FREQUENTLY ASKED QUESTIONS

March 4, 2003

Administrative Questions

What was the passing grade on the quiz? How are grades A, B, C determined?

This is determined by Prof. Roland. Usually the A/B/C division is determined at the end of the semester.

Can we go over the quiz with you?

I'm not going to cover the solutions in recitation, since I think you went over it in lecture. I think Prof. Roland will probably put the solutions on the web. If you want to go over any particular question, please come to my office hours or grab me before or after class.

I couldn't make it to recitation; how can I get my quiz?

You can get it next recitation, or find me in lecture tomorrow.

Content Questions

How does potential difference relate to capacitance? Does capacitance depend on potential or work, or both?

Capacitance is defined to be Q/V: it's the amount of charge you can dump on some object for a given potential. Potential is related to work: it's the amount of work per charge it takes to achieve some particular configuration of charges. So you can think of capacitance in two ways: it's inversely related to work needed to place a given charge on an object *or*, equivalently, it's a quantity which tells you the amount of charge you can store for a given potential.

An important point: capacitance is a *property of an object*. The amount of charge you can store for a given potential depends on the object's geometry and material.

For the spherical conductor, how did you relate C to R/k?

We found the potential on the surface of the spherical conductor to be $V = kQ/R$. V and Q are proportional, and C is the constant of proportionality. Since $C = Q/V$, plugging in V, $C = R/k$.

When finding the electric field from a sheet of charge, $\vec{E} = \frac{\sigma}{2\epsilon_0}$, where does the factor of 2 in the denominator come from?

See example 22-6 in your text. Imagine you have an infinite sheet of charge. Then imagine a Gaussian surface with the sheet going through the center of it, and the two ends of the Gaussian surface parallel to the sheet. This surface could be a box, a cylinder, – it doesn't matter, because Gauss' Law is true for any surface. The electric field from the infinite sheet is pointing perpendicular to the sheet, by symmetry. The vector $d\vec{A}$ of the Gaussian surface is parallel to $\vec{E}$ on the two ends of the surface, and perpendicular to $\vec{E}$ on the sides of the surface. So $\vec{E} \cdot d\vec{A}$ is only non-zero on the ends of the Gaussian surface. So the LHS of Gauss' Law is $\oint \vec{E} \cdot d\vec{A} = 2E \int dA = 2EA$, where you have a factor of 2 because you are integrating over *both* ends. The RHS of Gauss' Law is Q/ϵ_0, where Q is the charge inside the surface. So $2EA = Q/\epsilon_0$, and solving for E, $E = \frac{Q}{2A\epsilon_0}$, and since surface charge density is $\sigma = Q/A$, then $E = \frac{\sigma}{2\epsilon_0}$.

Notice that this field E is *constant*; in other words, it's *independent of distance* from the sheet. This is only true for an *infinite* sheet, which is an approximation you can use when you are a distance away from the sheet which is much smaller than the size of the sheet.

In the parallel plates example, how did you find the electric field? Why was the electric field outside zero, if points outside the plates are closer to one plate than the other? Why isn't E zero in the center of the plates?

To find the field both inside and outside, you can use superposition. Say you have a $+\sigma$ sheet on the right and a $-\sigma$ sheet on the left. Consider a point inside the plates. There's a contribution from the $+\sigma$ sheet, away from the

$+\sigma$ sheet, so to the left, of magnitude $E = \frac{\sigma}{2\epsilon_0}$. There's also a contribution from the $-\sigma$ sheet, towards the $-\sigma$ sheet, so also to the left. The total field is the vector sum, so $E = \frac{\sigma}{\epsilon_0}$ to the left. This value is *constant*, everywhere between the plates.

Outside the sheets, say at a point to the right of the $+\sigma$ sheet, you have a contribution from the $+\sigma$ sheet pointing away from it, so to the right, $E = \frac{\sigma}{2\epsilon_0}$. The contribution to the field from the $-\sigma$ sheet is to the left, and of the same magnitude. So these contributions are equal in magnitude and opposite in direction, so they cancel outside the sheet.

Notice that the contributions from the two sheets that cancel outside *don't depend on distance*, only on the charge density on the plates. This results from our approximation of an infinite sheet. (Of course in real life, things aren't infinite! This is an approximation you can use for sheets that are large compared to their separation and the distance away you are.)

In the tutorial, why did charge decrease when plates were moved farther apart?

The charge decreased only for the connected-to-battery case. The battery must keep a constant V between the plates. Since field is $E = V/d$, it must decrease if plates are moved apart and d increases. Since field is also σ/ϵ_0, the charge density is $\sigma = E\epsilon_0$; so if field decreases when the plates move apart, σ must decrease too.

In the tutorial, if the charge plates were not insulated, would the charge density change? If so, how?

If the charge plates are not insulated (for example if they are connected to a conductor or the ground), the charge will leave the conductor (since charge always tries to spread out as much as possible). If the plates are "grounded" (connected to the Earth, which is a very large conductor), the charge may leak away entirely, leaving the plates neutral.

In the tutorial, why was $E = V/d$? How did you get that integral for ΔV?

The potential difference is work done per charge by the electric force over a path. This translates to

$$\Delta V = V_B - V_A = -\int_A^B \vec{E} \cdot d\vec{l}, \tag{1}$$

Here A and B are points at each plate, the field E is constant between the plates, and $dl = dx$ is a path element, and we choose $V = 0$ at one plate. The integral becomes $\Delta V = V = -\int_0^D \vec{E}dx$. We get $V = Ed$ for the magnitude of the potential (which is the same as the potential difference, if one side is defined to have $V = 0$.)

What's the difference between normal conducting plates and insulated conducting plates?

The plates themselves are the same. If the plate is "insulated", that just means that any charges on it are prevented from leaving by some material that is an insulator (charges can't move in an insulator). For instance air is a pretty good insulator.

What would happen with *three* plates?

You could still calculate capacitance as the ratio of charge stored to potential. I think we will be seeing some examples of configurations more complicated than 2 plates.

If capacitors store charge, how is it released? What does it mean for something to be discharged?

If some charge has been put on a capacitor, it will stay there if the capacitor is insulated. If the capacitor is then connected to a conductor, the charge may flow away. When the charge has flowed away and the object is neutral, it's said to be "discharged".

Is capacitance always $\epsilon_0 A/d$, or is that just for plates?

That's specifically for parallel plates. Other types of objects will have different capacitances (related to their size, shape and material).

How can humans and the Earth act as capacitors? What did you mean about tiny capacitors?

Any object can have a charge and can be at some potential; we can therefore define capacitance for any object, even a Sparkly Frog. In general, the larger the object, the larger the capacitance. But capacitance is also related to material type: we'll talk about dielectrics shortly. So it's possible to have an object with the same capacitance as the Earth, but much smaller than the Earth, if its geometry and material are chosen cleverly. Although technically, anything is a capacitor, electronic components called "capacitors" are designed especially to have high capacitance. For instance, for a parallel plate, capacitance is proportional to area, and inversely proportional to separation. So you can get a very large capacitance for a thin wrapped up foil, which has a lot of area and small separation – see Figure 24-1 b in your text. That is how many capacitors are constructed. Dielectric materials make a difference, too, as we will see soon.

In the HVPS problem, what range of current should we be getting for the last 2 columns?

Note that the current in the last 2 columns is to be calculated (not measured) according to $I = V/R$, where V is the measured output voltage. The SI unit of current is amp, so you'll get amps if you use SI units for V and R, which are volts (V) and ohms (Ω) respectively. R is the equivalent resistance and should be in $M\Omega$ (don't forget that "M" means a factor of 10^6.) You should be getting hundreds of volts for the HVPS output voltages.

What are the real-world applications of capacitance? Can you give some examples?

There are *enormously* many real-world applications for capacitors. Capacitors are components of just about any kind of electronics that you use every day, from cell phones to computers. They are used in your LVPS and HVPS. In the coming weeks, we will see more explicitly how capacitors are used in circuits.

How does a battery work?

Think of the battery as a device whose job is to keep a constant potential across its terminals. It does whatever it has to do to keep that voltage: it pumps charge in and out as necessary. (This is a description of what a battery *does*. Well, how does it *work*, you might ask? This depends on the kind of battery. A chemical battery uses chemical energy to push charges around: see section 25-1 of your text. You may have seen this in the context of chemistry, too. Note that the symbol used for battery, a short and a long line parallel to each other, is also used to mean "power supply", which is not necessarily strictly a battery. It's a device that provides a constant voltage, like the LVPS and HVPS you use in your experiments. These take power from a wall outlet and convert it to a constant voltage that you specify by twiddling the pot. All of this will make a bit more sense later... hang in there.)

I didn't understand the demo in class Monday March 3.

This was a funny shaped object with a sharp tip at one end and a smooth round shape at the other. Prof. Roland showed that there was more charge collected at the sharp tip, by scooping up the charge there and measuring it with an electroscope.

This object has a small "radius of curvature" at the sharp end and a large "radius of curvature" at the round end (think of a sharp vs blunt point... the curvature of a blunt point is more like a big sphere than the curvature of a sharp point).

Since the object is a conductor, its surface is all at the same potential V. Although it is really all one object, imagine approximating the object by a small sphere 1 (representing the sharp end) connected to a large sphere 2 (representing the round end). The potential of a sphere is $V = kq/R$. The small sphere's potential is $V = kq_1/R_1$, and the large sphere's is $V = kq_2/R_2$. Since both are at the same V, $kq_1/R_1 = kq_2/R_2$. So the ratio of charges on the spheres is $q_1/q_2 = R_2/R_1$. So, big radius means small charge, and vice versa. So, charge density is greater for small radius of curvature, which is why there was more charge at the pointy end.

This is also why you get sparks at the pointy ends of things! When the charge density σ increases, so does the electric field. When the electric field exceeds about 3 million V/m in air, air "breaks down" into ions and no longer acts as an insulator. Charge then passes through the air, which appears as a spark. This is why a lightning rod works, too. The electric field is higher at the pointy end of a rod (where the radius of curvature is tiny) than at your house, so the "spark" of lightning from the atmosphere happens where the pointy thing is, not at some point on your house.

Tidbits

Best jokes from today's questionnaires:

What's long, green and has wheels? Grass, I lied about the wheels.

What's $5Q + 10Q$? $10Q$. (Say this one out loud!)

A hot dog walks into a bar and he's hungry. He asks the bartender "Can I get a burger?" The bartender replies, "We don't serve food here!"

What's $\frac{\ln(\text{cabin})}{\text{water}}$? A house boat.

(Better joke selection today!!)