FREQUENTLY ASKED QUESTIONS

March 6, 2003

Content Questions

I'm confused about how to read wiring schematics...

This usually just takes a little practice. The key point is that wires are *conductors* and so *have constant potential everywhere along them.* So any two points connected by a wire on a diagram have the same potential. It doesn't matter *how exactly* you connect up two points in a circuit, it just matters that they are connected (by a wire, or by solder, or by direct physical connection) in the way the diagram shows. To debug your circuit, it often helps to go through each point in the circuit and check that the connection is there. Also make sure that there are no spurious extra connections ("short circuits"), which can also mess things up.

Can you explain resistors? How do they work? How do resistance, voltage and current work?

We haven't quite gotten to talking about resistors. Essentially, they are circuit elements that relate current and voltage by Ohm's Law: the potential drop across a resistor is $V = IR$, where I is the current. We'll get to defining these things soon; have patience.

What are diodes, transistors, rectifiers, transformers, etc?

These are other kinds of circuit elements. A diode is a device that has a constant small potential drop across it; it also allows current to flow only in one direction. A rectifier uses diodes to turn an oscillating current (that goes back and forth in direction, also known as alternating current or "AC") into a constant current that just flows in one direction ("DC"). A transistor is a device with numerous uses; in our HVPS case it turns a small current into a big current. A transformer turns a small voltage into a big one. We'll be seeing explicitly how this works later in the course (Chapter 29 of the text)– to understand it, first we need to understand magnetic fields as well as electric fields.

Much of this will make more sense later, when you are more familiar with various aspects of circuits. We're getting there... please hang in there!

I'm still confused about dielectrics...

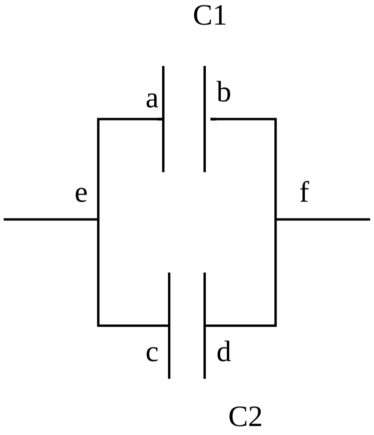
I wanted to give you just enough information to do your pset problem, *i.e.* that a dielectric material changes the capacitance of a capacitor by a factor κ, which is a property of the material. We'll see more about dielectrics in lecture tomorrow.

The first HVPS questions seems rather simple: do we just multiply 20000 Ω by 1000 V or is this number dependent on our measurements?

Yes, that's all! It doesn't depend on your measurement.

Why is V constant everywhere in a parallel circuit, whereas Q is divided between each branch?

Well, V is not constant *everywhere* in a parallel circuit. The potential drop across each capacitor is the same, though. Consider the parallel capacitors in the figure.

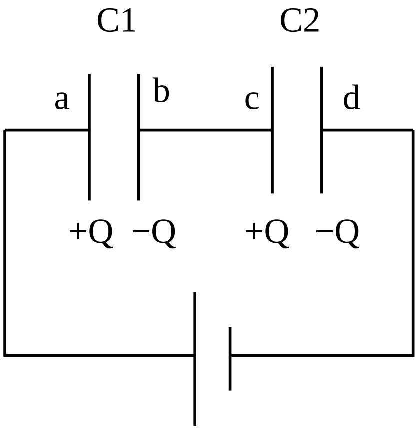


Because wires connect points at the same potential, a, c, and e are all at the same potential. Points b, d, and f are also all at the same potential.

(In general, this is a different potential than that at a, c, and e.). So the potential difference between a and b, which is V_1, is the same as the potential difference between c and d, which is V_2. Both of these are the same as the potential difference V between e and f.

For the question of charge on C_1 and C_2: each capacitor has a certain amount of charge. The total charge when they are connected is therefore the sum.

Why is Q the same for each capacitor when capacitors are in series? Why is $V_{\text{tot}} = V_1 + V_2$ for capacitors in series?



Perhaps the easiest way to see this is to imagine a battery providing the charge separation and potential difference. The battery does whatever it has to do to maintain a potential difference V between a and d. This means pumping $-Q$ of electrons onto plate d, and removing them from plate a, leaving a with charge $+Q$. Consider now plate c. Electrons on plate c are repelled from d. They are also attracted to b. Plate c therefore gets a charge $+Q$; because the two inner plates must be neutral, plate b gets a charge $-Q$. So each capacitor has an equal charge Q.

For the potential differences: potential difference means work done to take a unit charge across the plates. The total work done to take a charge across both capacitors must equal the sum of the work done for each (since the field goes the same direction inside each capacitor). So $V_{\text{tot}} = V_1 + V_2$ in series.

How can $C_1 = C_1 + C_2$?

If that was written on the board somewhere, it was a "write-o". You can check your notes against the handouts.

How do you tell if two circuit components are in series or in parallel?

If circuit components X and Y are "in parallel", that means that the potential difference is the same across X as it is across Y (one side of X is in contact with one side of Y, and the other side of X is in contact with the other side of Y). X and Y "in series" means that they back-to-back, so that the potential difference across both is the sum of the individual potential differences.

Do wires have constant potential both in series and in parallel?

Well, any individual wire has the same potential anywhere along its uninterrupted length. Potential can change when wires "run into" circuit elements (resistors, capacitors, batteries, etc.)

If there is an open space in a circuit between capacitors, is it still a closed circuit?

Yes and no... if the capacitor is charging or discharging, current can flow by induction. For instance, if charges are getting pumped on to one side of a capacitor, they are fleeing from the other side, so there is an "effective" current and we treat it like a closed circuit. If the capacitor is "charged up", it's a static situation and no current is flowing through the capacitor; we treat it as a static object with charges sitting on it and a potential difference across it. We'll see more of this later.

How exactly is a capacitor useful in a circuit? Why do you want to store charge?

You might want to store charge and electrical energy to use later, for instance in a camera flash, or for backup energy in case power is lost. Capacitors are useful in more subtle ways for signal processing. For instance, you might want to smooth a signal by adding extra charge to it at key times... a capacitor acts as a reservoir of charge. You might want to use a capacitor to ensure that you have particular voltages at certain points in a circuit (e.g. in your HVPS). We'll see a lot more later on how capacitors are used in AC and resonant circuits.

I didn't understand the demos in class on Monday.

For one demo, there was a parallel plate capacitor. Some charge was stored on the plates, and there was a potential difference across the plates. (This potential difference was measured by the rotation of a pointer.) When the plates were moved apart, the potential difference increased: $V = Q/C$, and although Q was the same when the plates were moved apart (there was nowhere for the charge to go), the capacitance decreased since $C = \epsilon_0 A/d$ for parallel plates. So V increased. Another way to think of it: $V = Ed$, and E is the same (it depends only on surface charge for "infinite" parallel plates), and d increased, so V increased too.

The second demo was supposed to demonstrate that a surface charge arises when you put an electric field across a dielectric. This demo had a copper cup, nesting inside a glass (dielectric) cup, nesting inside another copper cup. The copper cups were charged up: the inner cup became negative, and the outer became positive. Then the inner copper cup was lifted out, and was connected to the outer one: there was a spark as the cups discharged– charge was redistributed and the copper cups became neutral again. Then the neutralized copper cup was placed back inside the glass. You would expect that after this, when inner and outer copper cups were connected, no spark would happen because the cups were neutralized. But that wasn't what happened– again there was a spark! The reason was that *surface charges formed on the glass when the outer cups were originally charged up*: positive charge arose on the outer glass surface, and negative on the inner. These were the charges that neutralized with a spark the second time. I think this will be explained tomorrow.

How can we avoid getting confused by all the similar variables in

capacitance problems?

Well, I think there's nothing to do except label things carefully.

Are the circuit diagrams they ask for in the HVPS writeup the same as the ones you drew in class?

Yes, pretty much.

In the HVPS writeup, is the multimeter in parallel with the load? Is it in parallel or series with the resistors?

The multimeter is in parallel with the resistors. To see this, draw the diagram: the MMM has the same potential drop across it as across the resistors. The resistors are in series with each other, though (in part b).

My HVPS only gave output starting at 200 V. Is that OK?

Yes, the HVPS's can vary somewhat. I think that's OK.

What happens when a battery is removed?

Well, it depends on what it's removed from. If the system is an isolated capacitor, the charge will have nowhere to go and the capacitor will stay charged up. If it's a system connected to conductors or ground, charge may leak away and the potential difference created by the battery will go to zero.

Hints for the problem set:

- For problem #2: For part a, first figure out what charge each capacitor has before the battery is removed. After the positive plates are connected to each other, and the negative plates are connected to each other, what is the total positive charge, and the total negative charge? How does the potential difference across capacitor 1 compare to that across capacitor 2? (hint: are they in parallel?) What is the equivalent capacitance, and how does that relate to total charge and potential difference? For part b: the situation is actually the same as for part a, but the total charge is the difference, not the sum.

- For problem #3: there are several ways to write down energy stored. There are also different ways to do part b; one way is to use work-energy equivalence.
- For problem #4: this problem is easier than people think! Treat each half as a separate capacitor. Consider how the presence of dielectric changes capacitance. If the sides of the 2 capacitors are in contact and have the same potential difference across them, are they in series or parallel?

Tidbits

Some people have asked about what capacitors are actually made of. Here's some more engineering-style info I found:
`http://www.interq.or.jp/japan/se-inoue/e_capa.htm`