Electromagnetic Induction Lab

Equipment SWS, RLC circuit board, box with 2 coils and iron rod, magnet, voltage sensor (no alligator clips), 2 leads (35 in.)

Reading Review graph and scope displays, signal generator, and power amplifier II.

1 Introduction

The phenomenon of electromagnetic induction was discovered by Joseph Henry in New York in 1830 and by Michael Faraday in England in 1831. Faraday's name is commonly associated with the phenomenon (Faraday induction), although in this century Henry's contribution has been recognized by assigning his name as the unit for inductance. In the 1820's it was known that an electric current produces a magnetic field, and Henry and Faraday were trying to reverse the process and produce a current with a magnetic field. The result is elusive as a *steady* magnetic field will not cause a current to flow in a circuit. It is a time changing magnetic field that "induces" a current to flow. The changing magnetic field produces an electric field which is not conservative. The line integral of the electric field around a loop or circuit is not zero and is called an electromotive force or emf. The emf can drive a current in a circuit. Mathematically, the relationship between the non-conservative electric field $\vec{E}$ and the changing magnetic field $\vec{B}$ is given by Faraday's Law,

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}. \tag{1}$$

In this experiment an emf will be induced in one coil by

- moving a magnet near the coil,
- moving a second coil with a current in it near the first coil, and
- changing the current in the second coil.

For the most part your results will be qualitative. You should describe and explain what you observe. Bear in mind that the strength of the induced emf depends on the rate of change of the magnetic field. When an emf is induced in a coil the current that results will depend on the resistance of the circuit which the coil is part of. A voltage will also appear across the coil which can be measured by standard means. Because the voltage across the coil used in this experiment will be measured by a high impedance (resistance) device, the amount of current that flows will be small.

2 EMF Induced By A Permanent Magnet

An emf is induced in a coil by moving a magnet in and out of the coil. The emf will be is detected by measuring the voltage across the coil. The voltage across the coil as a function of time is shown on the graph display.

In the experiment set-up window drag the analog plug icon to channel A and choose voltage sensor. Open the graph display by dragging its icon to the voltage sensor icon below channel A. For a start, make the range of the vertical axis on the graph display -0.1 to +0.1 V and make the maximum value of the horizontal axis 20 s. (Click just to the left of an axis to change the axis parameters.) Click the sampling options button and adjust the sample rate to 100 Hz. Connect a voltage sensor directly across the coil on the RLC circuit board and see that this sensor is plugged into channel A of the interface. Click REC and thrust a magnet in and out of the center of the coil. You should see an induced voltage in the graph. Note the voltage polarities. Turn the magnet around and repeat your motions, noting the voltage polarities. Try slower motions and faster motions. Try not moving the magnet at all.

3 EMF Induced By Moving A Coil With A Current

The experiments of section 2 will be repeated with a current carrying coil instead of a magnet. A coil with a current has a magnetic field and if this coil is moved with respect to another coil the changing magnetic field will induce an emf. The induced voltages will be smaller so in the graph window change the vertical axes to read from -0.01 to +0.01 V. Drag the analog plug icon to channel C and choose power amplifier. Click AUTO in the signal generator window. Program the signal generator for 3 V DC. Connect the power amplifier to one of the coils from the wooden box. Double click the voltage sensor icon and change the sensitivity to medium (10X). The other parameters can stay the same as in section 2. Click REC and quickly move the 2nd coil in a coaxial fashion with the coil on the RLC circuit board. The recorder trace will be noisy, but an effect should be observable. Try reversing the current to the coil by switching the leads. (In theory, the coil could be turned over, but the connectors to the coil then make it difficult to move the 2 coils together.)

Comment There is a great deal of similarity between moving a magnet and moving a coil with a current. The magnet also has currents, but the currents are not produced by conduction electrons but by electron orbits and spins in the magnetized material from which the magnet is made.

4 EMF induced by Changing The Current In A Coil

A coil with a current has a magnetic field that is proportional to the current. If the current is changed the magnetic field is changed. This changing magnetic field will induce an emf in another coil. As far as this other coil is concerned, it does not make any difference whether the magnetic field is changed by changing the current or moving the coil.

Remove the graph display and drag the scope icon to the voltage terminals icon to open the oscilloscope display. Program the 2nd trace of the scope for channel A, the voltage sensor channel. Program the signal generator for a 3 V AC triangular wave with a frequency of 10 Hz. Lay the wired coil on top of the circuit board coil in a coaxial fashion. Click MON and observe the power amplifier voltage and the induced voltage on the 2 scope traces. How are the 2 traces related? Try the sine, square, and ramp outputs of the signal generator. What happens to the induced voltage if the iron rod from the wooden box is inserted into the 2 coils? You can do this while observing the scope display.

5 Finishing Up

Please leave the bench as you found it. Thank you.