FREQUENTLY ASKED QUESTIONS

March 11, 2003

Administrative Questions

What will be on the next quiz?

I am not sure yet. Prof. Roland will let you know.

Can we get a bigger room?

I have requested one but we are at the mercy of room scheduling.

Content Questions

Can you explain the last problem on last week's pset, with the dielectrics?

This was a capacitor filled with two different types of dielectric with constants K_1 and K_2. You can treat this as two capacitors in parallel (they have the same potential difference across them). So the total capacitance is $C_1 + C_2$. Presence of a dielectric just means the capacitance is multiplied by the dielectric constant. Capacitor 1, which has area $A/2$, has capacitance $K_1\epsilon_0 A/2d$ and similarly for capacitor 2. Then the total capacitance is just the sum $(K_1 + K_2)\epsilon_0 A/2d$.

What causes resistance?

You can think of it as atoms "getting in the way" of electrons trying to move through a material. Electrons cruising through will frequently crash into atoms, and how often and how disruptively this happens depends on the nature of the material.

Can you explain "drift velocity"?

It's the average velocity of electrons moving in a conductor under the influence of an electric field. If you zoom in and look at the path of any individual electron, that path could be quite irregular and windy path as the electron bumps into atoms... at any given time it could be moving in any direction, and even sometimes moving background. But on average, the electrons move some distance forward per unit time, and the drift velocity describes this speed. A mechanical analogy is a tub of ping pong balls drifting down a hill strewn with boulders.

I'm still confused about resistivity.

Resistivity tells you the proportionality constant between current density and electric field ($J = E/\rho$); it's a *property of a given material*, and for that material tells you how hard it is for electrons to get through for some given applied field. Resistance on the other hand, is a *property of a particular object*, and depends on the intrinsic resistivity as well as the geometric shape. For a uniform wire, $R = \rho l/A$. As A gets larger, it's easier for electrons to get through, so resistance decreases. As l gets larger, it's harder for electrons to get through, so resistance increases.

I disagree with what you said in class; you *can* change the density of lead without changing its chemical properties e.g. compress it, cool it... so you can get the same mass even for a different volume.

You are completely correct that you can change the density of lead by pressure etc. In fact, similarly you can change the intrinsic resistivity of a material by heating or cooling, for example. So you can change resistance, too, by heating or cooling. However the problem we were considering had just a block of aluminum, under normal conditions and no external change. The point is that resistivity is a *property of the material.* It therefore is constant everywhere in the body ... temperature changes the property of the material. Resistance on the other hand, depends on *both* material, *and* shape of material. This is analogous to mass depending on both density and volume; the density is a *property of the material* ... temperature, pressure, etc, change the property of the material. Mass depends on both density (for whatever conditions specified) and shape.

Can you give some examples of resistivities of materials?

There's a table on p. 640 of your text. An example of a low resistivity material (a good conductor) is copper, with resistivity $1.68 \times 10^{-8}\ \Omega m$. An example of a high resistivity material (an insulator) is glass with resistivity $\sim 10^{10}\ \Omega m$.

How does changing the resistance affect potential difference and current?

Potential difference, resistance and current are related by Ohm's Law, $V = IR$. If voltage is fixed (e.g. for a battery), if you increase R, then I will decrease. If current is fixed, then increasing R will increase V.

What are the relevant equations for current?

What we covered today:

- How to relate current density to drift velocity: $I = nv_dAq$
- Definition of current density: $J = I/A$.
- "Microscopic" Ohm's Law, relating current density to field: $J = E/\rho$
- Relation of resistance to resistivity: $R = \rho l/A$.
- Ohm's Law: $V = IR$
- Resistors in series: $R_{\rm eq} = R_1 + R_2$, and in parallel: $1/R_{\rm eq} = 1/R_1 + 1/R_2$

Could you clarify the convention for direction of current?

Remember, positive charges going in one direction is equivalent to negative charges going in the other direction... these situations both achieve the same separation of charge. So electrons going (say) to the right is equivalent to positive charges going to the left. Here's another way of thinking of this: if you have electrons moving to the right, "absences of electrons" (kind of like positively charged "holes") are moving to the left. The *convention* is that the direction of current I is the direction that positive charges are going in. In most everyday situations, if you have a current, what's *really* happening is that electrons are moving. This is equivalent to positive charges moving in the opposite direction. So the current is *opposite* to the direction of movement of electrons. A confusing convention? Yes, but blame Ben Franklin.

You wrote that $I = nv_dAq$... so how come current didn't depend on area in the practice problem?

The current I (charge per time) through the slab in a steady state has to be the same throughout the slab, because charges can't build up or disappear. Although we wrote that $I = nv_dAq$ relating current to drift velocity, bigger A doesn't necessarily mean bigger current. Consider that n, the number of charge carriers per volume, and v_d, the drift velocity, could change as the resistor narrows. In normal materials n is fixed– it's a property of the material– but v_d is not fixed. Just as water pushed through a pipe gets faster as the pipe narrows in order to maintain constant flow rate, v_d increases as the resistor narrows. Imagine the fish swimming through: they swim faster through the narrower part, but the number of fish per time is the same. (Remember the "equation of continuity" $A_1V_1 = A_2V_2$ from fluids last semester? Same idea here).

In the practice problem, wouldn't B have more resistance, since R_B has less area, so there would be less current?

If you consider small slices of equal width d at B and at A, yes, the slice at A would have less resistance because it has more area. But the potential drop across the slice at A would be less than that at B... the electric field is smaller at A than B ($J_A < J_B$, and $J = E/\rho$.) The current must be constant since charges can't pop in and out of existence!

What is "AC"? Will we be covering it?

"AC" stands for "alternating current". It's what comes out of a wall socket. It's a current that varies in time according to a sine wave: it goes negative, then positive, then negative, etc. wiggling back and forth. You can think of this as electrons sloshing back and forth in a wire. We'll be covering this in much more detail in late April.

How are resistors used? Why would you want less current?

They are used in all kinds of ways– a resistor is a basic building block of a circuit. Sometimes you want more current, and sometimes you want less. Resistors help you create voltages of size you want, where you want them.

We'll see plenty of examples. In fact, the next example we'll see (this week I think) is the RC circuit, a resistor in combination with a capacitor, which we have already used for a timing circuit. Another example: you use large resistors at the outputs of your HVPS to lower the current so you don't get shocked!

Why is the brightness of a light bulb proportional to current?

Brightness depends on power (energy per time). We'll see in a bit that $P = VI$. So for a constant voltage, brightness is proportional to current.

I have no idea how to start the last pset problem.

This is an RC circuit problem. We'll get there soon. See section 26-4 of the text.

What is horsepower?

This is just a unit of power, 1 hp=746 W.

How do you deal with more complicated resistor networks?

Often you can do these by breaking the network down into pieces that you know how to calculate the equivalent resistance for. For instance, suppose you have two resistors in parallel, and then those two in series with another. First, calculate the parallel equivalent resistance. Then calculate that resistance in series with the other. See example 26-4 in your text, for instance.

Can you help with the CyberTutor dielectric problem?

Hints: see text example 24-8 for a similar problem. Think about the work-energy theorem.

Can you explain the last experiment problem?

This one needs a mostly qualitative answer... ignore "fringe effects". What happens to the area if you have two disks with holes in them?

Tidbits

Best joke from today's questionnaires

Papa Tomato, Mama Tomatoe and Baby Tomato are all walking down the street. The Baby Tomato starts falling behind, so the Papa Tomato goes back to him and squishes him, and says “catch up”!