

Lab 5 – Faraday's Law

Name _____

Partner's Name _____

I. Introduction/Theory

The purpose of this experiment is to explore some aspects of Faraday's law of electromagnetic induction. According to Faraday's law, when the magnetic flux Φ_B through a loop of wire changes with time, a potential difference or electromotive force (emf) is induced in the loop whose magnitude is given by

$$\mathcal{E} = -\frac{\Delta\Phi_B}{\Delta t} \quad (1)$$

In this experiment, the current in a large solenoid (it will be called the "primary solenoid ") creates a magnetic field. When this current is changing in time, the flux through a smaller "secondary solenoid" inside the primary solenoid changes, inducing an electromotive force, given by (1), in the secondary solenoid.

Suppose the small secondary solenoid is in a magnetic field B due to the primary solenoid. The secondary solenoid's area vector, \mathbf{A} , is directed parallel to the axis of the solenoid. The magnetic flux through each turn of the secondary solenoid is given by

$$\Phi_B^{each} = BA \quad (2)$$

If we think of the field strength B as the "density of lines" of the magnetic field, then (2) is the total number of lines passing through each turn of the coil. (Note that this definition of magnetic flux has the same form as the definition of the flux of the electric field used, for example, in Gauss's law.)

For a solenoid of N turns, the total magnetic flux through the entire solenoid is

$$\Phi_B = N\Phi_B^{each} = NBA \quad (3)$$

If the magnetic field B is changing in time, then by (1) and (3),

$$\mathcal{E} = -\frac{\Delta\Phi_B}{\Delta t} = -\frac{\Delta(N_s B_p A_s)}{\Delta t} = -N_s A_s \frac{\Delta B_p}{\Delta t} \quad (4)$$

where N_s and A_s refer to the secondary solenoid and B_p refers to the primary solenoid.

The magnetic field B_p through the secondary solenoid is generated by the current I_p flowing in the larger primary solenoid. If the secondary solenoid is circular in cross section, with N_s turns of radius r , the magnetic field at its center is given by

$$B = \mu_o \frac{N_p}{L_p} I_p \quad (5)$$

where $\mu_o = 4\pi \times 10^{-7}$ T-m/A, N_p = number of turns on the primary solenoid, and L_p = the length of the primary solenoid. When the voltage across the primary solenoid changes, so does the current $I = V/R$ flowing in it and, consequently, so does the magnetic flux through the secondary solenoid.

Algebraically place $I_p = V_p/R_p$ into (5), then (5) into (4) to get the emf induced in the secondary solenoid. Note: the term $\Delta V_p/\Delta t$ is the only time varying term in \mathcal{E} .

$$\mathcal{E} = \underline{\hspace{10cm}} \quad (6)$$

In this experiment, you will measure $\Delta V_p/\Delta t$ (the rate at which the voltage across the field coil is changing), and the emf induced in the search coil, using the oscilloscope display, and use these measurements in several ways to check Eq. (6) above -- and therefore Faraday's law.

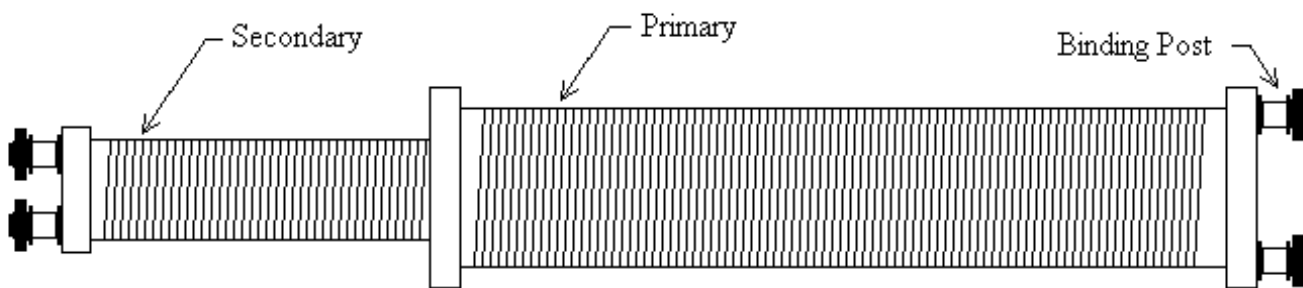


Figure 1

II. Equipment

Waveform Function Generator

Oscilloscope - dual trace

Misc. Connectors - 1 BNC to Banana, 1 BNC to BNC, and 4 Clips

Primary/Secondary Coil Induction Set

Multimeter with leads

Ruler

Calipers

III. Procedure/Data

0. The primary solenoid has 1250 turns and the secondary solenoid has 250 turns. Note: no extra credit will be given for counting turns in secondary solenoid. Watch your units in the next several steps!
1. Measure and record the resistance of the primary solenoid.

$$R_p = \underline{\hspace{10cm}}$$

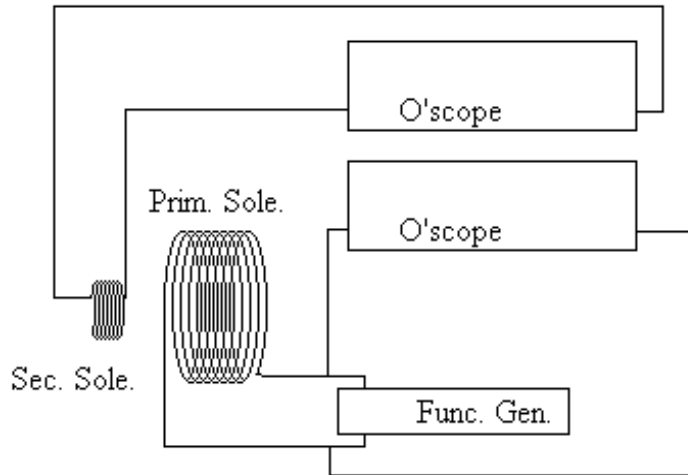


Figure 2

2. Measure and record the length of the primary solenoid.

$$L_P = \underline{\hspace{4cm}}$$

3. By measuring the diameter of the secondary solenoid, estimate the cross sectional area of the wire coils of the secondary solenoid.

$$A_S = \underline{\hspace{4cm}}$$

4. Configure the Primary/Secondary Coil Induction Set as per figure 2. Set the Waveform Function Generator to a frequency of 100 Hz, a triangular output waveform, and a peak to peak voltage of ± 1.0 volts. Do not include the iron core bar in the primary/secondary solenoid setup.
5. With the system configured as per the previous step with the primary solenoid and secondary solenoid fully inserted, record the following from the oscilloscope during a positive voltage rise:

$$\Delta V_P / \Delta t = \underline{\hspace{4cm}}$$

$$V_S = \underline{\hspace{2cm}} \pm \underline{\hspace{2cm}}$$

6. From the previous settings, sketch the temporal voltage output of the function generator and secondary coil as per the oscilloscope readings. Record/comment on the induced voltage observed in the secondary coil.

IV. Analysis

1. Using equation (6) and the parameters you measured during the lab theoretically calculate the value of E .
2. Statistically compare your theoretical value of E with your measured value and uncertainty of E observed in this lab. Comment on your results.

3. Evaluate $\lim_{\Delta t \rightarrow 0} \frac{\sin(t + \Delta t) - \sin(t)}{\Delta t}$. (Note: you should have done this before!).

4. Compare the results of the previous step with the last procedure step.

V. Conclusions (include physical concepts and principles investigated in this lab, independent of your experiments success, and summarize without going into the details of the procedure.)