# Induction: Magnet through a Coil

## Equipment

| | | |
|---|---|---|
| 1 | Modular Circuits | EM-3536-KIT |
| 1 | Magnets from Modular Circuits | |
| 1 | Voltage Sensor | UI-5100 |
| 1 | No-Bounce Pad | SE-7347 |
| 1 | Small A-Base | ME-8976 |
| Required but not included: | | |
| 1 | 550 Universal Interface | UI-5001 |

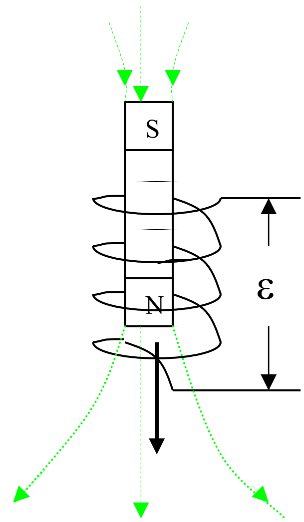

Figure 1: Falling Magnet

## Introduction

The purpose of this experiment is to examine Faraday's Law of Induction. A magnet will be dropped through a coil and the voltage across the coil graphed as a function of time. The total integrated flux as the magnet moves into the coil will be compared to the flux as it moves out of the coil.

## Theory

When the magnetic flux thru a coil of wire changes (as in a magnet falling thru a coil of wire in Figure 1), there is an EMF ($\mathcal{E}$) generated between the ends of the coil given by Faraday's Law:

$$\mathcal{E} = -N(d\Phi/dt) \quad (1)$$

where N is the number of turns in the coil and $d\Phi/dt$ is the time rate of change of the magnetic flux, $\Phi$, or the derivative of the magnetic flux with respect to time. The magnetic flux may be thought of as the number of magnetic field lines (green arrows in Figure 1) passing thru the coil. Integration of Equation 1 yields:

$$\int \mathcal{E}\, dt = -N\Delta\Phi = [\text{the area under the curve on an } \mathcal{E} \text{ vs. t graph}] \quad (2)$$

where $\Delta\Phi$ is the total change in flux (or total number of field lines).

## Setup

1. Assemble the circuit shown in Figure 2.

2. Plug the Voltage Sensor into Channel A on the 550 Universal Interface. Insert the sensor's banana plugs into the banana jacks on the circuit module.

3. Place the No-Bounce pad on the table where the magnet will hit. If the magnet hits the table without the pad, it may break.

4. Cut an 8.5" x 11" piece of paper in half so it is 8.5" x 5.5". Tightly roll up a piece of paper around a pencil to make a tube 8.5 inches long, remove the pencil, and insert it into the coil. This will guide the falling magnet so it hits the hole.

5. In this lab, we will use 8 disk magnets together to form a single long cylindrical magnet. Use the compass to identify which end of the magnet is the North end and stick a small piece of tape to that end for identification.

6. When you are ready to drop the magnet through the coil, stand the circuit on its side as shown. You can steady the circuit by slipping the feet of the small A-base into the back of the circuit modules. Hold the magnets so your fingers are just above the top of the tube.

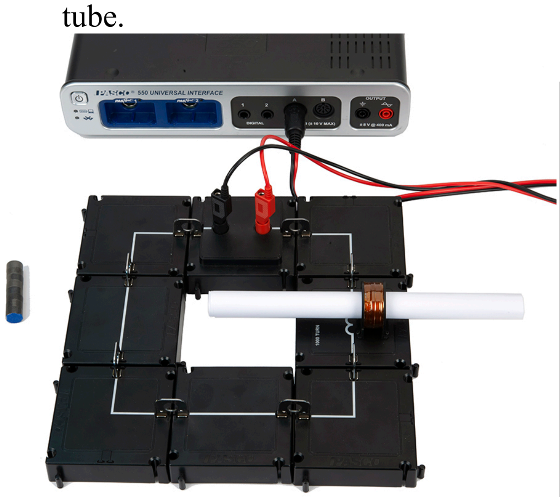

Figure 2: Setup

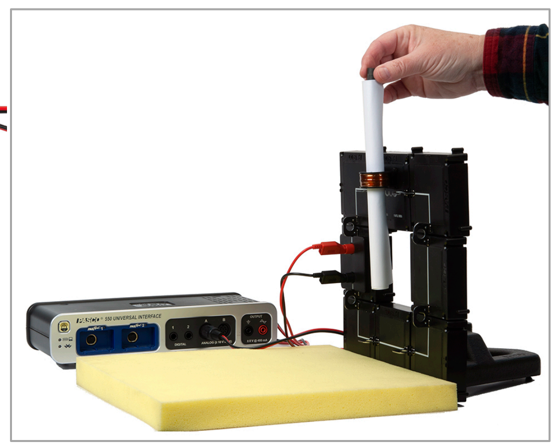

Figure 3: Paper Roll Guide

7. In PASCO Capstone, set the sample rate to 2.0 kHz and create a graph of Voltage vs. time.

## Procedure

1. When you are ready to drop the magnet through the coil, stand the circuit on its side as shown. Hold the magnets so the North end is down. Hold the magnets so your fingers are just above the top of the tube.

2. Start recording. Drop the magnet. Then stop recording.

3. Click open the Data Summary at the left of the page. Re-label this run as “N down”.

4. Repeat steps 1 & 2 with the south end down. Label it “S down”.

## Analysis

1. Create a table as shown below: All the columns are User-Entered Data sets.

Table I: Change in Magnetic Flux = N $\Delta\Phi$

| | System | First Pulse (Vs) | Second Pulse (Vs) | First Pulse Max V (V) | Second Pulse Max V (V) |
|---|---|---|---|---|---|
| 1 | N down | | | | |
| 2 | S down | | | | |

2. Select the “N down” run on the graph. Adjust the scale so induction part fills the graph.

3. Click on the Selection icon in the graph toolbar. Adjust the handles on the selection box to select the first pulse of the data.

4. Click the Area icon. It will calculate the area under the curve. Recall from Theory that this is the change in the magnetic flux through the coil. If the Area box does not show three significant figures, right-click on the Area box and change the properties to 3 significant figures. Enter the value in the First Pulse column of Table I on the N down line.
5. Move the selection box to select all the negative data. Enter the value in the Second Pulse column of Table I.

6. Use the Coordinates tool to find the maximum voltage of the first pulse and the second pulse and enter the values in Table 1.

7. Repeat for the “S down” data set.

## Conclusions

1. On the graph, select the “N down” run. Why is the peak voltage higher on the $2^{nd}$ pulse than on the $1^{st}$ pulse?

2. Why is one pulse up and the other pulse down?

3. Is the flux of the first pulse equal to the flux of the second pulse? Why or why not?

4. Select both the “N down” and “S down” runs. In terms of the magnetic flux, explain why they are reversed.