Magnetic Induction

In these activities that comprise today's lab Voltage Sensors (voltmeters) will measure the voltages (*emfs*) induced in a coil or coils by a magnet as the magnet moves through the coil. The activities examine how this field affects solenoids connected to Voltage Sensors (voltmeters) that monitor any change in voltage caused by the movement of the magnet. We will also look at the *emf* produced by a secondary coil when current is passed through a primary coil. And finally, how this pick up changes with the presence of a soft iron core.

Procedure: Induction I

The Capstone program records and displays the induced voltage versus time, and calculates the area under the curve of voltage vs. time plot. It is important that the data acquisition rate is sufficient that the data shown represents the full signal without loss of information. Be sure to refer to the homework assignment as well as the link in Blackboard 'Very brief tutorial on sampling data'.

1. Open Capstone and connect the voltage sensor on the interface. Setup appropriate graphs of voltage vs. time. Look at sampling rate – be sure to address the proper sampling rate needed for data acquisition during data taking – make sure to discuss how and why your group decided upon the sampling rate for each experiment.
2. Connect a voltage sensor to the large solenoid.
3. Hold the magnet so that the south end is about flush with the face of the solenoid, not inside.
4. Start data recording in Capstone and begin moving the magnet into the solenoid until the magnet end is flush with the other side of the solenoid. Then, move the solenoid back out to the original position. Stop recording. Your group will likely want to repeat this several times to examine repeatability.
5. Examine the graph produced – repeat again with a higher sampling rate – inspect the graphs and determine the sampling rate that provides the best detail while still holding the sampling frequency as low as possible to maintain this detail.
6. Using the Area under the Curve tool (see Bb for 'How to" image) find the area under the peak voltage ABOVE the x-axis. Note that this area has units of Volts-sec since it is an area calculation.
7. Repeat for the voltage peak below the x-axis.
8. Compare the Areas found in Capstone for ABOVE and BELOW the x-axis for each data run. Calculate the percentage difference between the two values for repeated data collections. Does your group feel that this experiment is precise? Explain.
9. Now, repeat the process flipping the magnet pole. Question: What difference is noticed between the graphs? Why? Explain.
10. Finally, switch the leads from the solenoid ends to the voltmeter (so switch the RED and BLACK leads), what happens when you repeat the process again for inserting the same magnetic end as in #9? From previous labs on voltage and current measurements, why did you expect this result?

Procedure: Induction II

Now we will work to determine how the number of turns of the solenoid, *N*, affect the voltage induced by employing two coils of different number of turns moving through the same magnetic fields.

1) Connect the 2^{nd} voltage sensor to the Capstone interface. Add the 2^{nd} voltage sensor to the vertical axis of the graph.
2) Connect one voltage sensor to a solenoid with 1600 turns (or loops) and the second voltage sensor to a solenoid with 400 turns.
3) Now perform the following sequence of actions at the same speed:
   a) Place the two solenoids side by side so they are coaxial.
   b) Rapidly insert the north end of the magnet all the way into the solenoids, pause and then rapidly remove it.
   c) Hold the magnet in a horizontal position and rapidly slide the coils so that the magnet passes through them, pause and then slide them off.
   d) Flip the magnet over and repeat the above sequence with slower motions and with the south pole inserted first.

After a few trials you should be able to complete this sequence in about 20 seconds. It is important that the magnet always enter both coils.

Examining the graphs what can be said about

a. The induced voltage and the number of turns of the solenoids, does a relationship exist?

b. How does the sign of the voltage depend upon the motion (velocity) of the magnet? Be specific by marking the graphs showing the motion of the magnet through the solenoids.

c. Does it matter which magnetic pole is inserted through the magnet? If so, what is affected by the action?

d. Does a relation exist between the voltage induced and the speed of motion (velocity)?

e. What is found when the magnet is stationary? Mark on your plots when the magnet is stationary. What can be said is a requirement for an induced *emf* to exist?

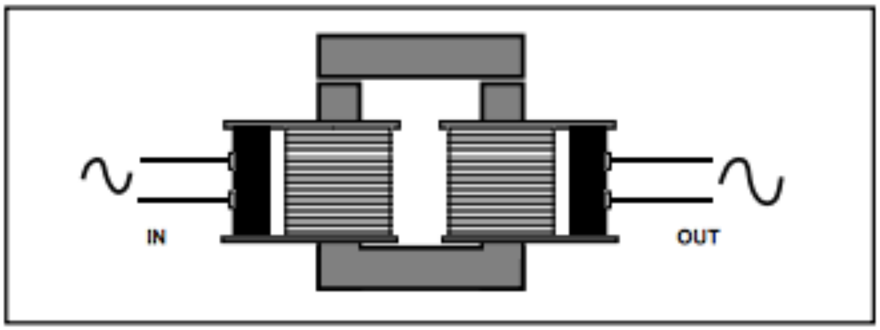
f. Does it make any difference whether the magnet is moved or the solenoids?

g. Repeat the above sequence for the two solenoids but change the orientation of the leads (banana wires) to the solenoids. What changes are seen if just the 400 turn solenoids leads are switched? What changes if only the 1600 turn solenoid leads are switched?

h. What happens when both sets of leads are switched? Produce graphs for each of these scenarios. You only need to do one pole face for each of these last runs but make sure all runs have the same magnetic pole face entering first for easier comparisons.

i. Now, assemble the two solenoids in the iron holders in the solenoid box. Have a bar through each solenoid and cap off the top as shown below. You will now need to supply the IN coil with a sine wave input. To do this – use the signal generator on the Pasco

Interface box (red/black banana plugs RHS). In Capstone – click on the Signal Generator Icon LHS. Now – choose stepped frequencies starting at 10Hz and going no higher than 1000Hz – sine wave is the default signal so you should not have to reset signal type. For each frequency – determine the output across the 2ndary solenoid NOT attached to the signal IN. How does this voltage value compare to the input signal across the IN solenoid. Is there any pattern? Do you find this relation frequency dependent for the range of frequencies tested? How can you hypothesize this dependence or independence from data results? Explain.



j. Finally – take the top off of the iron U-shape apparatus holding the two solenoids. Using a frequency of your choice – take data again for the sine wave IN and OUT. How do these voltages compare to the values found for the same frequency in (i). How can your group hypothesize a reason for this difference? Discuss.

For the laboratory conclusion – discuss parameters seen to change the voltage responses during these experiments. Could this have been anticipated looking at the equations governing Induction? Explain.