Lab 4: Magnetism

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Introduction

The purpose of this experiment was to verify the magnetic fields produced by various solid state objects and Faraday’s Law. In particular, magnetic fields produced by currents and permanent magnets were explored. Faraday’s Law was verified by measuring the induced voltage in a solenoid. The force between permanent magnets was also investigated upon. To verify the magnetic fields produced, a Hall probe was used. Using a toroidal coil to simulate an infinite current, the Gaussmeter was used to probe the magnetic field at different distances from the center. This method was also used to get magnetic field readings for the permanent magnets, albeit varying the angle parameters. To measure the force between magnets, one magnet was placed on a weighing scale and another magnet was placed directly in front of it and distance was varied. Lastly, Faraday’s Law was explored by driving a current through the solenoid and the induced voltage was measured.

Plots and Tables

Figure 1: The graph of magnetic field vs. radial distance from the toroid is shown. As can be seen, there is a clear 1/r correlation as the distance from the current was increased. Inside the inner radius and outside the outer radius, the magnetic field measured was extremely close to zero. The Hall probe was oriented perpendicular to the magnetic field of the toroid, which was acquired using the right-hand rule.

To make the radial distances taken match up with the physical dimensions of the toroid, a constant scaling factor was used. 3.2 cm was set at the maximum magnetic field measured, and then increments of 0.5 cm followed for the subsequent data.

Figure 2: The graph of induced voltage in the outer coil vs. time from the solenoid is shown. As can be seen, the induced voltage varies sinusoidally with respect to time. The amplitude Vo in this case can be acquired by getting the peak-to-peak value of the voltage and then dividing by 2. This is to account for the fact that the midpoint of the wave in the y-axis is not at 0.

Figure 3: The graph of current in the inner coil vs. time from the solenoid is shown. As can be seen, the current varies sinusoidally with respect to time. A resistor was used to get the current. The current values were acquired by diving the voltage drop across the 100-ohm resistor by its resistance. The amplitude Io in this case can be acquired by getting the peak-to-peak value of the voltage and then dividing by 2.

Analysis

Figure 4: The graph of magnetic field vs. the linearized radial distance from the toroid is shown. As can be seen, the form of the function is a linear one, with a positive slope of (0.000000170 ± 0.000000006). Inside the inner radius and outside the outer radius, the magnetic field measured was extremely close to zero, hence the data was discarded.

The R-squared value taken from Microsoft Excel had a value of (0.97036 ± 0.00004), which when taken the square root of yields the correlation coefficient. It is calculated to be (0.98507 ± 0.00004). This value is extremely close to 1, which yields perfect dependence. As can be seen from this value, the magnetic field is highly linearly correlated with 1/r.

The linearized distance was acquired by taking 1 and dividing it by the radial distance for all the data points. This yields a line with a slope of the form . The measured slope as shown by the graph has a value of (0.000000170 ± 0.000000006). By solving for I using algebra, a value of (0.850 ± 0.04) A was obtained. The uncertainty was obtained by accounting for the uncertainty present in the calculation of the measured current from the slope in Figure 4.

By driving a voltage of (16.0 ± 0.1) V through the toroidal coil and measuring its resistance of (10.7 ± 0.1) ohms, the theoretical current can be calculated using Ohm’s Law. The current has a value of (1.50 ± 0.01) A. The uncertainty in the current calculation was acquired by taking into account the uncertainties in the voltage and resistance measurements.

Comparing the theoretical value and the experimental value, the values appear close. The errors in their comparison is most likely due to the impreciseness of the Gaussmeter used. The units of the Gaussmeter were jumping up and down frequently during the measurement of the magnetic field at different points in the radial direction and as such a huge amount of error could have resulted.

To get the amplitude for both the current and the voltage in the time graphs, the average of the peak-to-peak values for both were taken. This is to account for the fact that in the y-axis, the wave does not start at exactly zero. Values of (0.0259 0.0001) A and (0.0000889 0.0000002) V were taken respectively. The uncertainty comes from eyeballing the graph and choosing good data points to measure the peak-to-peak values from.

To calculate the amplitude of the theoretical induced voltage, the formula was used. Using the measured value of 0.0000889 A for Io, \* 1000 Hz for the angular frequency, for the cross sectional area of the smaller coil, 8000 for n, 100 for N, and taking the cosine term at 1 to get the amplitude, a value of (0.00021 0.00004) V is obtained. This differs from the measured value of (0.0259 0.0001) V by a factor of around 123. Overall, the theoretical and the experimental data are extremely far apart. Ideally, the measured voltage amplitude of 0.0259 should be close to the theoretical value. Using the equation for the induced voltage stated above, the theoretically correct current can be obtained. An amplitude of A for the current should theoretically have been measured assuming that the measurement of the induced voltage is right.

The gap could be due to a variety of factors, most likely due to the state of the equipment used. In the first go around, the equipment used at my lab table failed the graph test completely, and we had to borrow equipment from another lab table. The wires used to measure the voltage across the resistor might have not been working properly as voltages hovering around the magnitude of is extremely small points to an extremely small current as well. The sine wave used to drive the current could also have been not exactly at around 1kHz. The sample rate also could have played a huge factor in taking the measurements. Also, the resistor used to acquire the current could have been at a different resistance compared to the its color codes because of general deterioration.