LAB 5: LORENTZ FORCE

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Abstract: *"In this lab report the relationship between current and magnetic forces is covered. This relationship is known as the Lorentz Force. There is a very basic setup for this experiment, where the independent variable can be altered based on what is being studied. The Lorentz Force can be created by an electrified coil attached to a magnetic field through magnets on either side. This can be measured by using load cells under the magnet apparatus. This measurement of the force will be related to the current, which is the Lorentz Force Law. This law is to calculator the strength of the magnetic field."*

Keywords: *Lorentz Force, Current, Magnetic Field, Right-Hand Rule*

1. Introduction

The goal of this lab is based on the Lorentz Force Law. This law states that the force on a charged particle is due to magnetic and electric fields. The results of executing this lab are to represent this relationship. To exert a Lorentz Force, two magnets are utilized, producing a magnetic field through a coil, while being dependent on the directions of the field and current. This is shown in the data with consideration of the current. Given this data, the student can also calculate the magnitude of the magnetic field. The orientation of the magnetic field is determined by the right-hand rule.

2. Experimental Procedure

To begin the setup of this lab, there consists of a set of masses, a 500 turn coil, a u-track that has two magnets, two load cells, and a power supply. The u-track is centered around the coil where either side is labeled A or B and runs and in between the two magnets. The red wire is plugged in the right-hand side socket of the coil and the black wire is plug into the left-hand side socket of the coil and that's attached to the power supply. Just set up represents that there will be a clockwise current through the coil.

Next to collect the data the student must calibrate the load cells. To achieve that the script, *daq_to_csv_with_input.py,* must be altered. In this case, *CHANNELS* '4,' and '5' must be specified to where the load cells are plugged in. The student must change *POINTS* to 15 and the *FILENAME,* to what the CSV output should be stored as, which in this case is 'calibration'. While running the script the user is asked to define the independent variable and its units, which in this case the independent variable is mass and its units are grams. The data starts collecting when the point begins with the mass value of 0, which is what the user inputs. For the second reading to be noted, the user place has a mass of 20 g on the orange u-track. The student continues to take readings in increments of 20 grams until the script is completed and then produces a CSV where the data is stored.

For the second step of the procedure to collect data, the student will use the same script as above but there are fewer data points required so *POINTS* is set to 10 instead of 15. The *FILENAME* will also be changed to what the CSV output should be stored as. the student has to determine the independent variable and its unit which in this case is current and the unit is amps. Utilizing the u-track, which should be centered about the coil which side B facing the user, and the first data point inputted by the user will be zero. The user done sets the power supply to 6 volts and the current to 0.025A, and at that value, the Lorentz force reading can be noted. The same step is repeated with increments of 0.025 until the script comes to an end. Given this data, the student can calculate this strength as a magnetic field along with finding the orientation by utilizing the right-hand rule and the direction of the current.

Utilizing Excel spreadsheets the applied force and the voltage are plotted on a graph and are shown to have a proportional relationship. To find the Lorentz force in the second part of this lab, the cell loads must be calibrated using the first equation displayed below.

Equation 1: $V_{output} = C_1F_{applied} + C_2$

Equation one shows V_{output} which is the average voltage given by two load cells, C_1 and C_2 are some constants and $F_{applied}$ is the force acting on the load cell. Channel 4 and 5 when the applied force is zero is where C_2 can be found by the average voltage. By plugging in the measured values for equation 1 and averaging the C_1 for both cells, the student will be able to calculate constant C_1.

After calibration of the cell loads, the Lorentz force can be calculated from the measured voltage by utilizing equation one. Finding Lorentz force for both channels and averaging them together, the student can then plot the Lorentz force against the change in current.

Equation 2: $\vec{F}_L = NI\int d\vec{l} \times \vec{B}$

The strength of the magnetic field acting on the wire can be found by utilizing equation two. F_L Is the Lorentz force, I is the current through the wire, l is the length of the wire, B is the magnetic field, and finally, N is the number of times the coil is wrapped. The NIB can be treated as the slope When the Lorentz force is plotted against the current because the current is considered as the independent variable. given this the NIB is set equal to the slope so then the magnetic field can we solve for. Define the uncertainties of all the measured values the Linear function in Excel will calculate that.

3. Results and Analysis

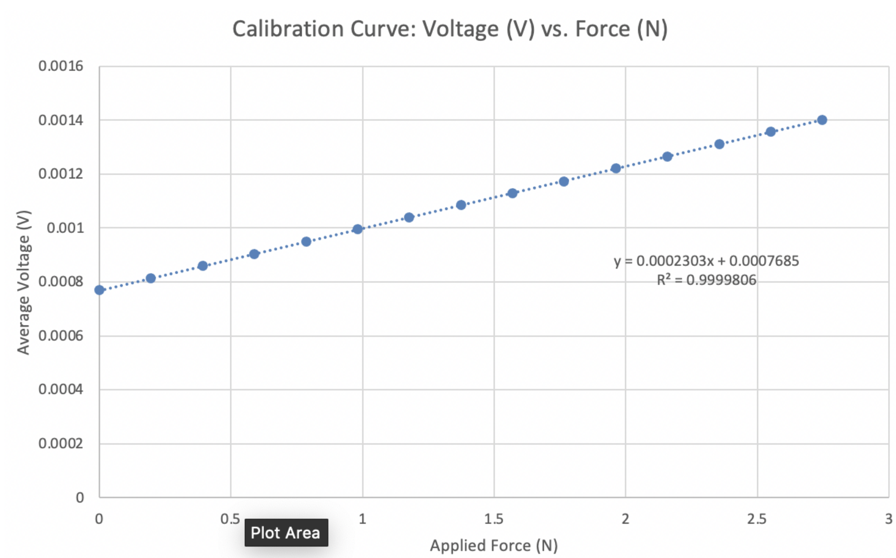
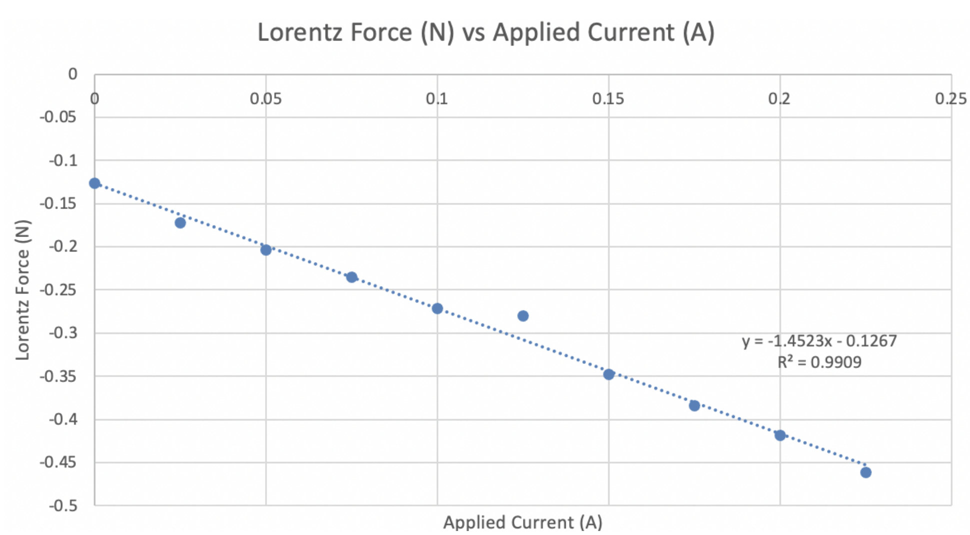


Figure 1 shows a direct relationship between Force and Voltage, as voltage increases as the applied force increases. Equation 1 can be used to calibrate the cell loads. The constants that are found to be C_1 = 2.29E-07 and C_2 = 7.69E-04.

Getting values for C_1 and C_2, we can calculate the Lorentz Force. The average voltage can be calculated the same way, by summing up channels 4 and 5 and dividing by 2.

Figure 1: Plot to represent load cell output voltage as a function of applied force



The Lorentz Force can be calculated from the measured voltages when the cell load device is calibrated. In *Figure 2,* the Lorentz Force represents an indirect relationship between Applied Current and the Lorentz Force. In order to calculate the strength of the magnetic field, we use the second equation, where the slope of the second figure is -1.4523. We know that equation 2 is a linear function where the slope equals N*Bl*. N is equal to 500 and l is equal to .085 meters and B is what we solve to find the magnetic field. The magnetic field of the two magnets on the wire is found to be around 0.04019 T (Teslas).

Figure 2: Plot to represent Lorentz force (FL) as a function of applied current (I)

Equation 3: $\frac{\partial B}{|B|} = \sqrt{\left(\frac{\partial l}{l}\right)^2 + \left(\frac{\partial F}{F}\right)^2}$

To find the uncertainty Of the slope is to use the “lines” function using the current and force data to an error of ±0.06181. The error in the measurements of the magnet is ±0.0002 m. The error propagation equation, which is the third equation is ±0.0316. So the final magnitude can be calculated to 0.04019 T ± 0.00136 T.

Given that the force on the cell load is increasing, and by conceptualizing the magnetic and electric fields remaining in parallel to generate a perpendicular force going upward on a wire, and that an equal and opposite force will be exerted downwards on the cell loads, can help determine the magnet’s orientation. We can use the right-hand rule since the current goes in a clockwise direction. This can be used on a current through a wire to determine the magnetic field going from side B to side A. From this, we can also determine that the electric field also goes from side B to side A, since the field has to be parallel to generate a Lorentz Force. Determining the orientation, we found that ‘Side A’ is the north pole (where it is exiting), and ‘Side B’ is the South pole, where it enters.

4. Conclusions

The purpose of this lab was to understand the strength and directions created by the magnetic field from the wires and the electric field created between two magnets, which led to measuring the Lorentz force on a coil, which is carrying current. From the data, we can also say that the Lorentz force and voltage increase as the current increases. We were able to determine the strength and orientation of the magnetic field once we found the Lorentz force and the amount of current through the coil. We knew this since the fields must be parallel to generate a Lorentz Force in the perpendicular direction. The strength of the magnetic field was 0.0342 T (Teslas) and we know that the orientation of ‘Side A’ is the North pole and ‘Side B’ is the South pole.