

Induction: Magnet through a Coil

Equipment

1	AC/DC Electronics Laboratory	EM-8656
1	Voltage Sensor	CI-6503
1	Bar Magnet Alnico (set of 2)	EM-8620
1	No-Bounce Pad	SE-7347
Required but not included:		
1	850 Universal Interface	UI-5000
1	PASCO Capstone Software	

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.

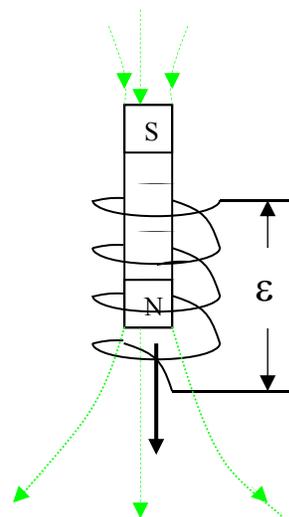


Figure 1: Falling Magnet

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, Φ , 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:

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

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

Setup

1. Remove the large plastic bolt from the center of the coil. Note: replace the bolt at the end of the experiment. Otherwise the coil tends to be pulled loose from the circuit board.
2. Connect white wire jumpers from the coil connector springs to the banana inputs for the Electronics Laboratory as shown in Figure 2. Connect red and black ends of the Voltage

Sensor to the banana inputs on the Electronics Laboratory and plug the Voltage Sensor into Channel A on the 850 Universal Interface.

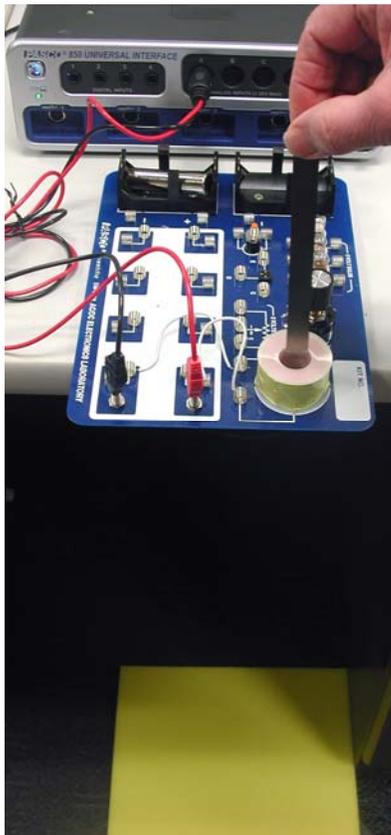


Figure 2: Setup

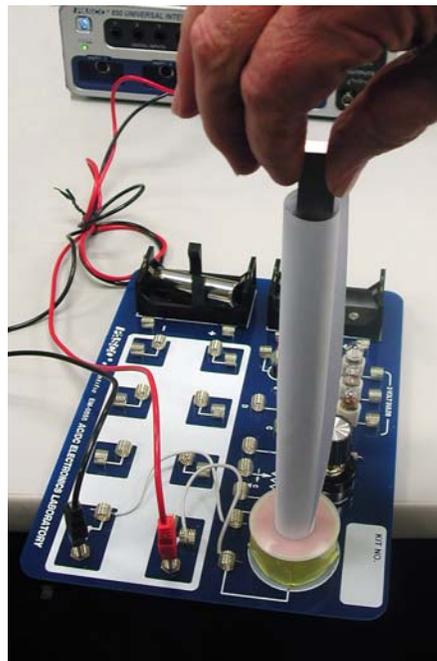


Figure 3: Paper Roll Guide

3. In PASCO Capstone, set the sample rate to 2.0 kHz and create a graph of Voltage vs. time.
4. Open the Recording Conditions and set a start condition for the measurement of Voltage rising above 0.01 V and set a stop condition based on a time of 0.25 seconds.
5. Position the Electronics Laboratory so it hangs over the desk enough so a magnet can be dropped through the coil. Placing the iron core for the coil (or any convenient mass) in one of the battery holders will prevent the Electronics Laboratory from tipping.
6. Place the No-Bounce pad on the floor where the magnet will hit. If the magnet hits the floor without the pad, it may break.
7. Tightly roll up a piece of paper to make a tube 8.5 inches long and insert it into the coil. This will guide the falling magnet so it hits the hole. Note where the magnet must be held so its lower end is about 5 cm above the coil.

Procedure

Note: The PASCO EM-8620 Alnico magnet has a groove near the North end. Hold one magnet so its north end is downward and is in the paper tube about 5 cm above the coil.

1. Click RECORD. Drop the magnet. Data collection will start and stop automatically. If you only see an “up pulse”, reverse the connections on the coil by reversing the red and black banana plugs from the voltage sensor.
2. Click open the Data Summary at the left of the page. Re-label this run as “N down”.
3. Click on Recording Conditions at the bottom of the page. Change the Start Condition to “Falls Below” and the Value to -0.0100. Click OK.
4. Repeat steps 1 & 2 with the south end down. Label it “S down”.
5. Click on Recording Conditions at the bottom of the page. Change the Start Condition to “Rises Above” and the Value to 0.0100. Click OK.
6. Repeat steps 1 & 2 with the north end down but held as high as possible in the paper tube. Label this run “N down hi”.
7. Remove the paper tube.
8. Stick the two magnets together (north to south). Hold them so one end is already in the top of the coil (they will just barely fit). Repeat step 2 and label “N to S”.
9. Tape the two magnets together so the north poles are together and the south poles are together. Hold them so the north end is already in the top of the coil (they will just barely fit). Repeat step 2 and label “N to N”.
10. Replace the plastic bolt holding the coil to the circuit board.

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)
1	N down		
2	S down		
3	N down hi		
4	N to N		

2. Select the “N down” run on the graph. Click on the Scale-to-Fit icon. Click on the Properties icon in the graph toolbar. Show Run Symbols and Show Data Points should not be selected (so you can see the line better). If they are selected, de-select them in both the Active Data Appearance box and the Future Data Appearance box. Click OK.
3. Click on the Selection icon in the graph toolbar. Adjust the handles on the selection box to select the data time = 0 to the point where $V = 0$ as the curve crosses the horizontal axis. You should have selected all the positive 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, click on Data Summary. Click on the Voltage Properties icon (not the Voltage Sensor Properties) and change to three significant figure under the Number Format. 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. Repeat for the “S down”, “N down hi”, and “N to N” data sets.

Conclusions

1. On the graph, select the “N down” run. Why is the peak voltage higher on the 2nd pulse than on the 1st pulse?
2. Why is one pulse up and the other pulse down?
3. Explain why the value for the magnitudes of the change in magnetic flux for the “N down”, “S down”, and “N down hi” are all essentially equal.
4. Select both the “N down” and “S down” runs. In terms of the magnetic flux, explain why they are reversed.
5. Select the “N down” and “N down hi” runs. Explain why they are different. Why doesn't this change the area under the curve?
6. Select the “N down” and “N to S” data. Explain the difference.
7. Explain why the “N to N” data in Table 1 are different from the other cases. Note: the two magnets probably were not equally strong. A 10% difference would not be surprising. You could check if you want.