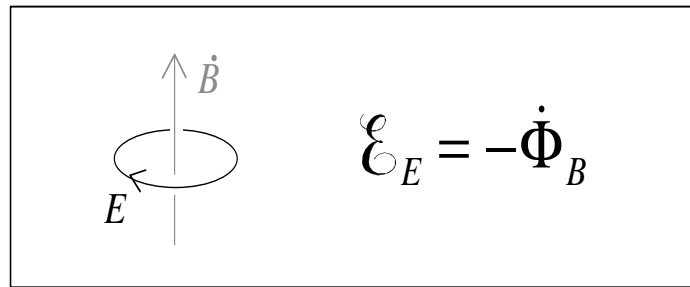


Experiment 7: Faraday Experiment



INTRODUCTION

Faraday's law precisely captures the fact that a changing magnetic flux induces a circulating electric field:

The circulation of the electric field around a closed loop is equal to minus the time rate of change of the magnetic flux through any area bounded by the loop.

The minus sign ensures energy conservation and is often referred to as Lenz's law.

MATERIALS

- Macintosh Computer
- Pasco Interface
- Power Amplifier
- *DataStudio*
- RLC Network (CI-6512): Inductor Coil
- Alnico Bar Magnet (EM-8620)
- Clamp (SE-9443 or SE-9446)
- Voltage Sensor (CI-6503)
- String
- Plastic support base with hole
- Smart pulley
- Mass set (counter weight)
- Giant solenoid and galvanometer (at instructor station)

THEORY

We learned that when a wire loop is subjected to a changing magnetic field that a current will be induced in that wire loop even though there is no external battery in the circuit. Faraday's law tells us how the voltage or emf (\mathcal{E}) associated with that current is related to the number of turns of wire (N) and to the change of the magnetic **flux** with time through the loop $\frac{\Delta\Phi}{\Delta t}$ (also written as $\dot{\Phi}$).

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

FARADAY'S LAW

Lenz's law is the special name given to the minus sign that embodies the conservation of energy in the law.

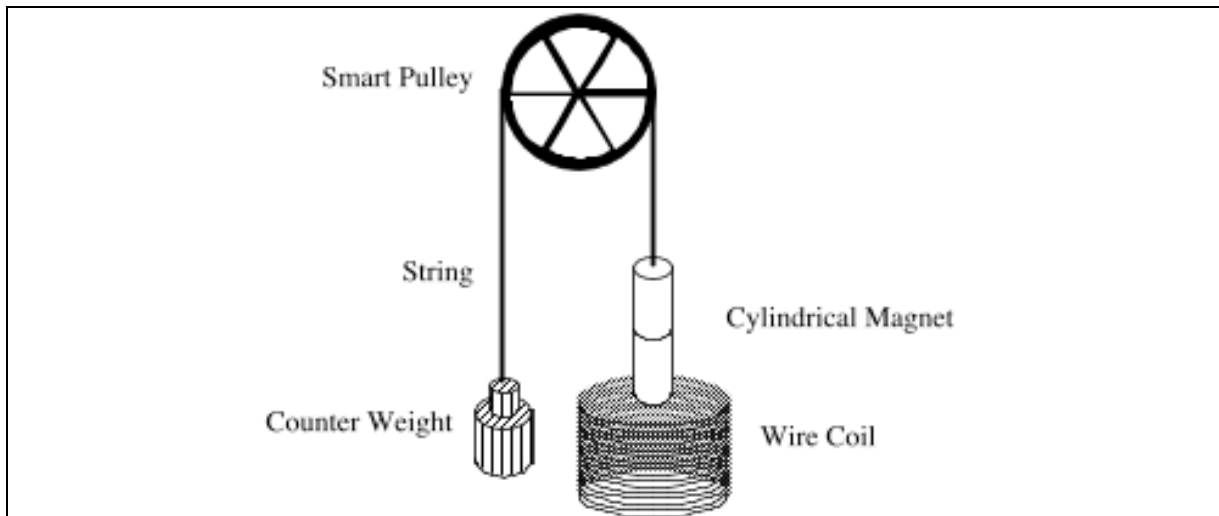
* Lenz's law states that the **direction of the induced current** will be such that the magnetic field associated with the induced current **will act to undo the change** in magnetic flux. *

This idea is very elegantly expressed in equation form, but it is a very abstract idea that can seem separate from our physical intuition until we see it at work.

You will put the idea to work by dropping a magnet through a coil and measuring the current through the coil so that you can test out your understanding of Faraday's Law.

SET-UP

- 1) Turn on the power to the Signal Interface box attached to your computer. Verify that the Smart Pulley is plugged into digital channel 1 of the interface and that the red and black leads attached across the current coil on the RLC circuit board are plugged into the \pm output jacks of the Interface box.
- 2) Launch *DataStudio*.
- 3) Drag the icon of the Smart Pulley sensor to channel 1 of the interface panel.
- 4) Drag the Signal Output icon to the \pm output jacks of the interface panel.
- 5) Select the "Signal Generator" menu item and increase the sampling rate to 500 Hz.
- 6) Verify that the Signal Generator is **off** (*not* on auto). (We are using the box only to **measure** the current, not to **provide** a voltage.) Check the "Measure Output Current" button; uncheck the "Measure Output Voltage" button.
- 7) Drag the "Velocity, Ch 1 (m/s)" down to the graph icon.
- 8) Add a Power Amplifier graph to the Velocity graph window by dragging "Output Current (A)" to the center of the velocity graph window.
- 9) Double-click on the graph to get the Graph Settings window and select the Layout tab. You can control the way 2 types of data are displayed on the same graph with the Layering control. Select "One Graph: Multiple Y Scales."



QUALITATIVE INVESTIGATION

For this section, you do not need the velocity measured by the Smart Pulley to be displayed on the graph, so make one more graph of just the Output Current.

Use the magnet and move it around and through the coil on the Pasco RLC board. Investigate what happens when you move the North Pole of the magnet through the coil. Investigate what happens when you move the South Pole of the magnet through the coil.

Summarize your procedure and your observations below. (Discuss the differences between the magnet's poles and any other phenomena you find.)

OLD SCHOOL QUALITATIVE INVESTIGATION

At the instructor's station, a large coil with thousands of turns is connected to a galvanometer. Use the large magnet provided and again experiment with moving the magnet around and through the large coil. Try moving the magnet at different speeds, and even try stopping the magnet completely when it is within the coil. Is there a difference between moving the North Pole in from the left and from the right?

Summarize your procedures and observations below.

Draw a schematic of what is happening to the coil when you approach it from the **top** with the **north** pole of a magnet. (Draw the coil, the field of the permanent magnet, and the induced magnetic field.) What direction must the current be flowing in the coil?

Draw a schematic of what is happening to the coil when you approach it from the **top** with the **south** pole of a magnet. What direction must the current be flowing in the coil?

Draw a schematic of what is happening to the coil when you approach it from the **bottom** with the **north** pole of a magnet. What direction must the current be flowing in the coil?

Draw a schematic of what is happening to the coil when you approach it from the **bottom** with the **south** pole of a magnet. What direction must the current be flowing in the coil?

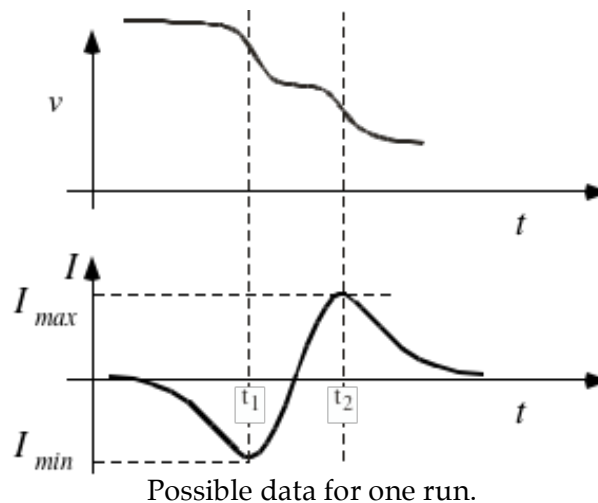
Do your conclusions about the direction the current must be flowing **match** the sign of the current that you measure in the coil?

Include a discussion of this section (along with at least one neatly-drawn schematic) in your lab report.

QUANTITATIVE INVESTIGATION: SCALING

Move the cylindrical magnet suspended from the Smart Pulley smoothly through the coil several times at different average velocities while recording both the current in the coil and the velocity of the descending magnet. Balance the magnet with a nearly equal weight tied to the other end of the string. This will reduce the acceleration of the descending magnet to near zero.

Use the graph tools to find the maximum induced current in the coil, which is just proportional to the emf \mathcal{E} induced. (Why?) Use the Cursor (xy) tool to find the velocity of the magnet that corresponds to those currents I_{\max} and I_{\min} . (Find I_{\max} and I_{\min} and their respective velocities *separately*. Don't combine or average them.) In Excel, plot I_{\max} and I_{\min} currents vs. velocity and attempt to fit the points with a straight line through the origin to test the theoretical prediction that the minimum/maximum current should be proportional to velocity. You will need at least 4 or 5 good points to make a convincing case, one way or the other.



QUESTIONS:

1. How is I related to \mathcal{E} ?
2. From your Excel plot, does I_{\max} depend linearly on the velocity of the magnet through the coil?

WORKSPACE

