FREQUENTLY ASKED QUESTIONS

February 25, 2003

Administrative Questions

What do I do if I forget to hand in my pset?

Just drop it in the box when you can. If you have a reason to be late please ask Prof. Roland.

How long will the quiz be?

It's in-class, so about 50 minutes. I don't get to see the quiz before it's given, so I don't know how many questions there will be, although I imagine 3 to 5.

Will the labs be covered for the test?

Yes, in general they will be.

What will be the format of the Wednesday night review session?

I'm not sure what Prof. Bertozzi will do. I will do the review for quiz 3 (not until April), and that will be mostly going through review problems.

I'm missing a page from Chapter 22 in my textbook.

My text seems okay; maybe you could borrow someone's text or get it from the physics reading room, and photocopy the page. If lots of people have the same problem, we could ask Prof. Roland to put it on the web.

Can the pset/CyberTutor deadline be Friday?

You'll have to ask Prof. Roland.

Content Questions

I'm confused about the difference between field vectors and field lines.

Field lines and vectors are different tools for visualizing electric fields (and other kinds of fields).

You can think of field vectors as vectors attached to every point in space, where the vector at each point gives the field (e.g. electric field) magnitude and direction at that point. A vector can have only one direction.

A field *line*, on the other hand, is a *continuous line* that could change direction (it can snake around, although it might be straight, too). It's the line *tangent* to the electric field vectors at every point.

So, imagine drawing the electric field vectors in space. Then, draw a line that connects the points such that it's always tangent to field vectors– that's the field line. Because a field line is a continuous line, it doesn't have a magnitude, but *density* of field lines tells you about the magnitude of the field.

Can electric field lines bend?

Yes, they can snake around (in a continuous way).

Can you explain some of the recent demos?

The demo in class on February 24 was supposed to show that charge collects on the outside of a conductor, and is zero inside. Prof. Roland put some charge on a hollow conducting sphere, and scooped some from the outside of it to the electroscope: the electroscope leaves repelled, showing there was charge on the outside of the sphere. Then he tried scooping some charge from the inside of the hollow conducting sphere and touching it to the electroscope: with the electroscope neutralized, nothing happened... so there was no charge on the inside of the conducting sphere. (With the electroscope leaves already repelling, and then touched by the charge-scooper which had just touched the inside of the sphere, the leaves repelled a bit less, because the charge-scooper was really neutral, and charge moved from the electroscope to the charge-scooper).

The sparking drop demo is a bit long to explain... here's a link I found with a nice explanation:

`http://www.amasci.com/emotor/kelvin.html`

Why do conductors have no charge inside them?

First I will argue that there can be no field inside a conductor. Since charges can move freely inside a conductor, if there's an electric field inside a conductor, the charges would be moving. They will continue to move until they have arranged themselves to cancel out the field. So if we have a static conductor, there can't be any field inside.

By Gauss' Law, $\oint \vec{E} \cdot d\vec{A} = \frac{Q_{\rm in}}{\epsilon_0}$, so if $\vec{E}$ is zero just inside the surface of the conductor, so must $Q_{\rm in}$ be zero inside the conductor. Any charge that gets placed on a conductor spreads itself out on the surface of the conductor.

Will we have to calculate the flux through irregular surfaces (*i.e.* not boxes, cylinders, etc.?)

In general, the flux can be calculated from $\Phi_e = \int \vec{E} \cdot d\vec{A}$ for any surface, but if it's not a regular surface this may be a very hard integral which must be evaluated numerically. You won't be asked to do this for this course.

What's the difference between positive and negative flux? Can you ever have a net negative flux through a closed surface?

Negative flux through a closed surface refers to field lines which poke into the surface. You can have a net negative flux through a closed surface if there is a negative charge inside the surface: the field lines enter the closed surface and end on the negative charge.

What is ϵ_0? Is it always constant? Where does it come from?

Yes, it's a constant of nature. Since $E = \frac{Q}{4\pi\epsilon_0 r^2}$ for a point charge, and the force on a test charge q is $F = qE = \frac{kqQ}{r^2}$ you can see that ϵ_0 is related to Coulomb's constant k by $\epsilon_0 = 1/4\pi k$. Its value is experimentally determined.

What is $\hat{r}$?

It's just a unit vector in the direction of $\vec{r}$. When dealing with problems with spherical or cylindrical symmetry, it means "a unit vector in the radial direction", *i.e.* a vector pointing out radially from the center of the sphere, or outwards from the axis of the cylinder.

What are ρ, σ, and λ?

ρ is charge per volume; σ is charge per area; λ is charge per length. For uniform charge densities, these are constants, but one could have non-uniform charge densities where they vary in space.

How do you change integrals over q ($\int dq$) into integrals over volume, radius etc.?

What an integral ($\int dq$) *means* is a sum over little pieces of charge. So to do this integral, what you need to figure out is how to divide an object up into pieces of charge that you know the volume (or area, etc.) of.

Let's take the example of a sphere. Suppose it has a charge density that depends on radius $\rho(r)$. Charge density is charge per volume, so $\rho(r) = dq/dV$. You know what the volume of a spherical shell is: it's surface area times thickness: if dV is the volume of the thin shell, then $dV = 4\pi r^2 dr$. So the amount of charge in a thin spherical shell of radius r is $dq = \rho(r)dV$, which is $dq = \rho(r)4\pi r^2 dr$, and the total charge in the sphere comes from adding up all the thin shells: $Q = \int \rho(r)4\pi r^2 dr$.

You can do a similar thing with a cylinder: this time add up charges in skinny cylindrical shells of length L, for which $dV = 2\pi r L dr$.

How do you choose a Gaussian surface? How do you decide what size to make it?

Generally, you want to pick one with the same symmetry as the charge distribution, such that the magnitude of E is constant (or zero) over the surface. For spherical symmetry, this is a sphere: everywhere equidistant from the center has the same E magnitude. For cylindrical symmetry, the surface of constant E is a cylinder. For planar symmetry, you usually choose a box with some of its sides parallel to the surface. For a plane parallel to the surface, the magnitude of E is constant.

You can pick *any size* of surface. Gauss' Law is true for any size (that's the beauty of it!). Just pick some size and give the size a name (for example, a cylinder of length L, etc.). You will find that this size cancels at the end of the problem!

In the practice problem in recitation, why did you use the area of the end of the cylinder (cross-sectional area) instead of its side area when calculating line charge density?

Line charge density $\lambda = Q/L$ is charge per length. You were given charge per volume $\rho = Q/V$. Volume is $V = AL$, where A is the cross-section area. Then $\lambda = \rho A = \rho \pi s^2$.

In the practice problem in recitation, why did you you get r in the denominator, not s? When to use r and when to use s?

The Gaussian surface used to find $E(r)$ is a cylinder at radius r (you find $E(r)$ generally for any r.) s is the radius of the charge distribution. So you use r in the LHS of Gauss' Law (the Gaussian surface) and s for the RHS (finding the charge inside the surface).

If you have more than one charged surface, how do you apply Gauss' Law?

Exactly the same way as if you have a single charged surface. When evaluating the RHS of Gauss' Law, consider only the charge *inside* the Gaussian surface. Anything outside should be ignored.

In Gauss' Law problems, if E is constant, how do you get $E(r)$?

Note that the magnitude of E is constant *on the chosen Gaussian surface only* (that's what lets you take it out of the integral). E can vary in other coordinates. For instance for spherical surface, E is constant on that surface, but $E(r)$ varies with r.

How come outside charges don't affect Gauss' Law?

Outside charges contribute zero net flux through a closed surface. Every flux line poking in must come out. You can only have net flux if there is charge inside.

Why does Gauss' Law work?

Well, maybe the best way to think of it qualitatively is to think of field lines. You can only get net flux through a surface if there's a *source* of charge inside it, because field lines can't appear or disappear from nowhere. Any flux line poking in must poke out somewhere. So net flux is always related to total charge inside.

What's the difference between potential and potential energy? If I see "potential", which do I use?

Agreed, this is not the best nomenclature in the world, but we're stuck with it. Potential energy U is, well, potential energy with a very similar meaning to gravitational potential energy. Potential V is U/q, *i.e.* potential energy "normalized" by q, so that you get a quantity that doesn't depend on any particular test charge q. Potential is a property of space, like $\vec{E}$, whereas potential energy refers to a particular charge. If you see just "potential", without the "energy", use V.

I didn't understand the line charge example in lecture on Monday.

Prof. Roland calculated the field due to an infinite line charge, which has cylindrical symmetry (essentially using the Gauss' Law how-to). You get $E = \frac{\lambda}{2\pi r \epsilon_0}$. The potential as a function of r is the path integral of E, so it's proportional to $\ln(r)$. We'll see more of this on Thursday.

I didn't understand the potential graphs in lecture on Monday.

One plot was $V(r)$ for a point charge, and it went like $1/r$ (it's the integral of $E(r)$ for a point charge). Another plot (the one where there was a $-V_0$ from 0 to r_0 followed by a potential increasing as $-1/r$ for $r > r_0$) was just an example of some potential, and the question was: what sort of charge distribution corresponds to this potential? The answer was: a spherical conductor with negative charge. Inside a conductor, potential is constant; outside a spherical negative charge distribution, field goes as $-1/r^2$, so potential goes as $-1/r$.

For the spherical conductor example in class, why is the potential inside the conductor not zero? Isn't the electric field inside zero?

The electric field is zero inside the conductor, but field is $-dV/dr$, so the potential $V(r)$ (for a spherical conductor) can be a constant; the derivative of this constant is $E = 0$.

(Actually, you can *choose* the potential to be zero at any point, so you could *choose* the potential to be zero inside the conductor if you wanted. However the convention is to choose $V = 0$ at $r = \infty$.)

Hints for problem set 3:

- For problem #1:

  This one's a lot like the Gauss' law problem in recitation. You can follow the how-to; use cylindrical symmetry.

- For problem #2:

  Remember that field inside a conductor is zero. For parts b and c, add the fields due to each infinite sheet of charge. For part d: use the Gauss' Law how-to, but invert the final 2 steps: here you know the field and want to find the charge density. Use a Gaussian surface that pokes through the charged skin of the conductor, with sides parallel to the surface. The charge inside this Gaussian surface is σ times the cross-sectional area of the Gaussian surface.

- For problem #3:

  Find the potential difference using the line integral of $\vec{E}$.

- For problem #4:

  "Equipotential surfaces": these are just surfaces perpendicalar to the field lines. Use the field from an infinite charged sheet.

Hints for Cybertutor:

- For the charged slab problem: this is quite a hard one, but you can do it using the Gauss' Law how-to. The trick is to select good Gaussian surfaces. For part B: pick a Gaussian box which sticks out of the surface on either side, with end surfaces parallel to the slab surface. For part C: pick a Gaussian box with one end flush with the $x = 0$ side of the slab and the other end at x. In each case carefully evaluate the charge inside the Gaussian surface.

What would *you* put on your formula sheet?

I'll do a brief "WUN2K" on Thursday.

Tidbits

How many surrealists does it take to change a lightbulb?

A fish.