

# Faraday's Law

## EQUIPMENT

1. Pasco primary coil and support stand – 200 turn, 10 cm radius
2. Secondary search coil, 2000 turns
3. Dual trace oscilloscope
4. Audio oscillator power supply with triangle wave or sawtooth waveform output
5. Meter stick or metric ruler

## INTRODUCTION

The voltage induced in a secondary search coil is measured, as the magnetic field flux passing through the coils is varied in a controlled way. The results are compared with the predicted values calculated according to Faraday's Law.

## THEORY

By Faraday's Law, the emf induced across the ends of a plane coil of N turns is given by

$$\mathcal{E} = -N \frac{d\phi_B}{dt} \quad (1), \quad \text{where } \phi_B \text{ is the magnetic flux}$$

passing through each of the N turns  $\phi_B = \oint \vec{B} \cdot \hat{n} dA = BA \cos \theta$  (2), for a uniform field with an angle  $\theta$  between the field and the normal to the coil.

## APPARATUS

The field coil has 200 turns and an approximate radius of 0.1 m. You will have to measure from the center of the coils on one side to the center of the coils on the other side to get a more accurate measurement of the primary coil diameter and record the result.

The primary side of the circuit has a 1200  $\Omega$  resistor so that the current in the field coil can be calculated from the voltage measured across this resistor. Using the channel 1 input leads of the oscilloscope.

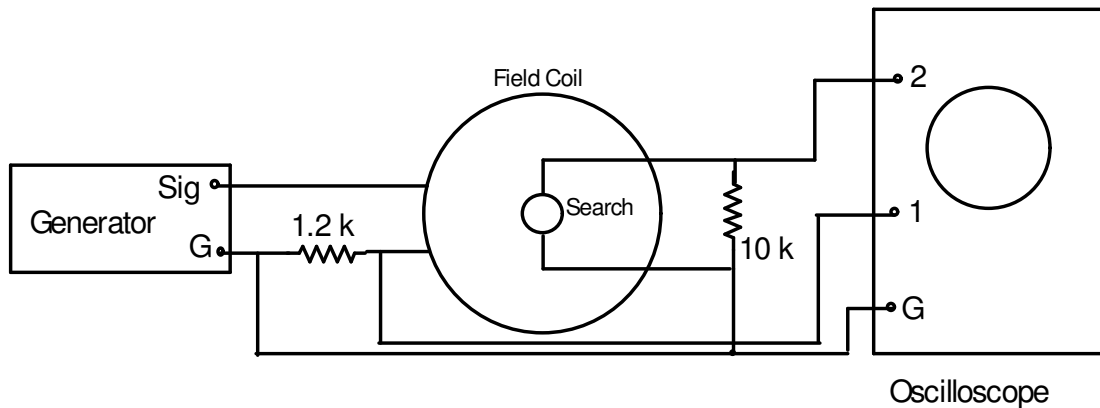


Figure 1

The small search coil to be mounted at the center of the field coil has 2000 turns, and an inner radius  $r_1$  and an outer radius  $r_2$  which you will need to measure and record. The radius of the search coil needed for the calculation of its effective area is really the root mean square radius, so that the effective area of the search coil is actually

$$A = (\pi/3)(r_1^2 + r_2^2 + r_1 r_2) \quad (3)$$

### SET UP

1. Attach the primary coil to the coil base. Connect the variable frequency power supply directly across the outermost terminals on the coil (including the coil's internal resistor), with the ground lead of the supply attached to the right-most (grey or black) terminal next to the 1200  $\Omega$  resistor on the primary coil. Set the frequency at 500 Hertz, and adjust the voltage to about half maximum using the voltage adjustment knob on the power supply.
2. Connect the channel 1 probe of the oscilloscope across the 1200  $\Omega$  resistor. Configure the oscilloscope according to the directions given in class by the lab instructor.
3. Attach the search coil in the vertical support so that it is mounted concentrically with the primary coil, and connect the channel 2 probe of the oscilloscope across the load resistor attached to the search coil.
4. Set the waveform to the triangle waveform, with a linearly increasing supply voltage.

## THE EXPERIMENT

Faraday's Law can be written

$$\mathcal{E} = -\frac{d}{dt}(BN_s A \cos \theta) = -N_s A \cos \theta \frac{dB}{dt} \quad , \quad (4)$$

Where  $\mathcal{E}$  is the emf induced in the secondary, B is the field produced by the primary,  $N_s$  is the number of turns in the search coil, A is the area of one turn of the search coil, and  $\theta$  is the angle between the central axes of the two coils.

By the Biot-Savart law, the magnetic field is given by

$$B = \mu_0 NI / 2r \quad , \quad (5)$$

where r is the radius of the primary coil. Since the primary current  $I$ , the voltage  $V$  across the 1200  $\Omega$  resistor in the primary circuit, and the resistance  $R=1200 \Omega$  are related by

$$V = I R \quad , \quad (6)$$

equation (5) can be written as

$$\mathcal{E} = -\left(\frac{\mu_0 N_s NA \cos \theta}{2rR}\right) \frac{dV}{dt} \quad (7)$$

This is the form of Faraday's Law that will be investigated in this experiment.

### PROCEDURE 1: Testing $\mathcal{E}$ vs $dV/dt$

1. With the coils set co-axially, adjust the amplitude of the input triangular waveform and/or the frequency to obtain an oscilloscope trace as depicted in Figure 2. Using the measurement controls of the oscilloscope according to the instructions of the lab instructor measure the values of the secondary emf  $\mathcal{E}$  (the amplitude of the square wave in channel 2) and the slope of the channel 1 input  $dV/dt$  and record in Data Table 1.

Then adjust for different values of  $dV/dt$  and record the data pairs in the data table.

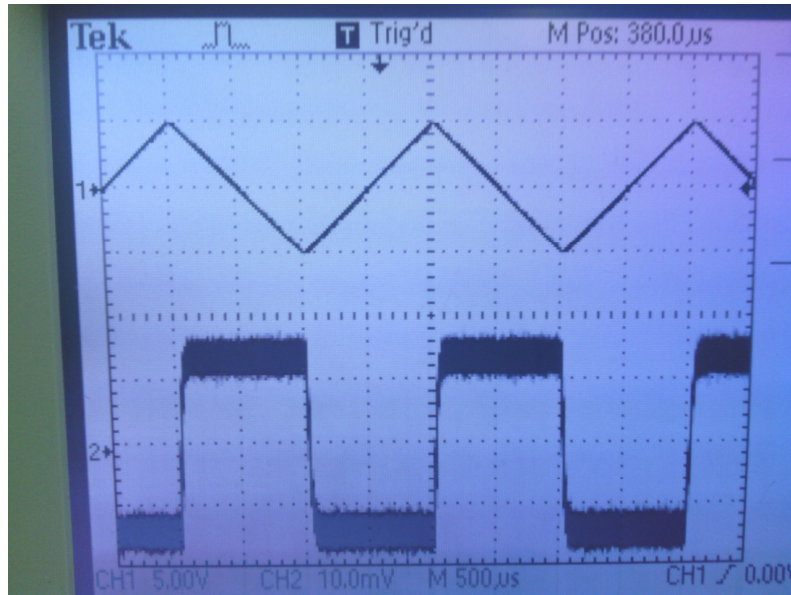


Figure 2- Channel 1 is upper trace

Table 1

EMF (V)	$dV/dt$ (V/s)

- Plot a graph of the data in Table 1, with the EMF plotted on the vertical and  $dV/dt$  on the horizontal. Ignore the minus sign in the equation and plot the magnitude of  $dV/dt$  so the graph slopes up to the right. The slope of the graph should correspond to the coefficient in parenthesis in equation (7). Evaluate the accuracy of the agreement and express percentage difference, and evaluate if this is within expected experimental error.

