Content Questions

How do you determine the polarity of a dipole?

Consider the magnetic field vector. The north pole is in the direction of the arrow tip.

What does $\epsilon$ mean physically? If it’s positive or negative, what changes, only current direction?

$\epsilon$ is the induced EMF: it’s a potential difference induced in a wire by the changing magnetic flux through the loop. The direction of the potential difference (corresponding to the direction of the electromagnetic field in the wire) determines the direction of the current: the current flows from $+$ to $-$.

How do you get the power in problem 28c?

Power dissipated in the resistor is $I^2R$; the current is the induced current.

How do you do $\Phi_B = \int \vec{B} \cdot d\vec{A}$ when the $dA$ is changing?

I’m not sure exactly what you mean by “the $dA$ is changing”. If $B$ is not constant (in space) across the loop, you can set up an integral by adding up contributions $d\Phi_B = BdA$ to the flux for a known variable $B$ and a $dA$ over which $B$ is known. For the loop-next-to-a-current-carrying-wire examples in this week’s homework, $dA = Ldr$ is a slice at a given distance $r$ from the wire, and $B(r)$ is known, so the integral is $\Phi_B = \int B(r)Ldr$.

If the area of the loop with field lines through it is not constant in time (say there’s a rolling bar, or a loop entering a magnetic field), then you can do the same integral to find $\Phi_B(t)$ at a given time. Then if you can find how $\Phi_B$ is changing with time, you can take the time derivative to find the induced EMF.
In the example of the loop moving through the field region, don’t you need to do an integral over $\vec{B} \cdot d\vec{A}$ because the area is changing?

In this case the flux is not changing in space at a given moment in time. The amount of flux through the loop at some time $t$ is just $Bwx$, where $x = vt$. You can just use the expression $\Phi_B = \vec{B} \cdot \vec{A}$, which is $BA$ since $\vec{B}$ and $\vec{A}$ are parallel vectors. (You could write this as an integral, $\Phi_B = \int B dA = B \int dA = BA$, but it’s a simple integral since $B$ is constant and comes out of the integral, and the integral over $dA$ is just the total area.)

The flux is varying in time, however, and it’s the time rate of change that gives you the induced current by Faraday’s Law.

**How would you determine current when a bar is moving away through a non-constant $B$ field?**

You can use the same “howto”. Find the magnetic flux $\phi_B$ through the loop at some arbitrary moment in time: this will likely depend on the coordinates of the problem somehow. Then find how it depends on time: if the bar is moving away, $\phi_B$ will have some time dependence via the coordinates that have time dependence. Once you have $\phi_B(t)$, take the time derivative to get $\epsilon$, and $I = \epsilon/R$.

**What do you do if $v$ is changing in time?**

Find $\phi_B$ as a function of $v$ and then plug in $v(t)$ to get $\phi_B(t)$. Then use Faraday’s Law to find $\epsilon$ as usual.

**How do you find the induced current direction?**

If you know the direction the induced magnetic field must be in (by Lenz’s Law, the induced magnetic field must be in a direction so as to oppose the change in flux), then use the RHR to find the current: point your thumb in the direction of $\vec{B}$, and your fingers curl around in the direction of the current.
How do you find the direction of the force on a wire with an induced current?

For this, use the regular cross-product RHR for $\vec{F} = I\vec{L} \times \vec{B}$: fingers point along the direction of current (direction of the first vector in the cross-product), curl them towards $\vec{B}$, and thumb is in the direction of $\vec{F}$. Here $\vec{B}$ is the external field, not the induced field.

What exactly are eddy currents?

These are induced currents you get in some kind of extended conductor. If you have a wire, charges are confined to move along the wire, but if you have, say, a big chunk of metal, then charges can move around anywhere inside it. So they are free to move around in loops in the bulk of material in such a way as to respond to changing magnetic fields in the material. This movement of charge is referred to as an induced “eddy current”. By Lenz’s Law, the induced eddy currents will arrange themselves in such a way as to oppose the change in magnetic flux.

In the electromagnetic brake example, why was there one eddy current behind and one ahead?

The brake electromagnet is sweeping along the rail. Just ahead of it in the direction of motion, the upward magnetic field starts to increase. This creates an induced eddy current that tries to oppose the upward increase: so the current will create a downward magnetic field and a CW (as seen from above) current. Now just behind the magnet, the upward magnetic field is decreasing, as the magnet moves away. The induced eddy current tries to oppose that change, so it creates an upward magnetic field. So the eddy current in the magnet’s wake is CCW as seen from above.

How did the eddy currents approximate as bar magnets in the electromagnetic brake example?

A circular current creates a $\vec{B}$ field with direction given by the RHR. It’s associated with a magnetic moment $\vec{\mu}$ in that direction. This magnetic moment acts in basically the same way as a little bar magnet with a north pole in the direction of the magnetic field arrow. So, you can treat a circular current as a magnet.
In the electromagnetic brake example, how did the eddy currents induce attractive and repulsive forces?

See above couple of questions: you get an eddy current ahead of the brake electromagnetic that creates a downward pointing field: this is like a little magnet with north pole downwards. On the trailing side, you get an eddy current that creates an upward pointing field; this is like a little magnet with north pole upwards. Now consider how these induced dipoles interact with the electromagnetic, which has south pole pointing downwards. The electromagnet and the induced leading eddy current dipole have south poles towards each other, so they result in repulsive forces between the train’s electromagnet and the bar. The electromagnet and the induced trailing eddy current dipole have south pole and north pole near each other, so they result in attractive forces. The train is pushed away from the direction it’s going in and pulled towards the direction it’s coming from, which results in a braking action.

For chapter 32, when you have an inductor and a capacitor, won’t you always have resistance in the wire so the oscillation will always decay?

Yes, in real circuits wires always have at least a tiny bit of resistance, so there will always be some decay of the oscillation (for very small resistance, the decay will be very slow).