Problems From Text: Ch 17: 4, 14, 20, 34, 54

17.4 : The definition of current is the amount of charge flowing through a cross section per unit time.

So the amount of electrons flowing past a cross-section of the picture tube in one second is

$$\begin{pmatrix}\text{\# of electrons} \\ \text{flowing through} \\ \text{cross-section of} \\ \text{the picture tube} \\ \text{in one second}\end{pmatrix} = \underbrace{(\text{current}) \times (1 \text{ second})}_{\substack{\text{total charge} \\ \text{flowing through} \\ \text{in 1 second}}} \times \left(\frac{1 \text{ electron}}{\text{charge of 1 electron}}\right)$$

$$= (60.0 \times 10^{-6} \text{ A}) \times (1 \text{ sec}) \times \left(\frac{1 \text{ electron}}{1.6 \times 10^{-19} \text{ C}}\right)$$

$$= 3.75 \times 10^{14} \text{ electrons}$$

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17.14 :

$$R = \rho \, \ell / A = (1.7 \times 10^{-8} \, \Omega \cdot \text{m}) \frac{(15 \text{ m})}{\pi \, (0.512 \times 10^{-3} \text{ m})^2}$$

$$= 0.310 \, \Omega$$

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17:20 :

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

We know $R$, $R_0$, $\alpha$, and $T_0$, and solve for $T$.

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

$$R/R_0 - 1 = \alpha (T - T_0)$$

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

$$T = \frac{R}{\alpha R_0} - \frac{1}{\alpha} + T_0 = \frac{1}{(4.5 \times 10^{-3} \, ^\circ\text{C}^{-1})} \left(\frac{140 \, \Omega}{19 \, \Omega} - 1\right) + 20^\circ\text{C}$$

$$= 1435 \, ^\circ\text{C}$$

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17.34 :

The total resistance of the power line is

$$0.31\ \Omega/\text{km} \cdot 160\ \text{km} = 49.6\ \Omega$$

The power loss due to resistance of the power line is

$$P_{loss} = I^2 R = (1000\ A)(49.6\ \Omega) = 4.96 \times 10^4\ W.$$

Why do we not use $P = IV$ ? Had we try it, we would get

$$P = I V = (1000\ A)(700\ kV) = 7 \times 10^5\ W$$

But this is the total power delivered, not the power loss.
The fraction of power lost is

$$\begin{pmatrix}\text{fraction of} \\ \text{power} \\ \text{loss}\end{pmatrix} = \frac{4.96 \times 10^4\ W}{7 \times 10^5\ W} \sim 7\ \%$$

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17.54 :

$\Delta Q = I\ \Delta t$ , and in this case we should think of change as area under the graph.

$$\Delta Q = \tfrac{1}{2}(1s)(6A) + (1s)(6A) + \tfrac{1}{2}(1s)(6A)$$
$$= 12\ C$$

The constant current $\bar{I}$ that delivers this amount of charge in 5 seconds is.

$$\bar{I} = \frac{12\ C}{5\ s} = 2.4\ A$$

Problems From Handout

## Saving on electric bill

(a) Answers will vary, so I will just show one example. Suppose we have 20 bulbs in the house, each is used 8 hrs per day. Each bulb would save 65 W in usage. The total energy saved in one month is:

$$E = (20 \text{ bulbs})\left(65 \frac{W}{\text{bulb}}\right)\left(8 \frac{\text{hrs}}{\text{day}}\right)\left(30 \frac{\text{days}}{\text{month}}\right)$$

$$= 312 \text{ kW-hr.}$$

$$\text{\$-saved} = \left(11\ ¢/\text{kW-hr}\right)\left(312 \text{ kW-hr}\right) = \$34.32$$

(b)

$$(CO_2\text{-reduction}) = \left(0.9 \text{ kg}/\text{kW-hr}\right) * (312 \text{ kW-hr})$$

$$= 280 \text{ kg of } CO_2$$

## Cell-Membrane

(a) $|\vec{E}| = V/d = 70 \text{ mV}/8 \text{ nm} = \frac{70\times10^{-3} \text{ V}}{8\times10^{-9} \text{ m}} = 8.75\times10^{6} \text{ N/C}$

(b) With di-electric, the potential difference is decreased by a factor of 3, so electric field also decreases by a factor of 3.

$$|\vec{E}| = 2.92\times10^{6} \text{ N/C}$$

(e)

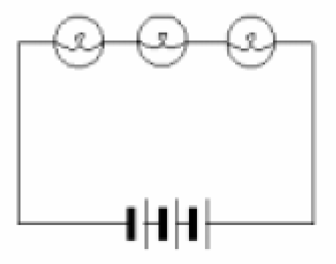
$$W = qV$$

$$= (1.6\times10^{-19} \text{ C})(70 \text{ mV}) = 1.12\times10^{-20} \text{ J}$$

A faster unit would simply be $W = 70$ meV

$= 70\times10^{-3}$ eV

# Tutorial Problem



Here's a circuit for you to consider, and I'm going to ask you to try to think about it in several ways. Each of the batteries is a 1.5 V battery, and the bulbs are all identical. (These both depict the same circuit. The overall question here is this: Which bulb, if any, would be the brightest? But I want you to answer it from three different ways of thinking about electricity.

a) Sometimes people think the reason there are two connections to the batteries is because a positive current flows out of one end and a negative current flows out of the other. It's when they hit each other that you get light. (Ampere had an idea just like that, in the early 1800s, known as Ampere's model of clashing currents.) How would someone thinking in this way answer the question?

One may think that only one light bulb would shine because all the oppositely charged particles would collide at one place. It may be hard to explain that all three bulbs light.

b) Consider an analogy to pulling a rope: Charge is like rope, moving charge is like moving rope, a battery is like someone pulling the rope to try to make it move, and a bulb is like something the rope rubs as it passes. How would someone using that analogy answer the question?

All three bulbs should shine equally using this analogy because all three bulbs rub against the rope in the same manner.

c) Consider an analogy to flowing air: Charge is like air, moving charge is like moving air, a battery is like an air pump with a high pressure output and low pressure input, and a bulb is like a whistle that constricts the flow of air a little. How would someone using that analogy answer the question?

In this analogy all three bulbs would again shine equally. The air flows from a place of high pressure to the place of low pressure with the same speed throughout the path. The speed at which the air flows through the whistle is the analog of brightness, and all three bulbs shine equally.

d) Now consider the model we discussed in class: metal consists of a fixed array of positive ions with an equal density of loose electrons so the overall metal is neutral. When an electric force is exerted on the material, the electrons flow in the metal like an incompressible fluid (something like water in a pipe). How would someone using this model answer the question?

In the flow of incompressible fluid, if the width of the tube in which the fluid is flowing through is constant, the speed of the fluid is the same. (What happens if one segment of the tube has fluid moving at a higher speed than another?) Using this analogy, the current (amount of fluid passing through a cross section per unit time) is the same at places where bulbs are placed, so all three bulbs shine equally.

e) When you were asked a similar question in tutorial (part II) with two bulbs, what was your intuition? Did you think one or the other of the bulbs would be brighter? Did your intuition correspond to one of the four models above or to something else? If something else, describe your reasoning. (If you didn't get to this part of the tutorial, read it over now and see what your intuition tells you.)

f) Where you surprised when you saw that the bulbs were of equal brightness? (If you didn't get to this part of the tutorial, if the bulbs are indeed identical, they will be of equal brightness when connected in series.) If so, were you able to reconcile your intuition with what you saw? Explain how or why not.