1 Introduction

We have discussed Faraday’s law in the past several classes. What we have found is that a changing magnetic flux through a coil of wire induced a current in the coil. In this lab we will explore, both qualitatively, and quantitatively, various aspects of Faraday’s law.

2 Setup

The setup for this lab is relatively simple, consisting of a two coils, one large and one small. The smaller coil is the sense coil and will be used to detect the curly electric field that is produced by the changing magnetic field. The larger coil, called the generator, will produce the changing magnetic field. To produce the changing magnetic field the generator will be hooked up to a signal generator that creates a sinusoidal AC current

\[ I(t) = I_0 \sin(\omega t + \delta) \]

Where \( I_0 \) is the amplitude of the signal, \( \omega \) is the angular frequency of the AC signal (\( f = \omega/2\pi \)), and \( \delta \) is the phase (this can be thought of as a horizontal offset in the sine wave). We will monitor the current in both coils using the computer interface box and the capstone program.

3 Procedure

3.1 Activity 1: A magnet and a coil

A) Lay the small coil flat on the table, connect it to the voltage probe, and connect the voltage probe to channel A in the Science Workshop Interface.

B) Open PASCO Capstone, select “Table & Graph.” Click on “Hardware Setup” at the left, click on the image of the Channel A port, then scroll down and select “Voltage Sensor.” Click the pushpin icon to the upper right of the window displaying the Science Workshop Interface box. In the graph window, click on the “<Select Measurement>” on the y-axis and select “voltage.”

C) Insert a bar magnet, with the taped end down, into the hole at the center of the small coil.

D) Click “Record” and then quickly lift the bar magnet straight up and then click “Stop.” The computer should display the emf induced in the small coil. Several trials may be required to get the correct timing between the start of data collection and the movement of the magnet.

1. What is the sign of the induced emf?

E) Now fill in the following table
2. Use the table you just filled in, and the diagram on the detector coil to determine which side of the magnet is the north pole, and which is the south pole. Explain your reasoning.

<table>
<thead>
<tr>
<th>Magnet Side</th>
<th>direction</th>
<th>emf sign</th>
</tr>
</thead>
<tbody>
<tr>
<td>Taped end</td>
<td>down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>up</td>
<td></td>
</tr>
<tr>
<td>Un-taped end</td>
<td>down</td>
<td></td>
</tr>
<tr>
<td></td>
<td>up</td>
<td></td>
</tr>
</tbody>
</table>

3.2 Activity 2: Two coils and a varying current — qualitative

A) Connect the low resistance output of the signal generator to the large coil (without the 1.2 kΩ. Resistor). Also connect the large coil to another voltage probe and connect that probe to Channel B in the Science Workshop Interface.

B) In Capstone, click on Hardware Setup, click on the Channel B image, and select “voltage sensor.” Move the cursor to the graph window, and then on the bar that appears at the top, select the sixth icon from the right to “Add a new plot.” Click on the “<Select Measurement>” on the new y-axis and select “Voltage, Ch B.” Keep in mind for the following that the Ch. A voltage is in the small coil and Ch. B is in the large coil.

C) In the bottom of the window click on “Recording Conditions.” For start condition set the condition type to measurement based, Data source to voltage B, condition to “rises above,” and value to 0.000. This tells the program to start taking data when the voltage in the generator rises above zero volts (we call this a trigger). Set the stop condition to time based, and record time to 0.100 s. This will record data for two periods of the sine wave oscillation that we will set up below.
D) Turn on the generator and set the frequency to 20.0 Hz, the waveform to “sine,” and the amplitude to about halfway of full.

E) With the large coil laying flat on the table, place the small coil at its center so that the axes of the coils coincide. Be sure no magnets are near either coil, and press the start button on the computer to take the data.

F) Fit both curves to a sine wave

3. Record the fit parameters for each curve into the table below.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Generator</th>
<th>Sense</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ω</td>
<td></td>
<td></td>
</tr>
<tr>
<td>δ</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Do the fit parameters make sense (i.e. think about the units)? Explain why or why not.

5. How do the amplitudes of the two curves compare? Comment, qualitatively.

6. What is the difference in phase between the two curves, δ_G − δ_S?
G) Tilt the small coil so that the plane of the coil is at 45° with respect to the plane of the large coil, but keeping the coil at the center of the large coil. While holding the small coil in this position, collect data.

7. How does the relative amplitude of the induced emf in the small coil compare to what you saw in the previous experiment? Does this make sense? Explain.

8. Repeat for 90° and 180°. Explain the results for each one.

3.3 Activity 3: Two coils and a varying current – quantitative

A) Disconnect the large coil from the system and measure its resistance using a DMM.

\[ R_{\text{coil}} = \]

B) Replace the large coil in the circuit, and position the small coil in the center of the large coil so that the axes of the two coils coincide.

C) Collect the data and record the maximum Voltage in both coils

\[ \Delta V_{\text{Gen}} = \]

\[ \Delta V_{\text{Sense}} = \]
4 Analysis & Questions

9. Use Faraday’s law to find an expression for the induced emf in the sense loop.

10. At what time should the induced emf be a maximum? Compare this to your answer to question 6. Explain why this does or does not make sense (i.e. where would you expect the maximum to occur).
11. Use the expression you derived above using Faraday’s law to compute the maximum emf you should measure in the sense coil. Compare this to the value you measured above, and comment on the agreement.