FREQUENTLY ASKED QUESTIONS

March 18, 2003

Administrative Questions

What will be on the quiz?

A very good guide is Prof. Roland's review slides, available on the web.

Do we have to know about voltmeters and ammeters?

Yes, you should know generally what they do, and what an "ideal" ammeter or voltmeter is. You don't need to know all the details of the inner workings.

To what degree of complexity do we need to know about RC circuits?

You should understand qualitatively what happens when you charge or discharge a capacitor through a resistor, and also quantitatively, *i.e.* what the functions $Q(t)$, $I(t)$ and $V(t)$ are for each case, generally how one derives these functions (using the Loop Rule), and how to use them; you should be able to answer questions similar to the pset and practice quiz problems.

What do we need to know for experiment EF?

You need to understand the concepts, which draw on many of the general concepts we've seen, and answer questions similar to the experiment questions and practice quizzes.

Will AC be on the quiz?

I don't think so; we haven't really covered it.

Can we use a formula sheet? Can we put graphs? Kirchoff's Rules?

Yes, I think the rules are the same as before. I would guess graphs are OK, but you should check with Prof. Roland. I think Kirchoff's Rules are

OK, but Prof. Roland said no how-tos.

What do I do if I didn't get my pset back?

There seems to be an unusually large number of missing psets this semester. If you're missing one (and you think others in your section have gotten theirs back), email me your name, recitation number, slot you think you put the pset in, and missing pset number.

Do we have recitation Thursday?

Yes.

Content Questions

How do we figure out the capacitance of dielectrics in series?

Just use the formula for capacitors in series, and remember that a dielectric changes the capacitance by a factor K, $C = KC_0$.

What happens when a capacitor is taken off a battery? Does that change energy or capacitance?

If the capacitor's geometry or material does not change, capacitance is fixed. When a capacitor is taken off a battery, charge does not change (the charge has nowhere to go). The energy stored will not change either. If however, something else changes (like moving plates, or adding dielectric), capacitance may change, but the charge is still fixed.

What is the difference between inserting or removing a dielectric from a capacitor? What about when the battery is connected or disconnected?

When you insert dielectric, the capacitance increases by a factor K; if you remove it, the capacitance decreases. If the battery is disconnected, then Q is constant (but V is not necessarily). Energy stored is $Q^2/2C$, so if capacitance increases for fixed Q, energy stored decreases. On the other hand, if the battery is connected, Q is not constant but V is; then if you write energy stored as $CV^2/2$, you can see that energy stored increases if capacitance increases.

Does the brightness of a light bulb depend on power or current?

Well, both. Brightness is proportional to power dissipated. But since $P = I^2R$, if resistance is constant, then both power and brightness increase if I increases.

What is constant or not constant in parallel/series configurations, for resistors and capacitors?

Two circuit elements in parallel have the same potential difference across them (this is true for both resistors and capacitors). In a steady state situation, resistors in series have the same current through them. Capacitors in series have no current flow in a steady state, but they each have the same charge on them.

Can you clarify the meaning of power rating? Is it power rating or power that determines brightness?

"Power rating" is really a convention for specifying the resistance of a bulb. Please note that it *does not give the power dissipated* in the bulb, except for the special case of constant wall outlet voltage. The power rating of a bulb is the average power you get when the bulb is plugged in to a wall outlet (which is actually not constant voltage– it's alternating, but power is related to rms voltage... we'll see this later). For our purposes now, consider power rating to be the power for a particular fixed voltage. The actual power dissipated could be anything, depending on how the bulb is hooked up!!

Can you clarify the first practice quiz problem? Doesn't e contradict d?

No. Power rating *does not mean the same thing* as power dissipated. If bulb 1 has a power rating lower than bulb 2, since $P_r = V^2/R$ *for fixed* V, this means that the resistance of bulb 2 is lower than the resistance of bulb 1. So in part d, if bulb 1 and bulb 2 are in series, they have the same current.

Since $P = I^2R$, bulb 1 with the bigger resistance will have more power (in spite of that fact that its power rating is lower! Remember power rating has nothing in general to do with actual power dissipated!) In part e, if they are connected the power supply one at a time, they have the same voltage, and in this case, the power for the lower resistance will be higher, so bulb 2 will have higher power than bulb 1.

For the first practice quiz problem, what would happen if the light bulbs were connected in parallel? Would the one with less resistance always burn brighter, or would it depend on the case?

Since in parallel the bulbs have the same potential difference across, them, this is equivalent to part e. At the same voltage, the one with less resistance will burn brighter, according to $P = V^2/R$.

For an ohmic resistor, why doesn't R depend on I? If R does depend on I why is it a non-ohmic resistor?

R generally is a property of the object... it's a measure of how easy it is for current to get through, and it depends on the type of material and the geometry. However some materials are especially peculiar and have a resistance which does depend on I (for instance, imagine if resistivity depends sensitively on temperature. If the material has current through it, it can heat up... which changes resistivity, which can further change current, etc. So this material will be non-ohmic.) Actually normal materials are not *perfectly* ohmic.

How do you know the direction of current? When is it negative?

Current is in the direction of movement of positive charges. When doing Kirchoff-type problems, you pick a direction. If you happened to pick the wrong direction, the current will come out negative after you crank through the math.

How do you choose the direction of loops when doing Kirchoff's Rules problems? Is it just arbitrary? How do you choose the direction of currents?

Yes, you can choose any direction for the loop and the problem will come out the same way. (Suppose you choose the opposite direction: then for the same loop you get the same equation with all quantities the negative of what they would be... so multiply the whole equation by -1 and you get the same thing!). You can choose the current direction in any branch arbitrarily, too. If you happened to pick the wrong direction, the current will come out negative.

If you chose the wrong direction for current, do you have to go back and change the arrows on your picture? Do you re-solve the equation? What do you do?

Well you could change the arrows if you wanted to make a final accurate picture. But you don't have to re-solve or do anything; you're done. You just know that the real current direction is opposite to the one you happened to choose. A negative current is no cause for anxiety!

Can the same point in a circuit be assigned two directions for current if it belongs to two internal loops?

No, you should choose a particular current direction in each branch and leave it the same for the whole problem. Different internal loops may traverse this branch in different directions, however.

In the Kirchoff Law practice problem, why was there a + sign for I_3R_3 in the bottom loop?

It was positive because the resistor was being traversed *against* the current in the loop we chose.

In the Kirchoff Law practice problem, how did you get $I_1 = I_2 + I_3$?

At the junction, the sum of the currents going in must equal the sum of the currents going out. "Going in" to a junction just means the current direction arrow points towards the junction. "Going out" just means the current direction points away from the junction. (Note that the Junction Rule has nothing to do with the loop direction.)

How do you know which junctions to use for the Junction Rule?

Any junctions may work. But sometimes junctions will give you redundant information (as in the problem today). You just need to have enough equations to solve for your unknowns.

Can you explain the solution to 2b from pset 4?

Here, when opposite charged plates are connected, the charge in them partially neutralizes, so the total charge is the difference of the charges. Otherwise, it's just like part a (capacitors in parallel).

Can you explain the solution to 2 on the practice exam??

After the power is disconnected, Q is constant, so E is constant. If plate separation is decreased, voltage decreases. A decrease to 5 V means separation has decreased by 2, so it's 0.5 mm. The charge is the same; it has nowhere to go. The capacitance changes when dielectric is inserted. Putting a dielectric halfway in is like creating two capacitors in parallel, one with dielectric and one without: $C' = C_1 + C_2$. C_1 without dielectric (for half the area) is $C_1 = \epsilon_0 A/2d$. $C_2 = K\epsilon_0 A/2d$. The sum is $(K+1)\epsilon_0 A/2d$. This is to be compared to the original capacitance of $\epsilon_0 A/d$, so $C'/C = (K+1)/2$. Since energy stored is $Q^2/2C$, for constant charge, the energy decreases by $U'/U = 2/(K+1)$.

Can you explain the solution to 3 on the practice exam??

Surface charge density is just Q/A. You could also write it as $CV/A = \epsilon_0 V/d$. Part b just wants you to state what could mess you up: non-flat surface, dirt.

Can you explain the solution to 5 on the practice exam? Why does energy go to heat?

When the capacitor is charging up, there is current through the resistor. Whenever there's current through a resistor, there's power dissipation in the resistor, and the energy goes to heat. Charge, on the other hand, must be conserved, since it can't escape the circuit (assuming it's an isolated circuit).

Can you explain the solutions to 5 on last year's exam?

This is a slightly weird problem. The seawater acts as both a dielectric in the capacitor and as a resistor, at the same time!! When the seawater is added, it's like adding a resistor in series with the circuit, and it discharges the capacitor. But you also increase the capacitance due to the dielectric properties of seawater. So you can treat it as an RC circuit, so $Q/Q_0 = e^{-t/\tau}$, where $\tau = RC$. $R = \rho l/A$, where $l = d$ and A is the area. $C = K\epsilon_0 A/d$. So $\tau = \epsilon_0 \rho K$ (notice A and d cancel. Now plugging $Q/Q_0 = 0.135$, $-t/\tau = ln(0.135) = -2$. So $t = 2\tau$.

Can you explain the solution to the last problem from pset 4?

See FAQ 8 (March 11).

Can you go over the demos?

Please be specific when you request demo explanations... there are lots and lots of demos and I can't explain them all, and some are straightforward anyway. I think the most important demos to make sure you understand are the ones in the review slides: the funny-shaped conductor (see Mar 4 FAQ); the demos showing that current is carried by moving charges (candle, molten glass); the demo showing what happens when a dielectric is put between parallel plates (see Mar 6 FAQ; the demo showing that resistance decreases for low temperature; and the demo showing explicitly that the sum of voltage drops over a loop is zero.

Why is power when discharging larger than power when charging a capacitor?

It is not always larger. In the specific case of the demo with the exploding wire, it was larger: the capacitor charged up over a long period (the time constant for large R was long), so energy per time was small. When the capacitor discharged (r of the wire was small), power was large because the same energy was dissipated in a very short time. You could imagine the opposite situation: a capacitor charging through a small resistor quickly, and discharging slowly through a large resistor.

When one resistor of a pair of parallel resistors increases, why does the total resistance not decrease?

Overall, if one resistor increases, it becomes harder for current to pass, so resistance decreases (think of the fish/boulder-filled-pipe analogy). A specific example: $R_{eq} = R_1 R_2/(R_1 + R_2) = R/2$ if $R = R_1 = R_2$; suppose R_2 doubles, then $R_{eq} = 2R/(R + 2R) = 2/3R$, more than $R/2$. On the other hand, if you *add a new resistor in parallel*, resistance will decrease (it's like adding a new pipe).

Could you explain problem 3 of last pset?

a. Potential difference across a battery is the same no matter what.

b. Imagine ammeter and battery as having little resistors in series with ideal devices. If one resistor increases, overall R_{eq} increases, so total current I decreases. $V_{AE} = \epsilon - I(r_a + r_b)$, where r_a and r_b are the ammeter and battery resistances. If I decreases, V_{AE} increases.

c. R_{eq} increases, I decreases, drop across R_4 decreases because less current across parallel network.

d. R_{eq} decreases, total I increases, current through R_1 increases.

e. R_{eq} decreases, total I increases, current through R_6 increases.

f. This one is hard. R_{eq} decreases, total I increases, but *relative* current through R_3 decreases since more current goes through R_2. Which effect is more important? To evaluate, imagine the limiting case where $R_2 = 0$. Then *all* the current goes through R_2, and the current through R_3 goes to zero, so it decreases. It will also decrease in a less extreme case.

g. R_{eq} increases, total I decreases, voltage drop across R_2 decreases.

h. R_{eq} increases, total I decreases, voltage drop across all the other resistors (except the 456 parallel network) must decrease. Since the voltage drops across all the resistors must sum to ϵ, the drop across 4, 5 and 6 must increase, so the drop across R_4 must increase.

i. ϵ does not change; the battery does what a battery has to do, which is keep potential difference constant across its terminals.

Could you explain the CyberTutor ranking problem? ... why would A get dimmer and C get brighter? Which way is current flowing? Where does current "start"?

The fish analogy may help here. The same current (fish/time) must flow through the A/B network as the C/D/E network. In the A/B network, current is divided in two for each branch. In the C/D/E network, more current goes down the C branch than the D/E branch. But the total current is the same in both cases. So C has more than 1/2 the current. So C must be brighter than A and B, and D and E must dimmer than A and B.

Current flows from + terminal of the part to −. It's a continuous flow in a loop... I guess you could say it "starts" at the battery, since the battery "pumps" it.

Can you give us a practice problem involving $J = qnv_d$?

You could try examples 25-12 and 25-13 in the text. This equation just gives just the relation between current density and drift velocity. The important concept here is that current density depends on number density of charge carriers, and also on drift velocity (a constant velocity of charge carriers moving through the resistor).

Suppose you have a resistor network which is a square with resistors on each side, and a resistor connecting two opposite corners. What's the equivalent resistance?

Numbering the resistors on the sides clockwise from bottom left 1,2,3,4 and the one from bottom left corner A to top right corner B resistor 5: note that 12 are in series, as are 34. 5 is in parallel with 12 and 34. So equivalent resistance is 12, 34, and 5 in parallel.

How do you get the equations for RC circuits?

These come from applying the Loop Rule to a circuit with a resistor and a capacitor. For a charging capacitor with a battery, capacitor and resistor in series, the Loop Rule gives $\epsilon - Q/C - IR = 0$. Plugging in $I = dQ/dt$, you get a differential equation for Q, and the solution is $Q(t) = Q_0(1 - e^{-t/RC})$ where $Q_0 = C\epsilon$. For a discharging capacitor (just a capacitor and resistor in series), the Loop Rule gives $Q/C - IR = 0$. This, too, gives a differential equation to solve, and you get $Q = Q_0 e^{-t/RC}$.

Do discharging capacitors have a different equation?

Yes, the equation is different for discharging than for charging: see above.

How do you deal with capacitors in multiloop circuits?

In a steady state, the capacitor is already charged up... there is *no current in the branch of the circuit with the capacitor.* Basically, you can ignore the branch in your Kirchoff Rule problem. However, if you're dealing with the short timescale after a switch is opened or closed, you may need to deal with it as an RC problem (see today's practice problem on the web).

Why do you need a resistor in an RC circuit?

If there's no resistor, the capacitor charges up instantly. The resistor controls how slow or fast the charging or discharging is.

How do RC circuits actually work? How does the charge flow to make the plates obtain a charge?

The battery pumps charge so that the potential difference across its terminals is ϵ. It pushes charges through the resistor to the capacitor plates: it puts positive charge on one plate and sucks it away from the other. It keeps trying to pile charge on, but because charges repel, its job gets harder and harder. Eventually, the capacitor "gets full" and reaches the maximum charge that can be stored, $C\epsilon$. When there's a resistor, that slows everything down, since the battery must push charges through the resistor, too. So what happens is that charge on the plates increases quickly at first, but then the process slows down and the charge reaches a maximum value.

How do U and W relate to how charge is assembled?

The battery must do work to put charges on the plates. You can evaluate this work in small increments (it takes more and more work to put the same charge on as the capacitor fills). You add up dW's as the plates get full, to find the total energy stored. See part d of Mar 4 "Parallel plate capacitor problem" on the Handouts web page (I didn't get to do this in class).

Can we have some hints on the pset 6 problem with the capacitors and resistors?

In this problem, assume that you are in a steady state (capacitors have finished charging, etc.). Remember that in a steady state there is *no current flowing through a branch with a capacitor in it.* You can ignore the branch with the capacitor when dealing with the voltage drops due to current through the resistors. "Charge flowing through the switch" is charge that goes on the capacitors; so it's the net charge on the capacitor plates connected to the switch after the capacitors are charged up.

Tidbits

Many of the concepts we are covering now are important in biology. For example, nerve cells and their actions can be described by circuit elements such as resistors, capacitors, etc. Basically your brain and nerves act like a very complicated electrical circuit. A couple of links:

`http://www.albany.net/~tjc/neuron.html`

`http://www.fortunecity.com/greenfield/buzzard/387/neuronsascircuit.htm`

Why did Jimmy fall off the bicycle?

Because he was a goldfish.