} = \frac{\text{distance}}{\text{time}}$

$v_d = \frac{L}{t}$ where L is length of wire

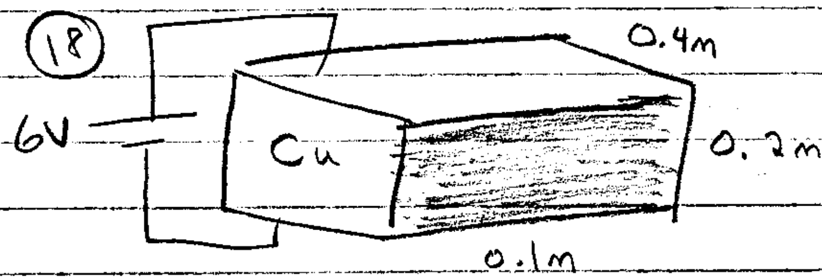
$\Rightarrow t = \frac{L}{v_d} = \frac{200 \times 10^3 \, \cancel{m}}{2.34 \times 10^{-4} \, \cancel{m}/s} = \underline{\underline{8.55 \times 10^8 \, s}}$

Now convert seconds $\longrightarrow$ years.

$$\left(8.55 \times 10^8 \, \cancel{s}\right) \times \left(\frac{1 \text{ year}}{3.157 \times 10^7 \, \cancel{s}}\right) \approx \boxed{27 \text{ yrs}}$$

It takes a long time ~~for~~ the actual electrons to move.

(18)



$\rho = 1.7 \times 10^{-8} \, \Omega \cdot m$ = resistivity of Copper

resistance $R = \rho \frac{l}{A}$, so resistance increases w/ length, and decreases w/ area.

It this problem there are 3 different possible resistances. The biggest resistance is associated with the largest value of $\frac{l}{A}$, and the opposite holds true:

$$\begin{cases} \left(\frac{L}{A}\right)_1 = \frac{(0.2m)}{(0.4m)(0.1m)} = 5\ m^{-1} \\ \left(\frac{L}{A}\right)_2 = \frac{(0.1m)}{(0.4m)(0.2m)} = 1.25\ m^{-1} = \left(\frac{L}{A}\right)_{min} \\ \left(\frac{L}{A}\right)_3 = \frac{(0.4\ m)}{(0.2)(0.1)m^2} = 20\ m^{-1} = \left(\frac{L}{A}\right)_{max} \end{cases}$$

so,

$$\begin{cases} R_{Min} = \rho\left(\frac{L}{A}\right)_{min} = (1.7 \times 10^{-8}\,\Omega \cdot \cancel{m})\left(1.25\frac{1}{\cancel{m}}\right) \\ = 2.1 \times 10^{-8}\ \Omega \\ R_{MAX} = \rho\left(\frac{L}{A}\right)_{max} = (1.7 \times 10^{-8}\,\Omega \cdot \cancel{m})\left(20\frac{1}{\cancel{m}}\right) \\ = 3.4 \times 10^{-7}\ \Omega \end{cases}$$

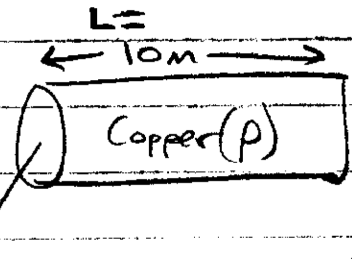
Now use Ohm's Law, $\Delta V = IR$ OR $I = \frac{\Delta V}{R}$

- more resistance means less current so:

$$I_{Min} = \frac{\Delta V}{R_{Max}} = \frac{6V}{3.4 \times 10^{-7}\,\Omega} = \boxed{2.8 \times 10^{8} A}$$

Also, $I_{Max} = \dfrac{\Delta V}{R_{min}} = \dfrac{6\,V}{(2.1\times10^{-8}\,\Omega)} = \boxed{1.8\times10^{7}\,A}$

(25)



$\rho = 1.7\times10^{-8}\,\Omega\cdot m$
at $T_0 = 20°C$

$A = (3\,\cancel{mm^2})\left(\dfrac{1\,m}{1000\,\cancel{mm}}\right)^2 = 3\times10^{-6}\,m^2$ in S I -units

at $T_0 = 20°C$, $R_0 = \dfrac{\rho L}{A} = \dfrac{(1.7\times10^{-8})(10)}{(3\times10^{-6})}\,\Omega$

$R_0 = 5.67\times10^{-2}\,\Omega$

(a) The resistance changes as:

$R = R_0\left[1 + \alpha(T - T_0)\right]$

where $\alpha = 3.9\times10^{-3}\ °C^{-1}$ for Copper

at 30°C, $T - T_0 = 10°C$

so $R = R_0\left[1 + (3.9\times10^{-3})(10)\right]$

$\boxed{R = 5.89\times10^{-2}\,\Omega}$ at 30°C

(b) at 10°C, $T - T_0 = -10°C$

...

$\boxed{R = 5.45\times10^{-2}\,\Omega}$ at 10°C

Notice resistance increases with temperature for Copper.

30 $\begin{cases} \text{at} \quad T = 0°C, & R = 200\ \Omega \\ \text{at} \quad T = ?, & R = 253.8\ \Omega \end{cases}$

for Platinum, $\alpha = 3.92 \times 10^{-3}\ \frac{1}{C°}$ by table 17.7, but this is @ $\underline{\underline{20°C}} = T_0$

use hint: what is R_0 at $T_0 = 20°C$:

$$R = R_0[1 + \alpha(T - T_0)] \qquad T = 0°, \ T_0 = 20°C$$

$$\Rightarrow R_0 = \frac{R}{1+\alpha(T-T_0)} = \frac{200\ \Omega}{1+(3.92\times10^{-3})(-20)}$$

$$R_0 = 217\ \Omega$$

Now, we can solve for the temperature for which $R = 253.8\ \Omega$, but first some algebra:

$$R = R_0[1 + \alpha(T - T_0)]$$

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

$$\frac{R}{R_0} - 1 = \alpha(T - T_0)$$

$$\frac{\left(\frac{R}{R_0} - 1\right)}{\alpha} = T - T_0$$

$$\Rightarrow T = \frac{\left(\frac{R}{R_0} - 1\right)}{\alpha} + T_0$$

Now plug in:

$$T = \frac{\left(\frac{253.8\,\Omega}{217\,\Omega} - 1\right)}{\left(3.92\times10^{-3}\,(°C)^{-1}\right)} + 20°C$$

$$\boxed{T = 63.3\,°C}$$

33 power is given by:

$$P = \Delta V I.$$

So maximum power is given at maximum current $(I = 15A)$

$$\Rightarrow P = (120V)(15A) = 1800\,W$$

Each bulb uses 100W, so $\boxed{\text{18 bulbs}}$ will <u>just</u> trip the circuit.

40 at $I = 1.75A$ and $\Delta V = 120V$,
the power input is:

$$P_{in} = I\,\Delta V = (1.75A)(120V) = 210W$$

$$= 0.210\ KW$$

If the rate is:

$$0.060\ \$/KW\cdot(hrs)$$

$\Rightarrow$ (total operating cost) = (energy used)(rate)

$$= (0.210\ \cancel{KW} \times 4\ \cancel{hrs})\left(0.060\ \frac{\$}{\cancel{KW\cdot hrs}}\right)$$

$$= \boxed{\$\ 0.05} \text{ in 4hrs of use.}$$

$$= 5¢$$

- efficiency is defined at the ratio of power output to power input.
- We know $P_{in} = 0.210\ KW$
- we need to convert $P_{out} = 0.20\ hp$ to SI units (KW).

$$P_{out} = (0.20\ \cancel{hp})\left(0.746\ \frac{KW}{\cancel{hp}}\right) = 0.149\ KW$$

So

$$\text{efficiency} = \frac{0.149}{0.210} = \boxed{71\%}$$

(44) The house use \$200 worth of energy in January.
How energy does this cooresphond to?

$$\text{energy} = E = \frac{\text{cost}}{\text{rate}} = \frac{200\,\cancel{\$}}{0.08\,\cancel{\$}/\text{KW}\cdot\text{hr}} = 2.5\times10^3\ \text{KW}\cdot\text{hr}$$

We know the rate at which energy is input to the furnace (this is the def^{n} of power): $P = 24\,\text{KW}$.
How many hours was the furnace on to use 2.5×10^3 KW·hr?

$$E = P\cdot t \Rightarrow t = \frac{E}{P} = \frac{2.5\times10^3\ \cancel{\text{KW}}\cdot\text{hr}}{24\,\cancel{\text{KW}}}$$

$$= 104\ \text{hr}$$

So,
the furnace was on for 104 hr is January.
There are 31 days in January, so on average, the furnace is on

$$\frac{104\,\text{hr}}{31\ \text{days}} = \boxed{3.36\ \text{hours/day}}$$

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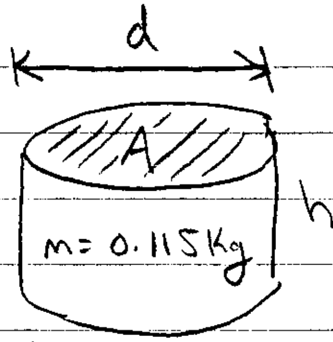

$d = h$; $A = \pi\left(\frac{d}{2}\right)^2$

- to know the Resistance ($R = \rho\frac{L}{A}$), we need to know: ρ (look it up in a table), L (here, $L = h$, the distance the current will flow) and A (the cross-sectional area $= \pi\left(\frac{d}{2}\right)^2$)

- to get d, h, we need to know the volume of the cylinder.

- Since we know the mass, we can determine volume if we look up the density of Al.

$$* \text{ density} = 2.7\times10^3 \text{ Kg/m}^3 *$$

$$\Rightarrow V = \frac{m}{\text{density}} = \frac{0.115 \cancel{\text{Kg}}}{2.7\times10^3 \cancel{\text{Kg}}/\text{m}^3} = 4.26\times10^{-5} \text{ m}^3$$

- now, for a cylinder volume is:

$$V = A\cdot h = \pi\left(\frac{d}{2}\right)^2 h = 4.26\times10^{-5} \text{ m}^3$$

- But recall, here $d = h$ so ...

$$\frac{\pi d^3}{4} = 4.26\times10^{-5} \text{ m}^3$$

- Solving for d on a hand-calculator,

$$d = h = 0.03785\,m$$

- So that makes the resistance R:

$$R = \rho\frac{L}{A} = \rho\frac{\cancel{d}}{\left(\frac{\pi d^2}{4}\right)} = \frac{4\rho}{\pi d}$$

$$\boxed{R = 9.49 \times 10^{-7}\,\Omega} \quad (w/\ \rho = 2.82 \times 10^{-8}\,\Omega m)$$

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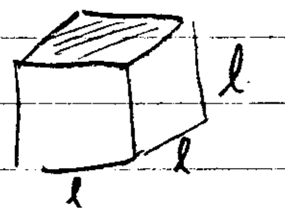
for a cube,



$$\text{Volume} = l^3$$

$$\Rightarrow l = V^{1/3} = (4.26 \times 10^{-5}\,m^3)^{1/3}$$

$$l = 0.0349\,m$$

$$\Rightarrow A = l^2 = 0.0012\,m^2$$

so $$R_{\square} = \rho\frac{L}{A} = \rho\frac{l}{l^2} = \frac{\rho}{l}$$

$$= \left(\frac{2.82 \times 10^{-8}\,\Omega \cdot \cancel{m}}{0.0349\,\cancel{m}}\right)$$

$$\boxed{R = 8.07 \times 10^{-7}\,\Omega}$$

So, the cylinder is more resistive than the cube!