Magnetics, Faraday's Law, and Simple Transformers Lab

This lab deals with magnetics and applications of Faraday's law. Part 1 introduces Faraday's law and demonstrates its principles. Part 2 deals with electromagnets. Finally part 3 introduces simple transformers and their underlying principles.

Part 1 – Faraday's Law

Faraday's law is given in equation 1 and relates induced EMF, e, to the flux linkage, λ.

$$e = -\frac{\partial \lambda}{\partial t} \qquad (1)$$

Equation 2 defines the flux linkage as flux, ϕ, times the number of turns in the coil, N.

$$\lambda = N\phi \qquad (2)$$

Lenz's Law as shown in equation 3 gives the relationship between EMF and voltage.

$$e = -v \qquad (3)$$

Substituting equations 2 and 3 into equation 1 we get equation 4.

$$v = N\frac{\partial \phi}{\partial t} \qquad (4)$$

From equation 4 it is seen that voltage is proportional to the time derivative of flux.

In this section you will be monitoring the voltage across a coil during a changing magnetic field. The setup consists of a coil hooked up to the oscilloscope directly and through a passive integrator. Moving a magnet in and out of the coil will create a changing flux. For the report you will compare the voltage waveform to the flux waveform (the output of the passive integrator).

For this section you need to capture and save plots for both polarities of the magnet at two different speeds, for a total of four plots.
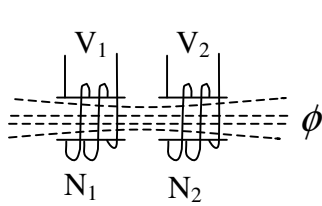
Part 2 – Electromagnets and RHR

In this section you set up an electromagnet using the coil and a DC power supply. Based on the principles of electromagnetics a magnetic field will be induced by the current flowing in the coil of wire. The polarity of the magnetic field is governed by the right hand rule (RHR). Using your ***right*** hand if the current is flowing in the direction of your fingers your thumb points to the north pole of the magnetic field. Some examples are listed below.
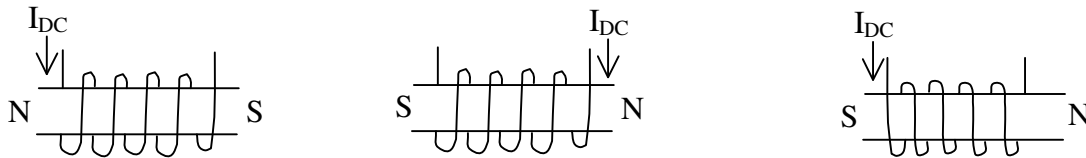
Once you have determined the polarity of the magnetic field you can find the polarity of the magnet from what you know about magnets (like poles repel and opposite poles attract). Vary the magnitude of the DC current and note the effects on the strength of the induced magnetic field.

Part 3 – Simple Transformers

This section introduces the concept of transformers based on Faraday's law. This is explained in the figure and equations below.

$$V_1 = N_1 \frac{\partial \phi}{\partial t}$$

$$\phi = \frac{1}{N_1} \int V_1 \partial t$$

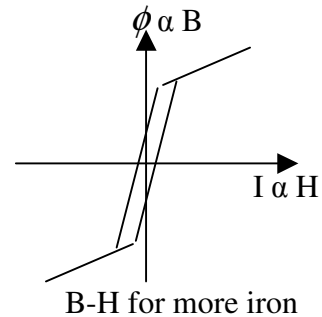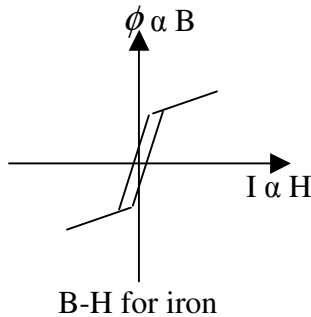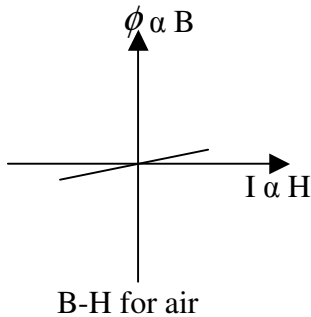$$V_2 = N_2 \frac{\partial \phi}{\partial t}$$

$$V_2 = N_2 \frac{\partial \frac{1}{N_1}\int V_1 \partial t}{\partial t} = \frac{N_2}{N_1}V_1$$

Which gives the voltage and current relationships in an ideal transformer:

$$\frac{V_2}{N_2} = \frac{V_1}{N_1} \qquad i_1 N_1 = i_2 N_2$$

In this section you will also investigate the effects of adding iron to the core. You should see hysteresis curves similar to the following.

B-H for air　　　　　　　B-H for iron　　　　　　B-H for more iron

The first plot shows the hysteresis curve for a transformer with only air in the core, in essence it shows how much flux you can get through the transformer for a given amount of current. Remember here that the flux is what links the input and output voltages and currents. Thus more flux means a larger amount of power that can be sent through the transformer. In the air curve we see that the slope of the line is very flat, meaning that a lot of current is needed to generate a very small amount of flux.

When iron is inserted into the core you should see the steeper region in the middle of the above graphs. This increased slope is due to the fact that the permeability of iron is about 1000 times bigger than that of air (or any other non-magnetic material). This steeper slope means you get more flux for less current. The tails of the iron B-H curves are due to saturation of the iron core. A given volume of iron can only handle so much flux before it becomes saturated, after which its permeability drops to that of air. The tails on the curve represent the regions where the magnitude of flux is large enough to saturate the iron; in these regions the permeability of iron should resemble that of the air core

In general magnetic permeability is: $\mu = \mu_{MATERIAL}\mu_o$ where $\mu_o = 4\pi * 10^{-7}$

The permeabilities of air and iron are: $\mu_{AIR} = 1$ and $\mu_{IRON} = 1000$

These permeabilities correspond to the density of flux a material is able to handle. For example if you were designing two transformers of the same rating, one with an air core and one with an iron core, the air core transformer would need to be 1000 times bigger than the iron core transformer to transmit the same amount of flux.