

# Lab: Electromagnetic Induction

## BACKGROUND

Many instruments used in research are electronic, with complex circuits. An understanding of electrical circuits allows for a better understanding of the function of an electronic instrument. In this lesson you will study and analyze the voltage induced in an electrical circuit by a magnet moving through a coil.

## RESEARCH QUESTION

What is the effect of a changing magnetic flux on the voltage in a wire coil?

## OBJECTIVE

You will evaluate the effect of a changing magnetic flux on the voltage in a coil using one and two bar magnets.

You will compare the magnetic flux effect on the induced voltage as the bar enters the coil to the effect as the bar exits the coil by analyzing the voltage versus time graph. You will also compare the voltage induced by a single magnet to the voltage induced by two magnets.

## EXPERIMENTAL PLAN

In the experiment you will drop a bar magnet through a wire coil. This will generate an induced voltage that will be measured by the voltage sensor. You will find the area under the voltage vs time graph. This area represents the magnetic flux. You will evaluate the effect of the changing magnetic flux on the voltage by measuring the area using the software tool. You will compare the magnetic flux and induced voltage as the bar enters the coil to the flux and voltage as the bar exits the coil.

You will repeat the experiment while dropping two magnets through the coil simultaneously. Once with two magnets taped with their poles on the same side and a second time with their poles at opposite ends.

## ASSESSMENT

Write a formal lab report (see guidelines). The answers to the research question and objective should appear in your conclusion.

**NOTE: The Equipment, Theory, Set-Up, Procedure and Teacher Notes sections that follow were adapted from PASCO.**

## Equipment

| Qty | Items   | Part Numbers |
|-----|---|--------------|
| 1   | PASCO Interface                                 |              |
| 1   | Voltage Sensor                                  | CI-6503      |
| 1   | AC/DC Electronics Lab                           | EM-8656      |
| 1   | Bar Magnet, Alnico                              | EM-8620      |
| 1   | Pad (for stopping the bar magnet when it falls) |              |

## Theory

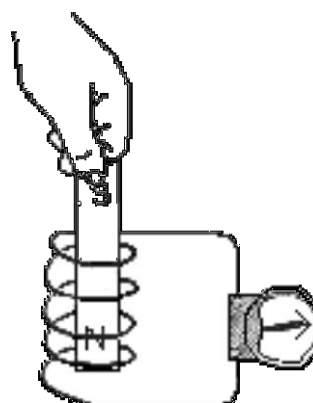
When electricity is passed through a conducting wire a magnetic field can be detected near the wire. Micheal Faraday was one of the first scientists to reverse the process. The essence of his work is decribed in the following statement:

*A changing magnetic field in the presence of a conductor induces a voltage in the conductor.*

When a magnet is passed through a coil there is a changing magnetic flux through the coil that induces an Electromotive Force (EMF) in the coil. This EMF is the induced voltage. According to Faraday's Law of Induction:

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

where  $\mathcal{E}$  is the induced EMF,  $N$  is the number of turns of wire in the coil, and  $\frac{\Delta\phi}{\Delta t}$  is the rate of change of the flux through the coil.



In this activity, a plot of the EMF versus time is made and the area under the curve is found by integration. This area represents the flux since:

$$\mathcal{E}\Delta t = -N\Delta\phi$$

## SAFETY REMINDER

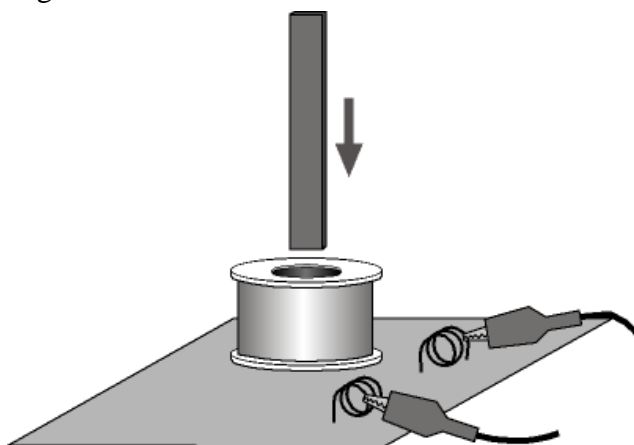
- Follow directions for using the equipment..

**THINK SAFETY**  
**ACT SAFELY**  
**BE SAFE!**

NOTE: During this experiment, keep the magnet away from the computer and from computer disks.

## Setup

1. Set up the PASCO Interface and the computer and start *DataStudio*.
2. Connect the Voltage Sensor to the PASCO Interface
3. Open the *DataStudio* file: **79 Induction - Magnet.ds**
  - The *DataStudio* file has a Graph display of Voltage versus Time and a Meter display of Voltage. Data recording is set at 200 Hz. The Start Condition is set to begin recording when voltage is at 0.005 V. The Stop Condition is set to stop data recording when Time = 0.4 seconds. (NOTE: The data recorded for 0.3 seconds prior to the Start Condition are kept as well.)
4. Put alligator clips on the ends of the Voltage Sensor leads.
5. Attach a Voltage Sensor lead to one component spring next to the inductor coil on the AC/DC Electronics circuit board. Attach the other lead to the other component spring next to the coil.
6. Arrange the circuit board so the corner with the coil is beyond the edge of the table, and the bar magnet dropped through the coil can fall freely. Place a pad on the floor below.



- The bar magnet will be dropped through the coil. Make sure that the magnet does not strike the floor, or it may break.

## Procedure

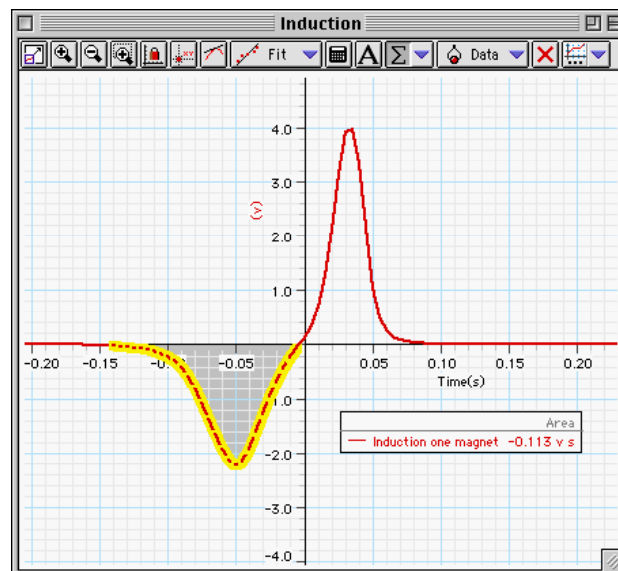
7. Hold the magnet so that the south end is about 2 cm above the coil.


- Note: If you are using the PASCO Model EM-8620 Alnico Bar Magnet the North end is indicated by the narrow groove near one end. For the first run, hold the magnet with groove end 'up'.

8. Click 'Start' in *DataStudio*. Let the magnet drop through the coil.
- Data recording will begin when the magnet falls through the coil and the voltage from the coil reaches 0.05 V. Data recording will end automatically after 0.4 seconds.

## Analysis

- Examine the graph of the voltage versus time.
1. Rescale the Graph display to fit the data if necessary.
  2. In the Graph display, use the cursor to select a rectangle around the first peak of the voltage plot.
  3. Set up the Graph to show the area in the selected area of the curve of voltage versus time.



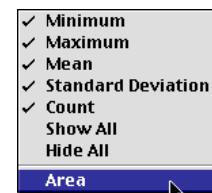
- In *DataStudio*, click the Statistics menu button () and select 'Area'. The value for 'Area' appears in the legend in the Graph.

4. Record the value of 'Area' for the left hand peak in the Lab Report section.

5. Repeat the process to find the area for the second peak. Record the value of 'Area' for the right hand peak.

6. Repeat the data recording and data analysis procedures for the following setups:

- Tape two bar magnets together so both south ends are together.
- Re-arrange the two bar magnets so that the south end of one is with the north end of the other.



## **Formal Lab Report Guidelines**

**Mrs. Coyle**

1 Heading: Cover page to include lab title, date, names of partners.

2 Research Question: State the research question of the experiment.

2 Objective: State the objective of the experiment.

5 Theoretical Background: Write a few paragraphs that explain the physics principles studied in this lab. Include mathematical equations if needed.

3 Procedure: A brief listing of the steps followed.

4 Diagrams: Labeled diagrams of the experimental set-up. Each diagram should have a title and a number.

6 Data: Data tables with units. They should have a title and number (example: Table 1: Velocity Data). **Note:** If graphs are the data include them here.

7 Calculations: Detailed calculations with formulas, substitution and units. One sample calculation for each data point.

8 Conclusion: One paragraph that includes the answer to the research question and objective. Here you should include error analysis and possible sources of error.

-Reports should be typed double spaced, font 12.

## Teacher Notes

|                       |                            |                         |
|-----------------------|----------------------------|-------------------------|
| <b>Time Estimates</b> | <b>Preparation: 30 min</b> | <b>Activity: 30 min</b> |
|-----------------------|----------------------------|-------------------------|

### Objectives

Students will be able to...

- use the Voltage Sensor to measure the voltage induced in a coil when a magnet falls through the coil.
- use the Graph display to determine the area under the curve of voltage versus time
- compare the 'flux' (voltage x time) induced by one end of the magnet to the 'flux' induced by the other end

### Notes

1. Any conducting wire wound into a coil and any bar magnet will produce similar results.
2. Remind students to put a pad or something soft under the coil so when the magnet falls, it does not strike a hard surface.
3. After your students have completed one run, ask them to predict what would happen if they reversed the red and black ends of the Voltage Sensor. After they make their prediction, have them collect data again. The voltage will be induced to the same magnitude, but the shape of the voltage versus time curve will be inverted across the X-axis.

### Data

$$\text{Area (first peak)} = -0.113 \text{ V}\cdot\text{sec}$$

$$\text{Area (second peak)} = 0.114 \text{ V}\cdot\text{sec}$$

### Sample Questions

1. Is the incoming flux equal to the outgoing flux?

*The value of the incoming flux is approximately equal to the value of the outgoing flux, but opposite in sign.*

2. Why is the outgoing peak higher than the incoming peak?

*The second peak (outgoing peak) is higher than the incoming peak because the magnet is moving faster during the second 'half' of the fall, and induces a higher voltage.*

3. Why are the peaks opposite in direction?

*The peaks are opposite in direction because the magnetic field at one end of the magnet is opposite to the magnetic field at the other end. Faraday's law predicts that the direction of the induced voltage is dependent on the nature of the magnetic field.*

## DataStudio Sample Data

