PHYSICS 176
UNIVERSITY PHYSICS LAB II

Experiment 9

Faraday's Law of Induction

Equipment: F   unction Generator, Oscilloscope.

Supplies: One large and two small (with handles) coils, plastic triangles, T-base
              BNC connector, graph paper.

A. Objective

    The objective of this experiment is to demonstrate the Faraday's Law of
    electromagnetic induction.

B. Theory

When current, i, runs through a circular coil with N turns each of radius, r, a magnetic
field is created. Its strength, B, at the center of the coil, is given by the Biot-Savart Law:

$$B = N\mu\, i/2r, \qquad\qquad (1)$$

where $\mu = 4\pi \times 10^{-7}$ T · m/A is the so called permeability constant. On the other hand, a
changing magnetic flux, Φ, through a coil of N turns induces an *emf*, E, given by the
Faraday's Law:

$$E = -N\frac{d\Phi}{dt} \qquad\qquad (2)$$

where $\Phi = \int \vec{B} \cdot d\vec{A} = BA\cos(\theta)$ for a magnetic field (B) which is constant over the area
(A). Here θ is the angle between the magnetic field vector and the magnitude of the area
vector (A). In this experiment we will use a large (field) coil with $N = 200$ turns of radius
r_f *(approx.)* =10.5 cm to create magnetic field, and two search coils: one with $N = 400$
turns and another with $N = 2000$ turns, both of radius r_s *(approx.)*=1.5 cm, to measure the
induced *emf*. During the experiment, the area of the field and search coils is constant.
The current in the field coil, however, oscillates thus creating an oscillatory magnetic
field (flux) through the search coil positioned at the center of the field coil. As a result, an
average *emf* is induced in the search coil, given by

$$E = -NA\frac{\Delta B}{\Delta t}, \qquad\qquad (3).$$

where $\Delta B/\Delta t$ is the time rate of change (oscillation) of the magnetic field, N and A (=
πr_s^2) are the number of turns and area of the search coil, respectively.

1. Set the Function Generator to produce a triangular wave with amplitude of 5 volts and frequency - 2 KHz.

2. Build the circuit shown below:
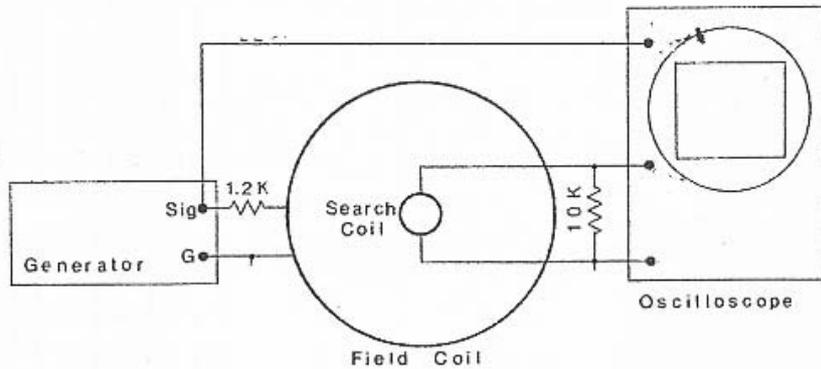
Note: the primary side of the circuit includes a 1.2 kΩ resistor, so that the current in the field coil can be calculated from the voltage delivered by the function generator. The resistance and self-inductance of the field coil are small compared to those of the 1.2 kΩ resistor. The 10 kΩ resistor in the secondary(search) coil damps out some of the unwanted oscillations (noise), so a relatively square wave *emf* can be seen on the oscilloscope screen. Position the triangular wave/voltage (generating the oscillatory magnetic field) and the resulting square wave *emf* as shown below to facilitate data reading from the oscilloscope screen. Use both Inputs (#1and #2) of the scope.
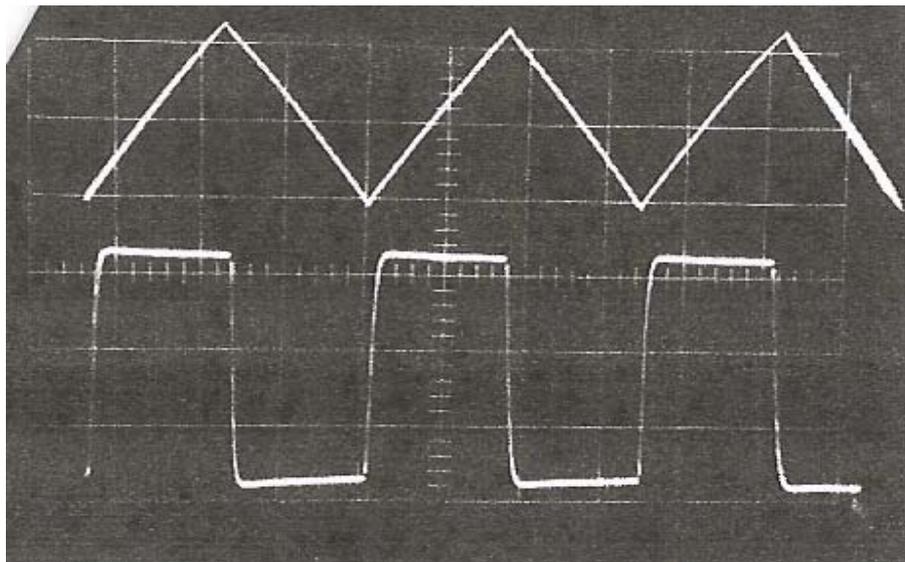
A. Using equation (1) and the known values of the circuit components calculate the strength of the magnetic field at the center of the field coil with r_f *(approx.)* =10.5 cm.

$$B = \ldots\ldots\ldots\ldots.[T]$$

B. Using the computed value of B and equations (2-3) predict the induced *emf* for the search coils with N = 400 and N = 2000 turns and radius r_s *(approx.)* = 1.5 cm. Measure those *emfs*. Compare the predicted and measured values. Comment.

Predicted: E (400 turns) =   …………..mV

E (2000 turns) = …………...mV

Measured: E (400 turns) = ……………..mV

E (2000 turns) = …………....mV

Comments:

C. Measure the *emf* dependence on the cosine of the angle between the magnetic field vector (B) and the area vector (A). Use the already set triangular wave with amplitude of 5 volts and frequency - 2 KHz , the search coil with 2000 turns and the provided plastic triangles. Plot the data. Comment.

θ[deg.]	cos(θ)	*emf* [mV]
0		
30		
45		
60		
90		

Comments:

D. Measure the *emf* dependence on the strength of the magnetic field/flux (at a fixed frequency of 2 kHz). For the purpose, vary the amplitude/voltage of the triangular wave provided by the function generator. Starting amplitude: 0.5 V; step: 0.5 V; end amplitude: 7 V. Use the search coil with 2000 turns. Plot the *emf* voltage versus the generator (triangular wave) voltage. Comment.

Ampl. [V]	*emf* [mV]	Ampl. [V]	*emf* [mV]	Ampl. [V]	*emf* [mV]
0.5		3		5.5	
1		3.5		6	
1.5		4		6.5	
2		4.5		7	
2.5		5			

Comments:

E. Measure the *emf* dependence on the rate of change of the magnetic field/flux (at a fixed generator amplitude of 5 V). For the purpose, vary the frequency of the triangular wave provided by the function generator. Starting frequency: 500 Hz; step: 500 Hz ; end frequency: 7.5 kHz. Use the search coil with 2000 turns. Plot the *emf* voltage versus the generator (triangular wave/magnetic field) frequency. Comment.

f. [Hz]	emf [mV]	f [Hz]	emf [mV]	f [Hz]	emf [mV]
500		3000		5500	
1000		3500		6000	
1500		4000		6500	
2000		4500		7000	
2500		5000		7500	

Comments:

F. Measure the *emf* intensity along an axis perpendicular to the field coil, at various distances from the plane of the coil, keeping the generator voltage/triangular wave amplitude (5 V) and frequency (2 kHz) constant. Plot the *emf* voltage versus the distance from the center of the field coil. Comment.

Distance [cm]	*emf* [mV]	Distance [cm]	*emf* [mV]
0		25	
5		30	
10		35	
15			
20			

Comments: