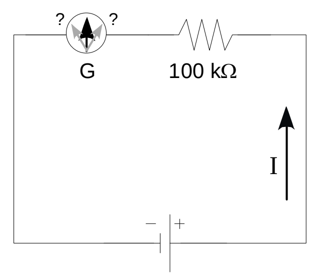
The Laws of Faraday and Lenz
Spring 2009

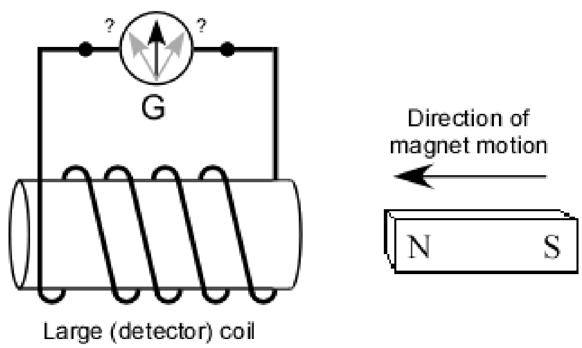
Introduction

This is a short laboratory exercise designed to help you envision the phenomenon of electromagnetic induction. *Faraday's Law* states that an *emf* ($\mathcal{E}$) is induced when the magnetic flux (Φ) changes through a coil of wire: $|\mathcal{E}| = \left|\frac{1}{c}\frac{d\Phi}{dt}\right|$. *Lenz's Law* states that the direction of the induced current in a wire coil always *opposes the change in magnetic flux* through the coil that induced the current. Your lab report will consist of a series of sketches showing the arrangement of components, direction of induced current flow, and direction of magnetic flux, for several configurations of coils and magnets.

Experiment



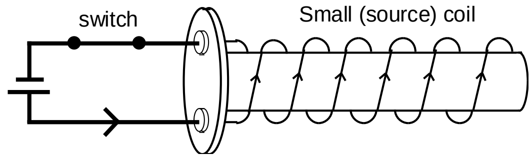
1. Connect a 100 kΩ resistor in series with the galvanometer to allow a small current to pass through the meter, as shown in the circuit diagram ***(If you connect the resistor incorrectly, you'll fry the meter!)***. The galvanometer in your circuit diagram should show the direction the needle is pointing, 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.
2. *Using a permanent magnet to induce current:*
   a. Use a known compass to determine the polarity of your bar magnet (recall that field lines *leave the north* pole, and *enter the south*).
   b. Connect the larger (detector) coil to the galvanometer as shown below (it's important that you draw your coils *carefully*):



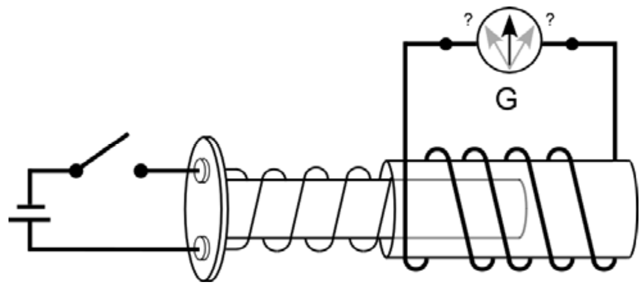
   c. Sketch the direction the needle points, the direction of the induced current in the coil, and induced $\vec{B}$ through the coil due to (*i*) inserting and (*ii*) withdrawing a north and south pole, from each end of the coil (you will have a total of *eight* sketches similar to the figure above).
   d. 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.
   e. Describe what happens when the magnet is moved toward and away from the coil quickly, and what happens when it is moved slowly. Explain your observations in terms of Faraday's Law:

$$|\mathcal{E}| = \left|\frac{1}{c}\frac{d\Phi}{dt}\right|$$

3. *Using an electromagnet to induce a current:*
   a. 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). You may find it useful to put a piece of tape on the coil with an arrow indicating the direction that current flows. Sketch the arrangement for your coil, as shown below:



   b. 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.
   c. Now insert the small source coil *completely inside* the large detector coil, and draw the sketch as shown below. Then create *four* sketches of *just the detector coil* to show the observed direction of the induced current (and induced $\vec{B}$) in the detecting 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!
5. Substitute the "new" galvanometer with an older galvanometer. Place a bolt inside the inner coil, and quickly close & open the switch. What happens to the galvanometer's response?
6. *Did I Understand This?* At the front of the lab, 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. 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 this "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 from part 2!*

Discussion:

- State Faraday's and Lenz's laws, and explain how your observations are consistent with these laws.