The Laws of Faraday and Lenz
Spring 2025

Introduction

The purpose of this experiment is to observe the current caused by a potential difference across a coil induced by a *change in magnetic flux*: Faraday's Law and Lenz's law.

Theory

Michael Faraday found that a potential difference is induced in a coil of wire that is proportional to the rate of change of the *magnetic flux* through the coil:

$$\Delta V = -\frac{N\Delta\phi_B}{\Delta t}$$

where ΔV is the potential difference 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 *resists* the original change in the flux that induced the current.

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 **Figure 1** (***YOU WILL DESTROY THE GALVANOMETER IF YOU OMIT OR INCORRECTLY CONNECT THE RESISTOR!***) The galvanometer in your circuit diagram should show the direction the needle points and the direction of current *through* the meter.

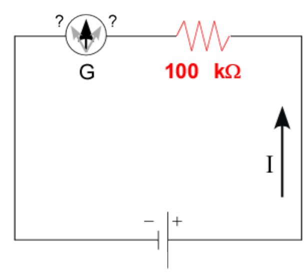

Figure 1: Galvanometer calibration

2. Does the needle point in the same direction as the current, or the opposite direction?
3. Reverse the direction of the current through the galvanometer to confirm your observation.

Using a permanent magnet to induce a current

1. We are using the same bar magnets (with a bump on one end) that we used in the *Magnetic Fields* experiment. Was the bump the North or South pole of the magnet? Check your journal from the previous experiment if you don't remember.
2. Connect the larger coil to the galvanometer using two short wires; the orientation of the coil does not matter (**Figure 2**).
3. *Try it!* Insert one side of the magnet into the right side of the coil, up to the coil's midpoint, and then withdraw the magnet. You should see that the needle moves to one side of the galvanometer while inserting the magnet and the other side when the magnet is removed. Using the other side of the magnet should move the needle in the opposite direction as you first observed.

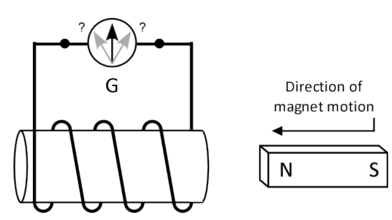

Figure 2: Inducing current with a bar magnet.

4. You will complete a series of diagrams on the accompanying worksheet that shows the direction the galvanometer needle points, the *induced* current, and the *induced* magnetic field, $\vec{B}_{ind}$ field through the coil due to (*i*) inserting and (*ii*) withdrawing a north and a south pole, from each end of the coil (a total of *eight* figures). Your observations for each figure should agree with your expectations using the right-hand rule! If your observations and the right-hand rule don't agree, you may have misidentified the poles of your magnet.
5. After completing the eight figures, write a summary of all your observations where you *generalize* what happens during the two situations observed: (1) when a pole is inserted into the coil, and (2) when a pole is removed from the coil. You only need to discuss the change in flux through the large coil and the direction of $\vec{B}$ in each situation: if the flux through the coil is *increasing*, are the directions of $\vec{B}$ (from the bar magnet) and $\vec{B}_{ind}$ (in the large coil) the same or opposite? How about when the flux through the coil is *decreasing*?

Using an electromagnet to induce a current

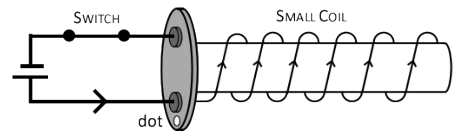

Figure 3: A small coil is connected to a power supply to create an electromagnet.

1. Connect the small coil and a knife switch to the *DC* power supply as shown in **Figure 3**, with the wire from the + terminal of the power supply connected to the terminal of the coil marked with a dot. When the switch is later closed, the current will flow through the small coil as shown, and you have created an *electromagnet*.
2. Use the right-hand rule to predict the direction of $\vec{B}$ when a current passes through the coil. Close the switch and verify with a known compass that your prediction is correct.
3. Now insert the small coil *completely inside* the left side of the large coil, as shown in **Figure 4** (the small coil is *partially* inserted into the large coil in **Figure 4**). Again on the worksheet you will complete *four* sketches of the large coil to show the observed direction of the induced current (and $\vec{B}_{ind}$) in the large 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 large coil.

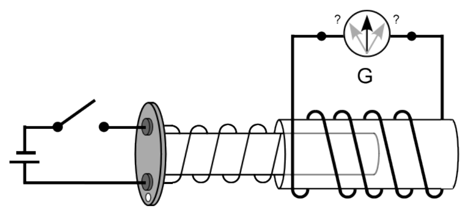

Figure 4: Small coil inserted into large coil. *Fully insert the small coil into the large coil.*

NOTE: DON'T LEAVE THE KNIFE SWITCH CLOSED FOR TOO LONG. THE SMALL COIL WILL GET VERY HOT!

4. Now, answer this question: Why are your observations *the same* when the current through the small coil is steady and when it is completely off? If you can answer this, then you *truly* understand the theory!
5. Think again about the pattern of flux change and direction of $\vec{B}$ and $\vec{B}_{ind}$ for these two coils. Describe the similarities with what you found for the large coil and bar magnet.

Discussion:

- State Faraday's and Lenz's laws *in words* and explain how your observations are consistent with these laws. *Be sure to hand in the worksheet!*