PHY 124 Lab 4 - Magnetic Force and Induction

Important! You need to print out the 4 page worksheet you find by clicking on this link and bring it with you to your lab session. [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/124lab4worksheet.pdf]

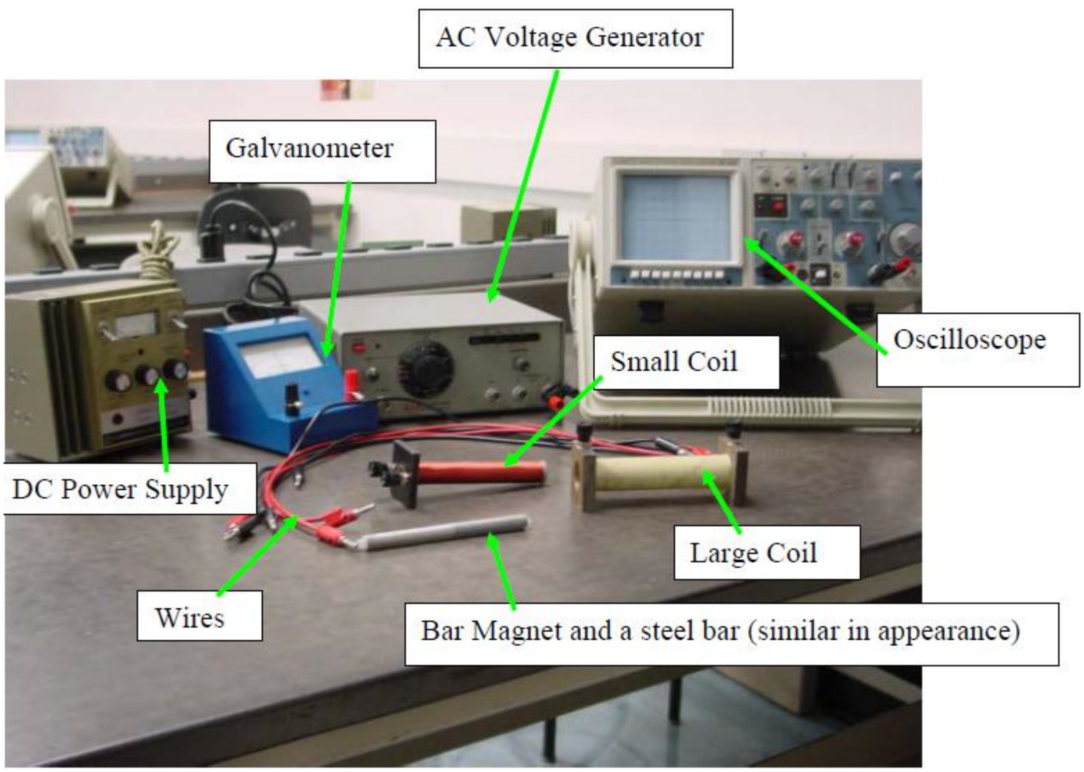
If you need the .pdf version of these instructions you can get them here [http://www.ic.sunysb.edu/Class/phy122ps/labs/dokuwiki/pdfs/phy124lab4.pdf].

Goals

The purpose of this laboratory is in Part I to observe the magnetic force on moving electrons due to the magnetic field from a bar magnet. The purpose of Part II is to observe the induction of a voltage in a coil by the change of the magnetic flux through the coil. In Part III the voltage induced in a coil by an alternating current (AC) from a second coil is observed. These two coils are arranged similar to a transformer.

Equipment

- 1 oscilloscope
- 1 bar magnet
- 1 small coil
- 1 large coil
- 1 DC power supply
- 1 galvanometer
- 1 AC voltage generator



Part I - Magnetic Force

In this part your goal is to determine the magnetic north and south poles of the bar magnet (see Ch18 sheet 5) by using its magnetic field to deflect moving electrons (the oscilloscope beam). You accomplish this use the right-hand rule [http://en.wikipedia.org/wiki/Right-hand_rule] for the magnetic force on a moving charge (see Ch18 sheet 7) along with the observation of the deflection of the electron beam (see Ch18 sheet 6). The right hand rule allows you to see the relationship between the velocity of the charged particle, the magnetic force acting on the particle, and the magnetic field of the magnet. For this lab the velocity of the charged particle is in the direction the electrons are traveling in the oscilloscope and you will observe the direction of the force a bar magnet exerts on the electrons. Using those two pieces of information you can use the right hand rule to solve for the direction of the magnetic field.

BE CAREFUL: When you use the right hand rule remember to account for the fact that the electron has a negative charge!

Procedure

Set the controls on the oscilloscope to:

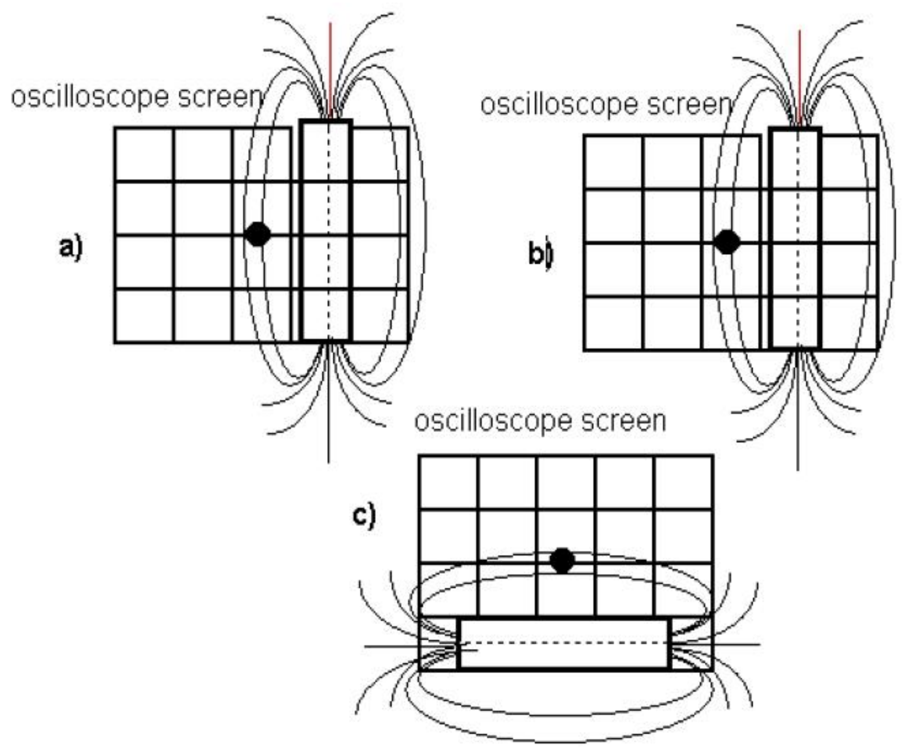
- VERT MODE to CH2
- X-Y pushed in
- ← POS → to mid range
- The white button at the bottom center to ANALOG

The positions of the other buttons should not matter.

Turn the oscilloscope power on and adjust the vertical position button (POS) for CH2 such that you see a stationary spot on the screen at approximately the center. This spot is caused by electrons hitting the fluorescent screen which lights up. Be careful to turn down the INTENSITY control so that the spot is not too bright (i.e., you should not see a “halo” around the spot.).

You will now use the bar magnet to deflect the electron beam. Watch out! You may find bar magnets already labeled with “N” and “S”. You CANNOT rely on this being correct!

1. Bring the bar magnet oriented vertically towards the the screen of the oscilloscope, as shown in the sketch a) below. Make sure you note which of the ends of the magnet is on the top by marking that end with a small dot. Whenever you have to label this bar magnet in your worksheet include that mark in your sketch. Since you have to find the north pole and south pole of the magnet, you need to know how it was oriented when you observed the deflection and applied the right hand rule.



Repeat bringing the magnet to the screen several times, always keeping the same orientation of the magnet. You should notice that when you bring the magnet closer the electron beam moves in some direction; that is it deflected from its original position. Observe the deflection of the spot and record this observation in sketch a) on your worksheet.

2. Turn the magnet by 180°. Repeat step 1 and record your observations in sketch b) on your worksheet as you did in step 1 above.

3. Now turn the magnet in the horizontal position as shown in sketch c) above. Again, repeat the instructions from step 1. Make sure you note where the marked end of the magnet is, on the left or on the right. Record your observations on your worksheet in sketch c).

For the 3 orientations in steps 1 through 3 apply the right hand rule to determine which way the magnetic field of the bar magnet points. Once you know the direction of the field, determine the north pole of the magnet and mark it. Record the poles on sketches a), b), and c) on Execution Sheet 1. These sketches should have the direction the electron beam is deflected, the direction of the magnetic field, the poles of the magnet, and an indication of which end of the magnet you put a dot on.

You have now a bar magnet with the north and south poles determined and marked. In any sketches for Part II always include your label "N" for the north pole of your bar magnet plus where your original mark on the bar magnet is. This will provide you with a check to make sure that your observations from Part 1 were correct.

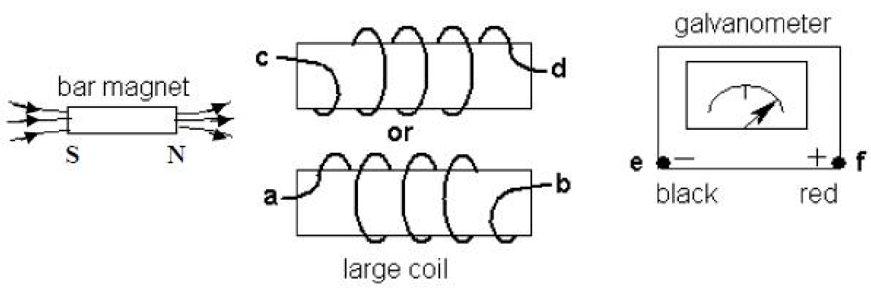
Part II - Induction

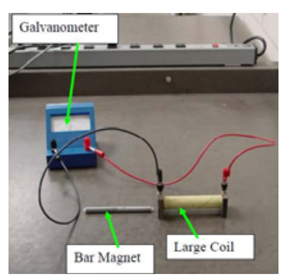
A - Induction using a Bar Magnet

Your goal is to verify Faraday's Law and Lenz' Law (see Ch19 sheet 4) of magnetic induction. For this part you will only be making qualitative observations.

In this part of the experiment (see Ch19 sheet 2), the current induced in a coil of wire by a changing magnetic flux (see Ch19 sheet 3) will be observed. The magnetic flux is due to the magnetic field produced by the bar magnet (see Ch18 sheet 5) for which you have determined the north pole in Part I. By bringing the magnet in and out of a coil you are putting a magnetic flux through that coil, which is what induces the current in the coil.

Before you make any observations you must set up a simple circuit so that the current through the coil can be seen. Connect the large coil to the terminals of a galvanometer (a current meter) as shown below. IMPORTANT: You have to inspect your coil and find out how the wire is wound, that is, whether the upper or lower coil picture in the sketch represents your case. The direction of the winding is very important because you will have to use the right-hand-rule for induced current for the rest of the lab. To do this correctly you need to know which way the current travels around the coil. In Part II on your worksheet you will see two options for the large coil. You need to pick the one that corresponds to how your coil is wound and then record your connections on the incomplete sketch given on your worksheet.





The galvanometer indicates whether a current flows through it by deflecting the needle on the scale. The deflection is to the right when the current goes into (not out of) the red or positive terminal of the galvanometer. This is important to know when you observe a deflection because to use the right-hand-rule you must know the direction of current flow. You will use the right-hand-rule for the magnetic field made by a current in a wire loop (see Ch18 sheet 25) or coil (see Ch18 sheet 27), and apply Lenz' Law (see Ch19 sheet 4) to figure out in which sense the induced current flows through your coil (see Ch18 sheet 2).

Inserting the bar magnet into the coil changes the magnetic flux through the coil. The result is an induced voltage (see Ch19 sheet 4) across the coil which causes an induced current to flow through the coil. This current generates an induced magnetic field in the coil itself, the direction of which is given by the right-hand-rule for the magnetic field made by the induced current in the coil (see Ch18 sheet 25).

Note: Here the magnetic field which contributes dominantly to the magnetic flux inside the coil is the magnetic field inside the magnet, indicated by the high density of field lines at either end of the bar. The average magnetic field is directed parallel to the axis of the bar and goes straight from the south to the north pole inside the bar. This is the direction of the magnetic field you are concerned about for this part of the lab. You are no longer interested in the field outside of the magnet like you were in Part I. (see the sketch for Part I above)

Insert the bar magnet north pole first from left to right, slowly into the coil and observe the needle deflection. Note whether the needle deflection stays at maximum or falls back to zero when the magnet motion ceases. Then withdraw the magnet slowly from the coil and observe the needle deflection. Note the direction of the needle deflection. Do it a couple of times.

Repeat this procedure with a fast motion of the bar magnet.

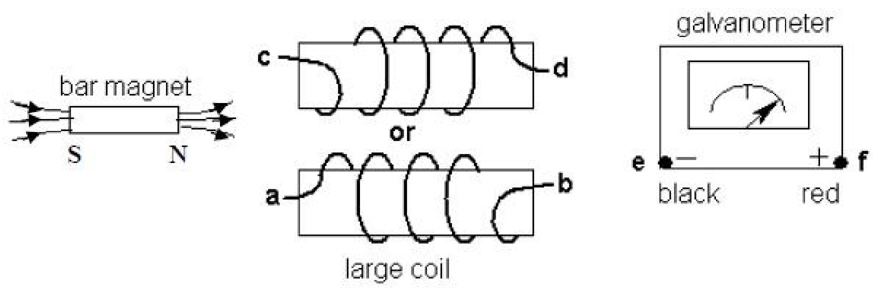
Record your observations on your worksheet.

Now we will apply Lenz's law to see if the direction of motion agrees with what we expect from our understanding of magnetic induction.

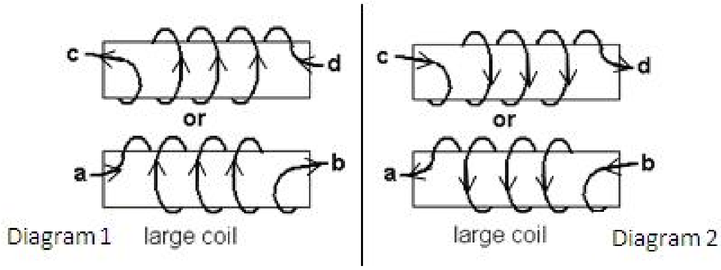
The form below will guide you through a set of questions from which you can deduce the direction the needle should have moved when you inserted and removed the bar magnet. When you click submit the computer will tell you whether your answers are correct based upon the connections you entered and the direction of the magnetization in the bar magnet. If some of the answers are marked as incorrect there are a few possible causes you should consider.

1. The wiring that you entered might be incorrect
2. You might have labeled the poles of the bar magnet incorrectly in Part I
3. You might have applied Lenz's law incorrectly
4. You might have applied the right hand rule for induction incorrectly

Hopefully by looking at which answers are incorrect you can work out which error you might have made and correct it until you get the right answer. (Of course, if you get it all right on the first go, you can move right on to the next part!)

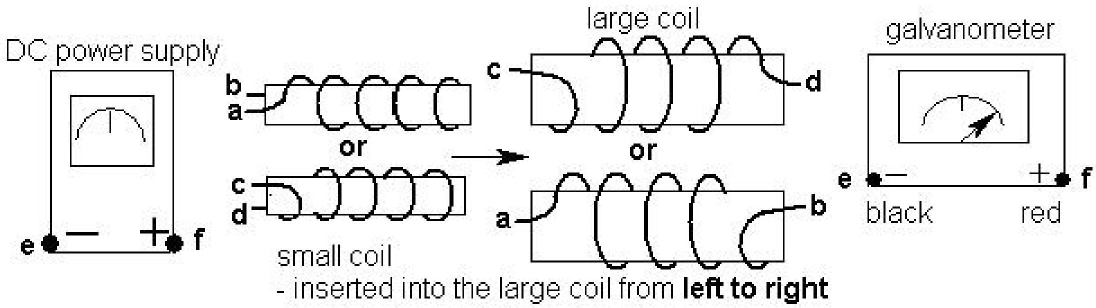


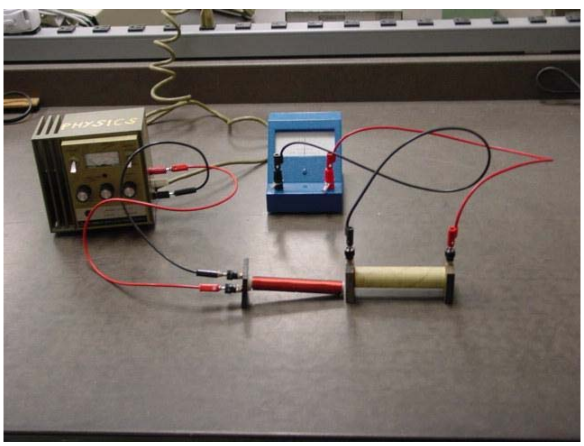
Which wire end was attached to terminal e? (a,b,c,d) a
Which wire end was attached to terminal f? (a,b,c,d) a
When inserting the bar magnet into the coil is the change in the magnetic field directed to the left or to the right? left
When removing the bar magnet into the coil is the change in the magnetic field directed to the left or to the right? left
Using Lenz's law, is the magnetic field induced in the coil to the left or right when inserting the bar magnet into the coil? left
Using Lenz's law, is the magnetic field induced in the coil to the left or right when removing the bar magnet from the coil? left
According to right hand rule does the current in the central part of the coil go like diagram 1 or 2 when the magnet is inserted into the coil? 1
According to right hand rule does the current in the central part of the coil go like diagram 1 or 2 when the magnet is removed from the coil 1
Which way did the galvanometer needle move when you inserted the magnet? left
Which way did the galvanometer needle move when you removed the magnet? left
submit



B - Induction using an electro-magnet

You make an “electro-magnet” by passing a DC current through the smaller coil of the induction set. If you use the right-hand-rule to find the magnetic field lines of this small coil, you will notice that they are identical to the magnetic field lines of the bar magnet. The small coil with a current through it is a magnet with a north and a south pole like the bar magnet. This part of the lab will be exactly the same as Part IIA, except that you simply replace the bar magnet by the electro – magnet as shown below.





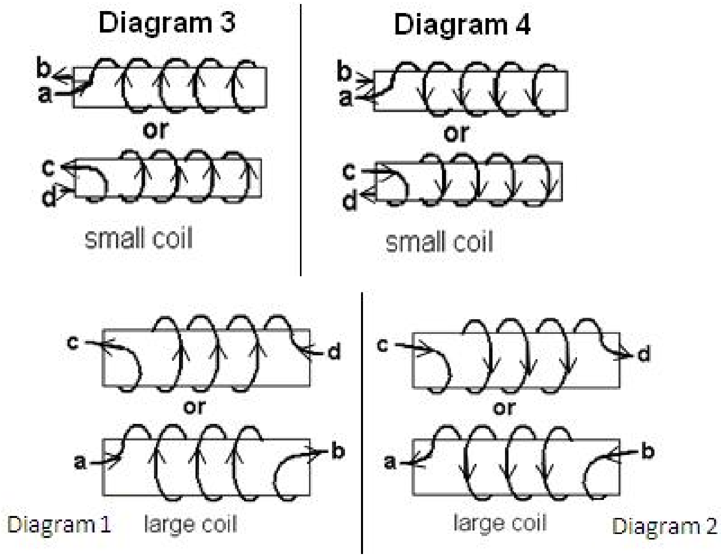
The large coil and the galvanometer will still be connected exactly the same as in Part IIA. There is no need to change that part of the setup.

Connect the small coil to the DC power supply as shown. As you did for the large coil, inspect your small coil carefully to get the correct winding of the coil. On Execution Sheet 3 choose the incomplete sketch of the coil with the correct winding as in your set up and draw the wire connections (dashed lines) to the coil. Draw the directions of the current on the wires of the small coil, taking into account how they are connected to the DC power supply (which end of the small coil is connected to the positive terminal of the power supply? the negative terminal?). Use the right-hand-rule (see Ch18 sheet 25) to determine the north pole of the electro-magnet and label it in the sketch.

Place the small coil inside the large coil with the DC power off. Turn the knobs on the DC power supply to maximum (clockwise). Turn the power on and observe the needle. Note! The needle deflection is very small. If you can hardly see any needle deflection, insert the bar labeled “steel” into the small coil, which enhances the strength of the electro-magnet. After the power has reached a maximum value, check whether the needle stays at maximum deflection or goes back down to zero. Turn the power off and observe the needle. Do this a couple of times.

Record your observations on your worksheet.

Now we will apply Lenz's law to see if the direction of motion agrees with what we expect from our understanding of magnetic induction. As before the form below will guide you through a set of questions from which you can deduce the direction the needle should have moved when you turned on and when you turned off the power supply.



Which wire end of the small coil was attached to terminal e of the DC power supply? (a,b,c,d) a
Which wire end of the small coil was attached to terminal f of the DC power supply? (a,b,c,d) a
Which wire end of the large coil was attached to terminal e of the galvanometer? (a,b,c,d) a
Which wire end of the large coil was attached to terminal f of the galvanometer? (a,b,c,d) a
When the DC power is on does the current go round the coil like in diagram 3 or diagram 4? 3
When the DC power is turned on is the change in the magnetic field produced by the small coil directed to the left or to the right? left
When the DC power is turned off is the change in the magnetic field produced by the small coil directed to the left or to the right? left
Using Lenz's law, is the magnetic field induced in the large coil to the left or right when the DC power is turned on? left
Using Lenz's law, is the magnetic field induced in the large coil to the left or right when the DC power is turned off? left
According to right hand rule does the current in the central part of the large coil go like diagram 1 or 2 when the DC power is turned on? 1
According to right hand rule does the current in the central part of the large coil go like diagram 1 or 2 when the DC power is turned off? 1
Which way did the galvanometer needle move when you turned on the DC power? left
Which way did the galvanometer needle move when you turned off the DC power? left

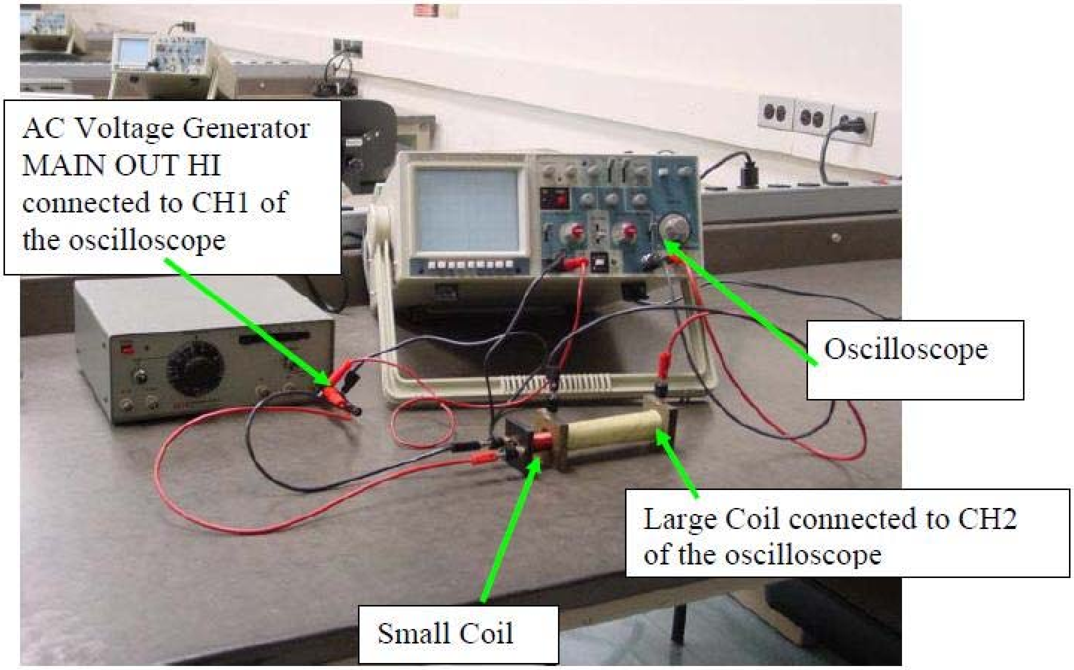
submit

Part III: Induction using alternating current (AC) power

Your goal here is very similar to PART II B. However you excite your electro-magnet (small coil) with an AC voltage which then induces an AC voltage in the large coil, essentially working like a transformer (see Ch19 sheet 24).

First, wire the large coil to Channel 2 of the oscilloscope the same as you had it wired to the galvanometer. This will allow you to measure/observe the induced voltage in the large coil. If you inserted the steel rod for the previous part remove it now.

Next, wire the small coil to the AC power generator the same as it was wired to the DC power generator. Now you want to connect the small coil in parallel with Channel 1 of the oscilloscope. Connect the high voltage (red) terminal of the oscilloscope to the junction where the high voltage (red) terminal of the power supply meets the red wire leading to the small coil. Repeat this with the low voltage (black) terminals of the oscilloscope and power supply. This will allow you to measure/observe the voltage on the electro-magnet. When you have done this your set up should look like the picture below.



Set the AC generator to a sine wave (push the button on the top right in) of 1000 Hz (push the MULT 100 button in and set the Frequency to 10). Use MAIN OUT HI and turn the AMPLITUDE to maximum (all the way clockwise) if you are using the coils with metal ends, or, if you are using the coils with the black plastic ends set the AMPLITUDE about halfway. Set the oscilloscope to:

- VERT MODE to DUAL
- All push buttons (except the power button) out
- VOLTS/DIV of CH1 to ~ 50mV
- VOLTS/DIV of CH2 to ~ 0.2 V
- Both CH1 and CH2 inputs to AC
- TIME/DIV to ~ 0.2 ms
- COUPLING to AC
- SOURCE to CH1

Turn the TRIG LEVEL until you see a stationary picture of two sine waves. Record the VOLTS/DIV settings of CH1 and CH2 and all your wire connections in the incomplete sketch shown on worksheet, again, selecting the correct windings of the small and large coils. Draw the observed voltage signals into the grid provided on your worksheet. Make sure you note which voltage signal is the induced one from the large coil and which voltage signal is from the AC generator or across the small coil (you can switch the signals off simply by setting the input of that channel to GND temporarily). Label the signals on your graph and indicate the scale of the boxes. Measure the peak-to-peak amplitude (from the minimum to the maximum) of your voltage signals with the oscilloscope (see Lab # 2) and record their values on the graph on your worksheet.

BE CAREFUL! When observing the signals from Channel 1 and Channel 2 remember that the signal for each channel has its own VOLT/DIV setting. Take this into account when labeling your sketch and when computing the amplitude of each wave.

From the ratios of the voltages you can calculate the ratio of the number of turns in the two coils. ($\frac{V_2}{V_1} = \frac{N_2}{N_1}$ See Ch 19 Sheet 24)

Are the frequencies of the two waves the same? Discuss with your TA whether they are or aren't and whether you observation is consistent with your expectation.