FREQUENTLY ASKED QUESTIONS

April 17, 2003

Administrative Questions

Will self-inductance be on the quiz? What about mutual inductance, back-emf, eddy currents, counter torque, transformers?

Probably the best guide to what will be on the quiz is Prof. Roland's review slides from Wednesday. Transformers, back-emf etc. are not mentioned in the slides; however concepts of mutual inductance and eddy currents are integral to the material that is covered, so you should probably understand them.

What demos will be covered on the quiz?

Again, I don't know exactly, but I would may special attention to what's on the review slides.

What do we need to know about the experiments?

Again, focus on the review slides; I think what you need to know is there for EB. The concepts in MF are extremely relevant and intertwined in the course material, so general understanding will help there.

Please could the solutions to MF and pset 8 be posted?

I'm afraid I don't have them! Please ask Prof. Roland.

Content Questions

Is flux always in the same direction as $\vec{B}$ field?

Strictly, since $\Phi_B = \vec{B} \cdot \vec{A}$, it depends on the direction you choose for the area vector. But you can choose that whatever direction you like and usually you choose it in the direction of some external $\vec{B}$ field.

Could you sketch the magnetic field for experiment MF?

See Fig. 28-18 in your text for a picture of the magnetic field for a current loop (and for lots of loops, you just add them).. Basically, it acts like a dipole. When you put 2 dipoles together back-to-back (current in the same direction), it's like a S-N-S-N configuration of 2 bar magnets... they attract. The fields in between add.

Please can you clarify the RHRs again, and which RHR to use when?

One RHR (I call this one the "first RHR") tells you how to relate force, velocity and magnetic field for a charged particle moving in a magnetic field. This is really just the RHR for any cross-product, since $\vec{F}_m = q\vec{v} \times \vec{B}$. The other (the "second RHR", which Prof. Roland calls the "Corkscrew Rule") tells you how to relate magnetic field and current.

Ask yourself what you are trying to find, and what you know. If you're trying to find force due to current (moving charge) in a magnetic field, use the first RHR. If you're trying to find field due to a current (or current direction for a field), use the second RHR.

What do you do with the RHR when you have negative charge?

If q is negative, the force is in the opposite direction to that given by the RHR.

In the Lorentz force equation, if you have negative charge is the force negative?

Yes, it's in the opposite direction. You can just think of that as a minus sign in the charge giving a negative force (a negative force means a force in the opposite direction).

I didn't understand part b of today's practice problem. What does the current oppose? How does it oppose the force?

In this case, it's not the force that it opposes. The current is in a direction such that *it creates a B field that opposes the change in flux.* If flux is *increasing* through the loop, the current makes a B field in the opposite direction to the external changing B field to *decrease* it. If flux is *decreasing* through the loop, the current makes a B field in the same direction as the external B field to *increase* it.

In the practice problem, why did the induced current jump and not increase linearly? How did you get that graph?

The induced EMF in coil 2, and hence the induced current I_2, is proportional to the *rate of change of* the magnetic flux through 2. The magnetic flux through 2 is proportional to I_1. Therefore, I_2 is proportional to the *slope* of I_1 vs t. This is a very important point!! *The induced current depends on the rate of change of the sou*
When I_1 started increasing, its *slope* jumped from zero to a constant value. This is why the current jumped from its "baseline" value I_0 to a higher value. The rest of the graph was made by considering the *slope* of I_1 vs t. Let me say it again. *The induced current depends on the rate of change of the source current, not the source*
And one more time: *The induced current depends on the rate of change of the source current, not*

In the practice problem, if you changed the current in coil 1, wouldn't that induce an EMF in coil 1 too?

Well, yes, you get a "back-EMF". We are ignoring this for the moment; we'll get to this when we talk about self-inductance.

Can we have some Biot-Savart examples like what we would have on the test?

See the examples listed under the Biot-Savart howto. Some of these problems do involve tricky integrals, and if you got any of these on a test, you would be given any formulae needed and would not have to do the integration. You might be asked only about direction of the magnetic field, for instance.

Can we see an example of Ampère's Law?

See the examples listed under the Ampère's Law howto.

How do you calculate the Lorentz force quantitatively?

Just use $q\vec{v} \times \vec{B}$. If $\vec{v}$ and $\vec{B}$ are perpendicular, this is just qvB. If not, then $\vec{v} \times \vec{B}$ is just $vB \sin\theta$, where θ is the angle between them.

Can you explain the eddy current demo in lecture?

I assume you mean the pendulum demo. If you have a pendulum made of metal, current can flow everywhere in the metal, so you can have current loops anywhere on the surface. When it enters a magnetic field, the flux through any loop on the surface is changing. So you get induced currents ("eddy currents") in the metal, happening all over the surface. According to Lenz's Rule, these induced currents create B fields opposing the change in flux, which create forces that oppose the motion (whichever way the motion happens to be). So the pendulum slows down as it goes through. The more of the pendulum's area in the magnetic field, the more flux inside the loop, and the bigger the change in flux as it swings, so the more dramatic the effect. Then, if slits are cut in the pendulum: this impedes the flow of current, so it decreases the effect.

There was also the levitating magnet, which was also designed to show Lenz's Law and eddy currents in action. The rotating disk is made of metal, so currents can flow everywhere. The little piece of disk the magnet is sitting on is pierced by magnetic field lines. As the disk rotates, consider a little piece of disk that sweeps under the magnet. The flux through it will change as it sweeps by the magnet. So a current is induced in the piece of disk. The direction of this current creates a field which opposes the magnet's field, by Lenz's Rule. So it acts as a repelling magnet, and the magnet levitates.

How do you find $d\Phi_B/dt$?

First, find $\Phi_B = \vec{B} \cdot \vec{A}$. Either $\vec{A}$, $\vec{B}$ or the angle between them may be changing in time; find the time dependence. Then just crank through the derivative. The Faraday how-to may help.

In problem 4 of pset 8, why did I get a different result from constant ε_0 where the only resistance was the rolling rod? Why wasn't the answer for ε_0 just I/R?

The total potential difference across the rod is the sum of a part which comes from the battery (ε_0) and a part which is induced (in the opposite direction). So the total current is $(\varepsilon_0 - \varepsilon_{\text{ind}})/R$. It may help to imagine the moving rod as another little battery in series (the moving rod acts as an EMF, like a battery). You could also just think of it directly in terms of current as $I_{\text{tot}} = I_{\text{battery}} - I_{\text{ind}}$.

Where does mutual inductance M come from? What's its significance? What do we need to know about it?

I think the easiest way to think of it is in terms of two coils nearby each other. If you change the current I_1 in one, it will change the flux through coil 2, $\Phi_{2,1}$ (the flux through coil 2 due to current in coil 1) . This changing flux will induce a current I_2 in coil 2. The flux $\Phi_{2,1}$ is proportional to I_1. The EMF in coil 2 is therefore proportional to the rate of change of I_1. The constant of proportionality is given the name "mutual inductance", so we write $\varepsilon_2 = -M_{21} dI_1/dt$; you can show that $M_{21} = N_2\Phi_{2,1}/I_1$. Physically, this constant of proportionality M_{21} tells you "sensitivity to change in current": it tells you how big an EMF you will get in coil 2 for a given change in current in coil 1. The bigger M, the easier it is to induce a current. Note that mutual inductance depends on geometry of a configuration. (There's a current in the definition of M, but that will cancel out when you work out the flux and divide by current. It's sort of similar to the way that the definition of capacitance involves charge and voltage, but then capacitance ends up being a property of the object only, not what particular charge and voltage it has.)

I think because mutual inductance was not in the review slides, it won't be directly on the test... but the concepts of induction involved are integral to what you *do* need to know, so you should have some understanding.

Would mutual inductance change if you changed the radius of one or both coils?

Yes, it would. $M_{21} = N_2\Phi_{2,1}/I_1$, so if you changed the radius, the flux $\Phi_{2,1}$ would change, so the mutual inductance would, too.

In the DC and AC graphs, what are the axes? Time and voltage?

I'm not sure exactly what you're referring to, but often one plots voltage versus time.

Can you explain self-inductance? Will it be on the test?

No, I don't think it will be on the test. We'll get there.

Tidbits

Please remember! The Sparkly Frog wants you to remember that induced EMF/current depends on **RATE OF CHANGE** of flux, not on flux directly!! NO CHANGE MEANS NO INDUCED CURRENT!! Please don't disappoint the Sparkly Frog!