LAB SECTION: ______________________________ NAME: ______________________________

EXPERIMENT 11: FARADAY'S LAW OF INDUCTION

Introduction: In this lab, you will use solenoids and magnets to investigate the qualitative properties of electromagnetic inductive effects due to changing magnetic fields.

A simple statment of Faraday's Law of Induction, suitable for beginners, is that nature always tries to resist a changing magnetic field; when the changing magnetic field passes through a conducting loop, nature can resist, by means of inducing a current in that conducting loop. In the first part of this lab, you will move a magnet, by hand, into and out of a solenoid, and you will measure the direction of the induced current which results from nature's opposition to the changing magnetic field (which you will have created by moving the magnet). In the second part of this lab, you will use a variable-speed cart to tow a magnet, at various speeds, through various solenoids. One goal of part two will be to determine whether the maximum voltage which results from nature's opposition to the changing magnetic field is proportional to the towing speed (and therefore to the rate of change of the magnetic field within the solenoid). Another goal of part two will be to determine whether, for a giving towing speed, the maximum voltage which results from nature's opposition to the changing magnetic field is proportional to the number of turns in the solenoid.

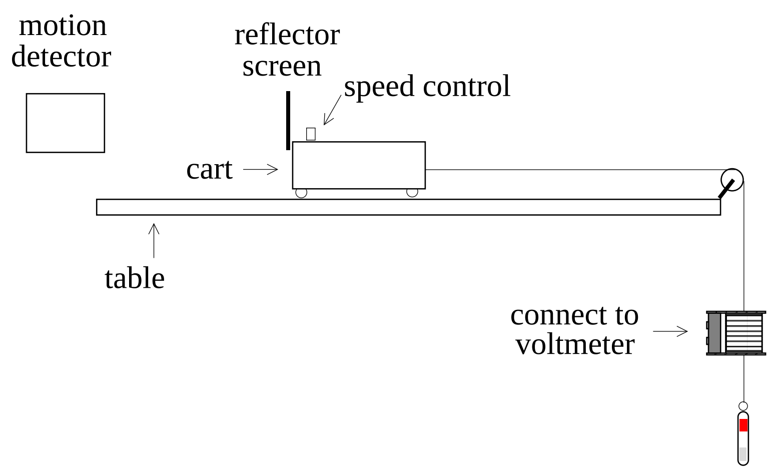
Procedure for Part One

1. You have been provided with a sensitive ammeter known as a galvanometer. Use a battery and a resistor to investigate the response of the galvanometer to current. See the figure at the beginning of Results on page 3 for the proper setup. BE SURE NOT TO CONNECT THE BATTERY DIRECTLY TO THE GALVANOMETER WITHOUT USING THE RESISTOR; SUCH A CONNECTION CAN DAMAGE THE SENSITIVE GALVANOMETER. If a current passes through the galvanometer from left to right in the figure (or from right to left), how does the galvanometer respond? Indicate the results of your investigations on the Results page, item 1.
2. Connect the solenoid with 200 turns directly to the galvanometer using the setup shown in the figure on page 3, item 2; the label giving the number of turns should be on the left-hand end of the solenoid. You have been provided with a strong bar magnet in the shape of a rod with rounded ends; the north and south ends of this bar magnet have been marked with red and white tape, respectively. Check the correctness of the red and white markings by bringing the red end of the bar magnet within 5-10 cm of a compass; the red end should of course attract the south end of the compass. Then pass the bar magnet through the solenoid in as many ways as possible, noting the

resulting response of the galvanometer. Also, try holding the bar magnet at rest at several positions within the solenoid and note the galvanometer response. Use your notes to answer the questions in the Results section, item 2.

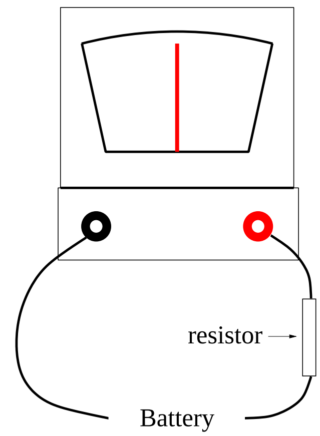
Procedure for Part Two

1. Set up the experiment as shown in the figure below. The carts travel at a constant selected speed; the speed control knob is indicated in the figure. To measure the selected speed, we will use the reflector screen and motion detector (as previously used in Lab 3). The objective will be to use the carts to tow the magnets through the solenoids at a set of selected speeds. The string attached to the carts has a small iron ring at its lower end to which the magnets will attach magnetically; attach your magnet with the north (red) end upward. Connect the solenoid to a digital voltmeter (DVM), with the DVM set to measure the maximum voltage produced as the magnet passes through the solenoid (see the figure on page 5). Orient the solenoid so that the label giving the number of turns is facing upward.



2. Make several practice runs (see the list of necessary actions between runs on page 5). Try using several different selected speeds. The motion sensor is collecting position-versus-time data for the reflector screen. Your computer data-collection program has been designed to determine the speed of the cart directly from the slope of its position-versus-time graph (you have already done this task in Lab 1, so you should understand what the computer is doing). After each run, highlight a straight, downward-sloping, portion of the graphed data on the computer screen, and then request the calculated slope (click on Fit, then Linear Fit); the absolute value of the slope is the measured speed. During your practice runs, insure that everyone in your group understands this process for measuring the selected speed. You should observe that larger selected towing speeds produce larger maximum voltage readings, for a given solenoid.

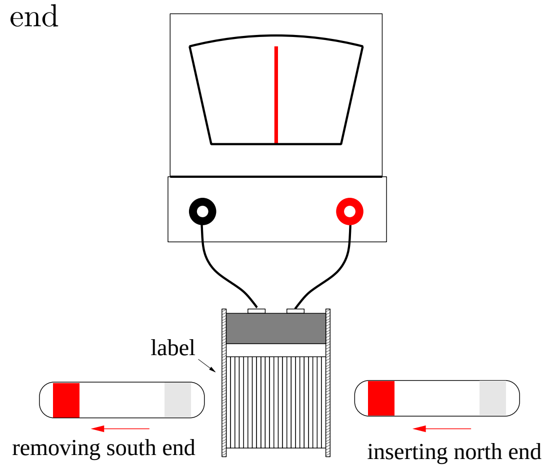
3. You will need to collect data at four selected speeds for each of the three different solenoids (having 200, 400, or 800 turns). Begin with a low selected speed, something between 4 to 6 cm/s. Make three runs at that selected speed, changing the solenoid for each run. For each run, record the measured speed (which should be nearly the same in each case) and the maximum solenoid voltage, as measured with the connected voltmeter; record these values in Data Table 11.1. Now make three more sets of three runs, with each set having a slightly higher selected speed; your highest selected speed should be around 17-19 cm/s.



Results

1. Answer with "TO THE RIGHT" or "TO THE LEFT".
   (a) When the current flows through the galvanometer from left to right, the needle deflects __________________.
   (b) When the current flows through the galvanometer from right to left, the needle deflects __________________.

2. Answer from the following list of nine possible choices. The figure illustrates two of the choices: "inserting north end from right" and "removing south end from left".
   - inserting north end from right
   - inserting north end from left
   - inserting south end from right
   - inserting south end from left
   - removing north end from right
   - removing north end from left
   - removing south end from right
   - removing south end from left
   - holding magnet at rest at any location



   With the set-up as shown in the figure, a clockwise current in the solenoid (when viewed from the left), results in a left-to-right current through the gavlanometer.
   (a) Which actions result in a left-to-right current flowing through the galvanometer?

(b) Which actions result in a right-to-left current flowing through the galvanometer?

(c) Which actions result in no current flowing through the galvanometer?

3. Make a graph having the average measured speed (in cm/s), for each solenoid, on the x-axis and resulting maximum voltage (in mV) on the y-axis. You have four data points for each different solenoid. Draw three best-fit lines, one for each different solenoid; each line may use the origin (zero volts at zero cm/s) as a good data point. Do your three lines verify that, for a given solenoid, the maximum voltage which results from nature's opposition to the changing magnetic field is proportional to the rate of the change of the magnetic field within the solenoid? Why or why not?

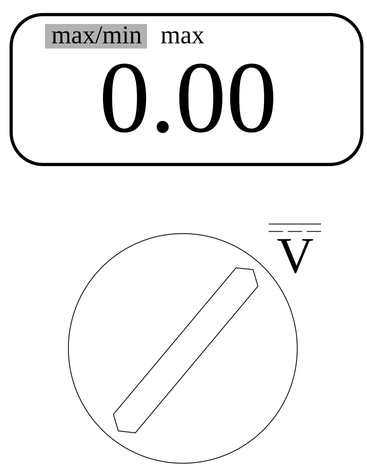
4. Make a graph having number of turns on the x-axis and maximum recorded voltage on the y-axis (in mV). You have three data points for each different speed. Draw four best-fit lines, one for each different speed; each line may use the origin (zero volts for zero turns) as a good data point. Do your four lines verify that, for a given rate of change of magnetic field within a solenoid, the maximum voltage which results from nature's opposition to the change is proportional to the number of turns in the solenoid? Why or why not?

Data Table 11.1

	selected speed 1	selected speed 2	selected speed 3	selected speed 4
measured speed for 200 turns (cm/s)				
measured speed for 400 turns (cm/s)				
measured speed for 800 turns (cm/s)				
average of three speeds (cm/s)				
maximum voltage for 200 turns (mV)				
maximum voltage for 400 turns (mV)				
maximum voltage for 800 turns (mV)				

List of actions to be taken between runs:

- record the measured speed
- record the measured maximum voltage
- deselect Linear Fit on the computer
- change the solenoid if necessary
- recheck solenoid to voltmeter connections
- reset the voltmeter to take the next reading
- return the cart to its starting position



The figure shows the voltmeter set up which will save the maximum voltage that occurs during the passage of the magnet through the solenoid. The voltmeter must be reset (turn off, turn on, press max/min button) before each new run.