9. Faraday's Law of Induction

INTRODUCTION

Faraday's Law of Induction is one of the famous Maxwell's equations which relate electricity and magnetism. It tells us that when there is a change in the magnetic flux of a circuit, an induced voltage emerges. In other words, a time-varying magnetic field induces electricity. Electric motors, electromagnets, electric hot plates, etc. are all examples of Faraday's law of induction. With this experiment, we will be able to deepen our understanding in Faraday's law.

THEORY

According to Faraday's Law of Induction, a changing magnetic flux through a coil induces an electromotive force (EMF) given by

$$E = -N\frac{d\Phi}{dt}, \tag{1}$$

where $\Phi = \int \vec{B}\cdot d\vec{A} = BA$ for a magnetic field (B) which is constant over the area(A) and perpendicular to the area. N is the number of turns of wire in the coil. For this experiment, the area of the coil is constant and as the coil passes into or out of the magnetic field, there is an average EMF given by

$$E = -NA\frac{\Delta B}{\Delta t}. \tag{2}$$

EXPERIMENTAL SETUP AND PROCEDURE

1. Measure the radiuses of 200 turn coil and 2000 turn detector coil.

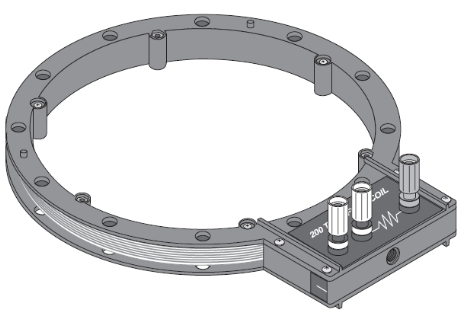

Fig.1. 200 Turn coil.

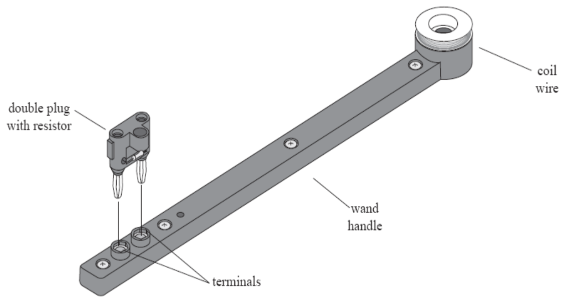

Fig.2. 2000 Turn detector coil.

2. With the aid of multimeter, confirm the range of the voltage range from the function generator by slowly varying the voltage from zero to the top. Then measure the resistances of the 2000 turn coil, the 200 turn coil, and the two ends resistor socket. This is to make sure whether the current limit of the detector coil is satisfied or not. DO NOT EXCEED THE CURRENT LIMIT OF 125mA OF THE DETECTOR COIL.

3. Using a T-shape BNC socket, connect the one output of the function generator to channel 2 of the oscilloscope. Plus, connect the other output of the function generator to two 200 turn field coil white ends. You may use one BNC end and the other sawtooth clips end cable.

4. Connect channel 1 of the oscilloscope to the 2000 turn detector coil.

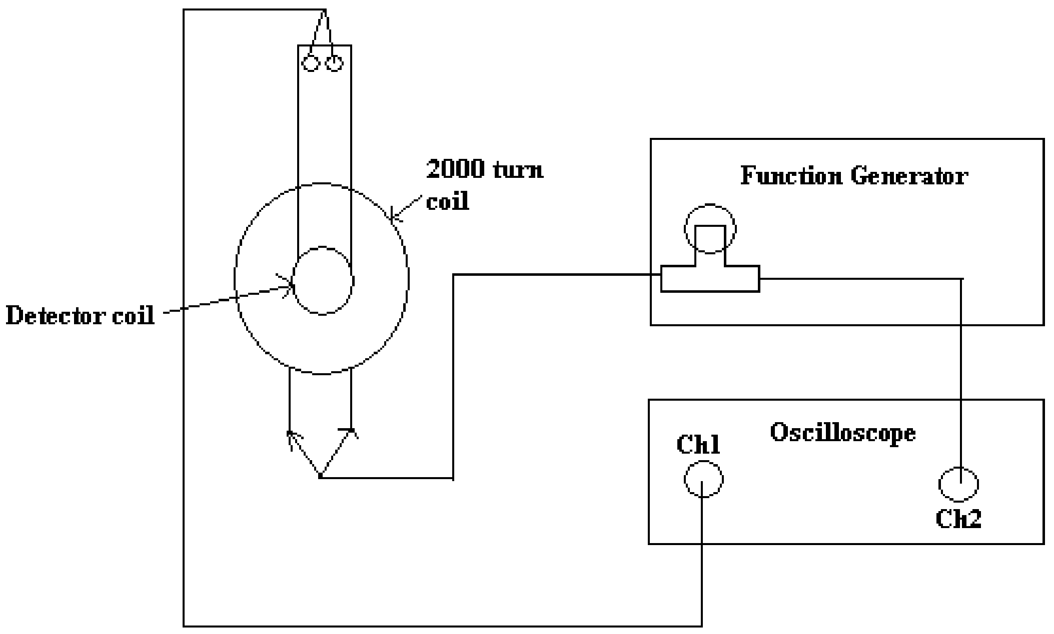

Fig. 3. Schematic circuit diagram.

5. Set the function to sinusoidal wave and vary the frequency. Locate the detector at the center of the 200 turn coil. Confirm the difference between the generator signal and the detector signal. Check what happens as the frequency increases.

6. Measure the amplitude and the period for each to the induced voltage and the source voltage.

7. Repeat the procedure with triangular wave.

ANALYSIS

1. Plot EMF *vs*. dV/dt graph. dV/dt increases as frequency increases.
   (Here, V is the source voltage amplitude.)

2. Derive the B-field at the center of the 200 turn field coil from the Biot-Savart Law

$$dB = \frac{\mu_0}{4\pi} \cdot \frac{i \cdot d\bar{s} \times \bar{r}}{r^3}. \tag{3}$$

3. As the frequency increases, the pattern between the source voltage and the induced voltage could change. See if this change happens and try to find out why.

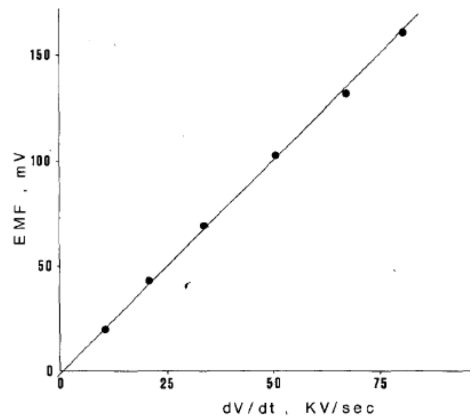

Fig. 4. Typical EMF *vs*. dV/dt graph.

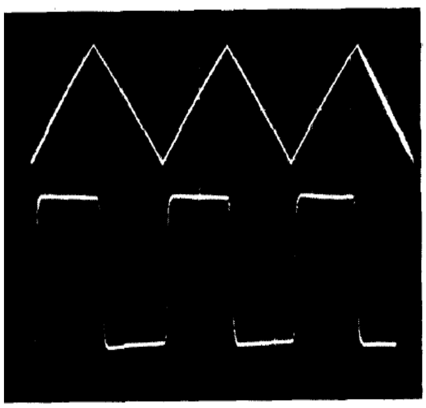

Fig. 5. An example of oscilloscope data, where the upper signal represents source voltage, and the lower signal represents induced voltage.