

Electromagnetic Induction Experiment

In this experiment, the activity will be based on a Phet simulation called Faraday's Electromagnetic Lab, created by a group at the University of Colorado at Boulder. This group has a number of good simulations of various topics. You can get to the main Phet site at <http://phet.colorado.edu>

The link to take you directly to the simulation you'll be interacting with today is

http://phet.colorado.edu/simulations/sims.php?sim=Faradays_Electromagnetic_Lab

When you run the simulation, note that it is actually five different simulations in one. You can switch from one to the other by using the tabs at the top of the simulation window.

Part 1 – Bar Magnet

Start with the bar magnet simulation. In the menu at the right, check all of the checkboxes. You can click-and-drag to move the magnet, the compass, or the field meter around the screen. Move all three of these around to see what happens.

A compass can be used, both in the simulation and in real life, to determine the direction of the magnetic field at a particular point. How does the compass indicate the field direction? The direction of the field is in the direction that the _____ pole of the compass needle points.

The field meter will give you the numerical value of the magnetic field at a particular point. Note that the field meter gives field in units of G, which stands for gauss.

What is the conversion factor from tesla to gauss? Approximately what is the strength of the Earth's magnetic field in gauss? (Feel free to make use of the internet through the computer right in front of you!)

At which point on the field meter is the meter measuring the magnetic field?

Move the field meter around, and see where you can place it to find the highest possible magnetic field. Note that there is a slider in the menu. What is the magnitude of the largest field possible in this simulation, and where do you find that maximum field?

Part 2 – Pickup coil

Now, use the second tab at the top of the simulation window to switch to the Pickup coil simulation. This shows a bar magnet near a coil of wire. The coil of wire can be connected to a light bulb or a voltmeter. For now, leave the coil connected to the light bulb. Note that you can click-and-drag to move the magnet, or you can click-and-drag to move the light bulb (the coil will come with it, of course).

In this simulation, there are at least five ways to get the light bulb to light up briefly. List the methods you come up with to light the bulb.

- 1.
- 2.
- 3.
- 4.
- 5.

Describe what you should do so that the bulb brightness is maximized. What should the sliders be set to? What should you do when you move something on the screen? Feel free to switch to the voltmeter to try to maximize the voltmeter reading instead.

In this simulation, adjusting the coil area doesn't seem to make much difference. This may, at first, surprise you, because you have been taught that induced voltage is related to the rate of change of magnetic flux, and magnetic flux has a factor of area in it. Why do you think that, in this simulation, increasing the coil area, even by a factor of 5, has a relatively minor impact on the induced voltage when you move the magnet or coil?

What do the blue dots in the coil represent?

☐ positive charges ☐ negative charges

When you move the coil toward the magnet, the dots should move in a direction consistent with the right-hand rule associated with $F = qvB \sin \theta$. Do they? Explain. Think carefully about the component of the magnetic field that matters here.

Part 3 – Electromagnet

Now, use the third tab at the top of the simulation window to switch to the Electromagnet simulation. In the menu at the right, check all the checkboxes, which gives both a compass and a field meter on the screen.

Here, instead of a bar magnet, we have an electromagnet – a magnetic field is created by setting up a current in a coil. Start with the DC case, in which a battery is connected to the coil. DC, by the way, stands for _____ .

In this situation, what is the magnitude of the maximum magnetic field that can be achieved? Where is that maximum field located?

Compare the magnetic field created by the electromagnet (in the DC case) to the magnetic field created by a bar magnet. Think about the case of a short stubby bar magnet, the same size as the coil. Do the electromagnet and the same-size bar magnet create similar fields? Identical fields? Completely different fields? Explain.

In the DC case, can we change the magnitude of the magnetic field at a particular point without moving the coil? Explain.

Now, switch to AC, which stands for _____ .

For the AC situation, you see a graph. What is this a graph of?

On the vertical axis of the graph is ...

On the horizontal axis of the graph is ...

What does the magnetic field do, with the coil connected to the AC source?

Part 4 – Transformer

Use the fourth tab at the top of the window to switch to the Transformer simulation. This shows an electromagnet magnet near a pickup coil. The pickup coil can be connected to a light bulb or a voltmeter. For now, leave the coil connected to the light bulb. Note that you can click-and-drag to move the electromagnet, or you can click-and-drag to move the light bulb (the pickup coil will come with it, of course).

In this simulation, there are at least six ways to get the light bulb to light up briefly, in the DC situation. List the methods you come up with to light the bulb. It might help to place the pickup coil so the coil for the electromagnet is inside the pickup coil.

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.

Now, switch to the AC electromagnet. Do you have to do anything special to make the light bulb light now?

Staying with the AC source, use the meter on the pickup coil instead of the light bulb. You should be able to make the meter go from its maximum positive reading to its maximum negative reading and back. Describe everything you have to do to cause this to happen.

Place the coils so that the coil for the electromagnet is inside the pickup coil. One thing you should observe is that using a larger-area pickup coil is less effective than using a smaller-area pickup coil. Explain why this is.

Are the charges (blue dots) in the pickup coil in phase with those in the electromagnet? In other words, when the charges in the electromagnet are moving fastest, are the charges in the pickup coil moving fastest? Why or why not?

Part 5 – Generator

Now, use the last tab to switch to the generator situation. This shows a model of the process used by a hydroelectric power plant (such as at the Hoover Dam, near Las Vegas, or at Niagara Falls) to generate electricity.

In this simulation, you have a pickup coil attached to a light bulb, a magnet attached to a wheel, and a faucet with a slider on it, that you can adjust to control the flow of water that will turn the wheel. Turn on the water. What happens to the light bulb?

Assuming that the water starts with a lot of gravitational potential energy, as it does at a place like Niagara Falls, explain all the steps involved in transforming the water's gravitational potential energy into the electrical energy we see that lights up the bulb.

You have a number of variables under your control in this simulation. Switch to the voltmeter instead of the light bulb. To make the voltmeter oscillate with its largest possible amplitude, describe the settings you should use on the simulation.

Unlike what you have observed previously, increasing the area of the pickup coil in this situation produces more voltage. Explain why more area corresponds to a larger voltage in this situation.