Phys122
HW 5: Due Thursday, March 9, 2006

Problems from the Text:
Chapter 17
4, 14, 20, 34, 54

Saving on your electric bill

a) Fluorescent bulbs deliver the same amount of light using much less power. If one kW-hr costs 11¢, estimate the amount of money you would save each month by replacing all the 75 W incandescent bulbs in your house by 10 W fluorescent ones. *Be sure to clearly state your assumptions, since grading on this problem will be mostly based on your reasoning, not on your answer.*

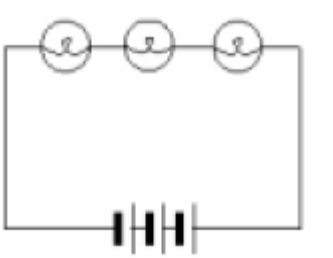
b) Assuming your electricity is generated at a coal fired power-station, producing 0.9kg CO_2 pollution per kW-hr, what is your monthly reduction of CO_2 emissions.

A cell membrane

The inner and outer surfaces of a cell membrane carry a negative and positive charge respectively. Because of these charges, a potential difference of about 70 mV exists across the membrane. The thickness of the membrane is 8 nm.

a. If the membrane were empty (filled with air), what would the magnitude of the electric field inside the membrane?
b. If the dielectric constant of the membrane is $\kappa = 3$ what would the field be inside the membrane?
c. Cells can carry ions across a membrane *against the field* ("uphill") using a variety of active transport mechanisms. One mechanism does so by using up some of the cell's stored energy converting ATP to ADP. How much work does it take to carry one sodium ion (charge = +e) across the membrane against the field?

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?

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?

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?

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?

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.