Force and Measurement of a Moving Charge Using a Current Balance

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Abstract

We used the magnetic field created by the solenoid to investigate the force on a moving charge. The graph created by plotting magnetic field on the y-axis versus the product of the current on the x-axis gives the plots to find μ_o. This is done by finding the slope of the graph. What to expect from the theory of μ_o, is that the μ_o found in the experiment will almost exactly be the same as the expected calculation of μ_o. Disagreements between theoretical and experimental result should have little differences. The experimental result differs from the theoretical results because of improper oscillations of the balance arm and the technicalities of the smallness of the washer made it hard to weigh.

Introduction

Solenoids are "thin loops of wire, often wrapped around a metallic core, which produces a magnetic field when an electric current is passed through it" (Wikipedia 2012). It is used in this experiment because with the solenoid, we are able to create a magnetic field. Which is then used to investigate the force on a moving charge, this force is then measured using a current balance. We will try to find the value of the permeability constant, μ_o, by putting a current balance in the solenoid. Half of the current balance is kept outside the solenoid and the other half inside the solenoid. We then put a known mass on the edge of the current balance which is outside the solenoid and increase the current in solenoid. The increase of current in the solenoid increases the magnetic force on the current arm inside the solenoid until a balance point is reached. A graph will then be made using the plots, magnetic field versus the product of current at balance point, and the number of turns of coil on solenoid. The value of μ_o is then found by finding out the slope of the graph.

Theory

From the Lorentz force equation, the Force, *Fmag*, on a charge, *q*, moving with velocity, *v*, in the magnetic field, B, is

$$Fmag = qvBsin\ \theta, \tag{1}$$

θ is the angle between the velocity, v, and the magnetic field, B.

From Newton's second law, the gravitational Force, *Fg*, on a body is

$$Fg = mg, \tag{2}$$

m is the mass of the body and g is the acceleration due to gravity.

From Ampere's law, the formula for the magnetic field, *B*, inside the solenoid is

$$B = \mu_o\ nIsol, \tag{3}$$

where μ_o is a constant, *n* is the number of turns and *Isol* is the current through solenoid.

Procedure

We used a solenoid for the experiment that had 3720 turns of thin copper wire. The current balance arm was aligned in the north-south direction and was put in place in the solenoid, so that the magnetic field of the Earth runs parallel to the wire on which we are going to measure the force. This procedure made sure that the magnetic field of the Earth had minimal effect on the experiment. We clipped a non-magnetic paper clip on the current arm balance so that the balance arm was perfectly horizontal when there was no current in the wire. We checked the balance of the arm by standing a file card next to it and drawing a line on the file card at the balanced position. And this same file card was used for all the further balances.

After the small plastic washer's mass had been measured accurately by the weighing machine, it was placed outside on the end of the balance arm. We used the scale to measure the length of the wire on the balance arm. The combined objects were then connected to the power supply, shown in figure 1 below. Current from the power supply was increased until the balance arm went back to its balanced position. Using equation (3), magnetic field inside the solenoid was calculated. Mew knot (μ_o) was calculated from the magnetic field versus the product of current at the balance point and number of turns of coil on the solenoid. Data of the mass of the washer and the current at the balanced position were saved.

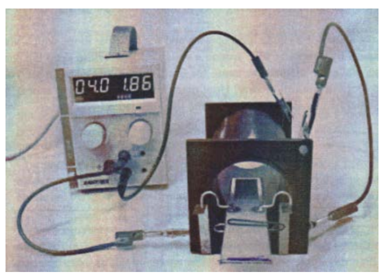

Figure 1: Power supply connected to solenoid and balance arm (Laboratory Manual)

Results/Data

The findings of the experiment are recorded into the table below.

Trial #	Mass(kg)	Current(I)	Bsol(T)
1	2.4x10^-5 ± 1x10^-6Kg	1.82 ± 0.02A	5.12x10^-3 ± 2.21x10^-4T
2	4.8x10^-5 ± 1x10^-6Kg	2.32 ± 0.02A	8.12x10^-3 ± 1.85x10^-4T
3	7.2x10^-5 ± 1x10^-6Kg	2.88 ± 0.02A	9.81x10^-3 ± 1.56x10^-4T
4	9.6x10^-5 ± 1x10^-6Kg	3.40 ± 0.02A	11.08x10^-3 ± 1.38x10^-4T
5	12.0x10^-5 ± 1x10^-6Kg	3.59 ± 0.03A	13.12x10^-3 ± 1.61x10^-4T
6	14.4x10^-5 ± 1x10^-6Kg	3.90 ± 0.03A	14.48 x10^-3 ± 1.58x10^-4T

Figure 2: The results of the experiment

Weight of 10 plastic washers: *0.24g ± 0.01g*
Weight of 1 plastic washer: *0.024g ± 0.001g*
D1 is the height of edge to center = 84 ± 0.05mm
D2 is the height of other edge to center = 84 ± 0.05mm

The force on the wire in the magnetic field

$$Fmag = Isol\ * L * B, \tag{4}$$

Balance the $Fmag$ and the Fg, so we combine the equation (2) and equation (4) and then multiply by the ratio of the height from the edges to the center

$$B = \frac{(mg)}{(Isol\ *L)} * (\frac{D1}{D2}), \tag{5}$$

Length, L, of wire on balance arm measure is

$$0.025 \pm 0.00005m, \tag{6}$$

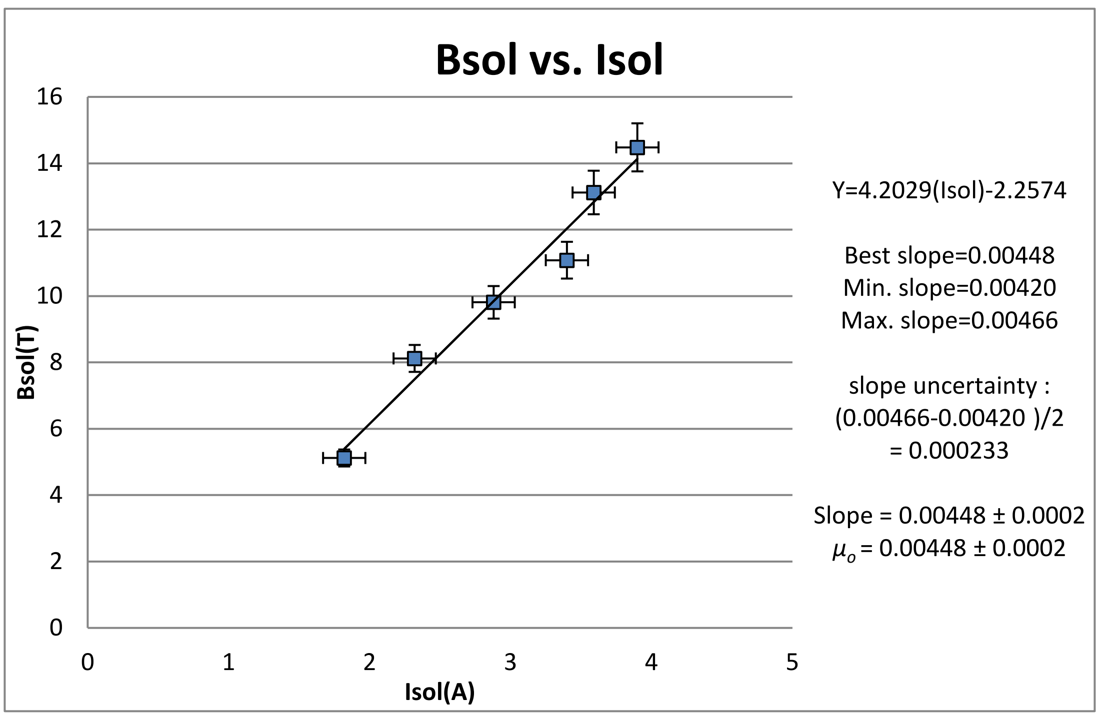

Figure 3: magnetic field versus the product of current

We then calculate, *B*, using equation (5) and chosen values from figure 3

Calculations for trial 3:

$$M = 7.2x10^{-5} \pm 1.0x10^{-6}\ Kg,$$

$$Isol = 2.88 \pm 0.02\ A,$$

$$L = 0.025 \pm 0.00005m,$$

$$G = 9.81msec^{2},$$

$$B_{sol} = \frac{(7.2x10^{-5})(9.81)(0.084)}{(2.88)(0.025)(0.084)},$$

$$B_{sol} = 9.81x10^{-3}\ T. \tag{7}$$

Using trial 3 as the example used to find its uncertainty

$$\Delta B = (B)\sqrt{\left(\frac{\Delta A}{A}\right)^2 + \left(\frac{\Delta B}{B}\right)^2 + \left(\frac{\Delta C}{C}\right)^2},$$

$$\Delta B = (9.81x10^{-3})\sqrt{\left(\frac{0.02}{2.88}\right)^2 + \left(\frac{0.001}{0.072}\right)^2 + \left(\frac{0.05}{25}\right)^2 + \left(\frac{0.05}{25}\right)^2 + \left(\frac{0.05}{25}\right)^2},$$

$$\Delta B = 2.7x10^{-4}\ T, \tag{8}$$

Therefore

$$B = 9.81x10^{-3} \pm 1.56x10^{-4}\ T. \tag{9}$$

Calculation of μ_o from Figure 3:

From equation (3)

$$n\ \mu_o\ I = B,$$

Writing (3) another way

$$\mu_o = B/nI, \tag{10}$$

$$\Delta\mu_o = (0.00466-0.00420)/2$$

$\Delta\mu_o = 0.000233$

$$\mu_o = \frac{9.10x10^{-3} - 8.05x10^{-3}}{3720x(2.75-2.50)} \quad ,$$

$$\mu_o = \frac{0.00448}{3720} \quad ,$$

$$\mu_o = 12.9x10\text{^-}7 \pm 2.3x10\text{^-}4\ N/A\text{^}2. \tag{11}$$

Discussion

The value μ_o = 12.9x10^-7 ± 2.3x10^-4 N/A^2 in comparison is really close to the actual value of 12.4x10^-7 N/A. There is an error because of improper balance and the oscillation of the balance arm. As measurements were made the washers were small and were therefore hard to weigh.

Conclusion

We can conclude that the disagreements between theoretical and experimental result had little differences. The experimental result differs from the theoretical results because of improper oscillations of the balance arm and the technicalities of the smallness of the washer made it hard to weigh. Putting a known mass on the edge of the current balance and the increase of current in the solenoid affect the results we received. The increase of current in the solenoid that increased the magnetic force on the current arm inside the solenoid might have been measured mistakenly and therefore have errors.

References

Laboratory Manual. Physics 131 Spring 2012. Simon Fraser University, Physics Department. *Electromagnetism Experiment 4.*

Wikipedia. February 2012. Solenoid. March 2012 <http://en.wikipedia.org/wiki/Solenoid>