The Laws of Faraday and Lenz

Spring 2009

Introduction

The purpose of this experiment is to observe the current caused by an electromotive force ($\mathcal{E}$*mf*) induced by a *changing* magnetic field: Faraday's Law and Lenz's law.

Theory

Michael Faraday found that an $\mathcal{E}$*mf* is induced in a coil of wire that is proportional to the rate of change of the *magnetic flux* through the coil:

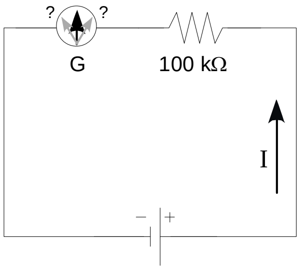
$$\mathcal{E} = -\frac{N\Delta\phi_B}{\Delta t}$$

where $\mathcal{E}$ is the $\mathcal{E}$*mf* induced in the loop, N is the number of loops of wire, $\Delta\phi_B$ is the change in magnetic flux, and Δt is the time interval over which ϕ_B changes.

The negative sign in Faraday's Law comes from Heinrich Lenz, who discovered that the direction of the induced current in a coil of wire is such that the coils own $\vec{B}$ field *opposes* the original change in the flux that induced the current. Therefore, the coil will always *resist* a change in magnetic flux.

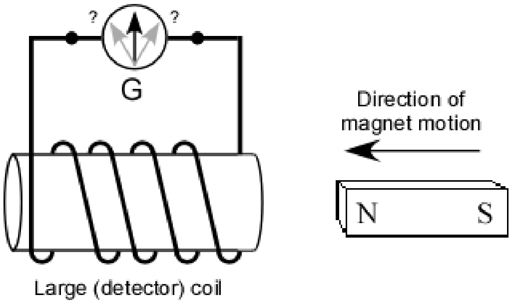
Experiment

Determine the direction of current with the galvanometer



1. Connect a 100 kΩ resistor in series with the galvanometer to allow a small current to pass through the meter, as shown in the circuit diagram (***If you connect the resistor incorrectly, you'll fry the meter!***). The galvanometer in your circuit diagram should show the direction the needle is pointing, and the direction of current *through* the meter (the + and – signs on the meter *do not* indicate direction). Reverse the direction of the current through the meter to confirm your observation.

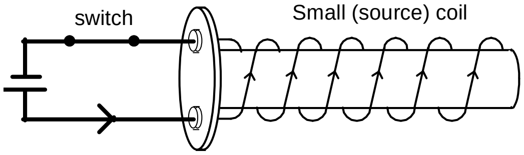
Using a permanent magnet to induce a current



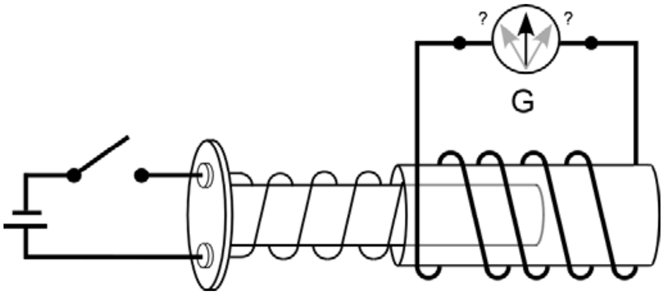
1. Use a compass of known polarity to determine the polarity of your bar magnet (recall that field lines *leave the north* pole, and *enter the south*).
2. Connect the larger (*detector*) coil to the galvanometer as shown at right (it's important that you draw your coils *carefully*):
3. Sketch the directions of the galvanometer needle, the *induced* current, and the *induced* $\vec{B}$ field through the coil due to (*i*) inserting and (*ii*) withdrawing a north and a south pole, from each end of the coil (you will have a total of *eight* sketches similar to the figure above). Draw your coils *carefully*; your observations should agree with predictions using the right-hand rule! (If they don't agree, you've misidentified the polarity of your magnet, or your coil is not connected properly!)
4. Include a summary of your observations where you generalize what happens during the two cases observed: (1) when a pole is inserted into the coil, and (2) when a pole is removed from the coil.

Using an electromagnet to induce a current

1. Connect the small (*source*) coil and a knife switch to the *DC* power source (connect the wire from the + terminal of the power supply to the marked terminal of the coil). Sketch the arrangement for your coil, as shown below:



2. Use the right-hand rule to predict which electromagnetic pole will be at each end of the small coil when a current passes through it. Connect the small coil to the power source, and verify with a known compass that your prediction is correct.
3. Now insert the small source coil *completely inside* the large detector coil, as shown (the sketch below shows the source coil *partially* inserted into the detector coil). Create *four* sketches of the detector coil to show the observed direction of the induced current (and induced $\vec{B}$) in the detector coil *i)* the *instant* the switch is closed (current turned on); *ii)* the switch stays closed (steady current); *iii)* the *instant* the switch is opened (current turned off); and *iv)* the switch stays open (current off). You only need to experiment with one side of the detector coil.



Note: Don't leave the knife switch closed for too long. The source coil will get ***very hot!***

4. Now, answer this question: Why are your observations *the same* when the current through the source coil is steady and when it is completely off? If you can answer this, then you *truly* understand the theory!

Did I Understand This?

At the front of the room you will find a coil and several magnets with tape covering the ends. Your instructor will ask you to determine the polarity for one of these unknown magnets *without* the aid of a compass. You will have to explain your answer as you are performing the experiment; the initials of your instructor will signify that you have mastered the Laws of Faraday and Lenz. In order for you to determine the polarity of the unknown magnet, you will follow the same series of steps as you did when inducing a current with a permanent magnet:

- Move the magnet in or out from the left or right side (only one motion is required)
- Note the direction the galvanometer needle points
- Determine the direction of the induced current from the galvanometer reading
- Follow the direction of the induced current around the coil
- Use the right-hand rule to determine the polarity of the coil's induced magnetic field
- Finally, infer the polarity of the bar magnet from the direction of the induced magnetic field, and the motion of the permanent magnet

✓ Successful completion of the "Exit Quiz" will earn you 1 extra point for this experiment! *Note that the coil used for the exit quiz will not necessarily be connected in the same manner as the one you used, so you will not pass by simply memorizing your pictures!*