E12
Magnetic Field in a Solenoid

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B.Sc in Applied Physics.

Tuesday 3rd March, 2020
10:00 A.M - 1:00 P.M

1 Introduction:

A common method of generating a magnetic field in physics is by creating a coil and running current from one end to the other, A solenoid is the scientific name for this coil. In this experiment we will use a metal slinky which replicates the exact shape of a solenoid which we will run current through in order to generate a magnetic field inside.

In this experiment we will use a Vernier Magnetic Field Sensor to verify the existence of a magnetic field, as well as determine characteristics and phenomenon regarding magnetic fields and solenoids. One of the main goals of this experiment is to measure the permeability constant μ_0, which is a well known physical constant which has a value of 1.26×10^{-6} T*m/A.

We will do this using the equation:

$$B = \mu_0 n l \tag{1}$$

B is the magnetic field, μ_0 is the permeability constant, n is the number of turns and l is the length of the solenoid.

Other outcomes of this experiment include understanding the relationship that exists between the current we put into the solenoid and the magnetic field which is created by the solenoid, as well as how the magnetic field differs when measured at different points along the solenoid, meaning there is a different number of turns in the coil.

2 Method Experimental Set-up:

We initially stretched the slinky to be 1 m in length, based on screw holes that were placed in the table at different intervals of length. A voltage probe was connected across our resistor making sure to connect the positive end to the positive side of the power supply, leads with clips on the ends were used to secure the connection to the slinky.

Next we connected the voltage probe to a LabQuest in Channel 1 and the Vernier Magnetic Field Sensor was connected to the Lab Quest in Channel 2 and the sensor was switched to high. At this point the LabQuest was displaying values for both the voltage (measured in Volts) being supplied and the magnetic field (measured in mT microTesla) being generated by the solenoid.

After carrying out these steps all that was left to is turn on the power supply and set the current to 2 A and begin recording our measurements. First we determined the relationship between magnetic field and the current flowing through the solenoid. Followed by the relationship between the magnetic field and the number of turns in the coil, by changing where we placed Vernier Magnetic Field Sensor.

3 Results:

Q1. Turn on the power supply. Set the current to 2.0 A. Place the Magnetic Field Sensor between the turns of the Slinky near its centre. Rotate the sensor and determine which direction gives the largest positive magnetic field reading. What direction is the white dot on the sensor pointing?

The white dot is facing left, towards the negative end of the terminal

Q2. What happens if you rotate the white dot to point the opposite way? What happens if you rotate the white dot so it points perpendicular to the axis of the solenoid?

We get a smaller negative magnetic field, when the sensor is perpendicular we get an extremely small value for our magnetic field

Q3. Insert the Magnetic Field Sensor through different locations along the Slinky to explore how the field varies along the length. Always orient the sensor to read the maximum magnetic field at that point along the Slinky. How does the magnetic field inside the solenoid seem to vary along its length?

Length (cm)	Magnetic Field
10	-0.2180 mT
20	-0.2180mT
30	-0.2070 mT
40	-0.2380 mT
50	-0.2200 mT
60	0.2130 mT
70	0.2442 mT
80	0.2283 mT
90	0.2380 mT

Once the Magnetic Field Sensor passes the midpoint of the solenoid we notice a shift in the direction, as our magnetic field readings go from being highest at negative values, to being highest at positive values.

Q4. Check the magnetic field intensity just outside the solenoid. Is it different from the field inside the solenoid?

The magnetic field measured outside the solenoid is much lower than the values recorded inside the solenoid

Experiment 1:

Q5. Tabulate the results for the magnetic field versus the current flowing in the solenoid.

Voltage V (V)	Current I (A)	Magnetic Field B (mT)
0	0	0.07
0.5	0.5	0.0784
1	1	0.1481
1.5	1.5	0.1877
2	2	0.2416

72 turns in the solenoid, Length = 96.5 cm, 74.61

Q6. Plot a graph of magnetic field B (mT) versus the current I (mA) flowing in the solenoid. What does the slope of this graph represent?

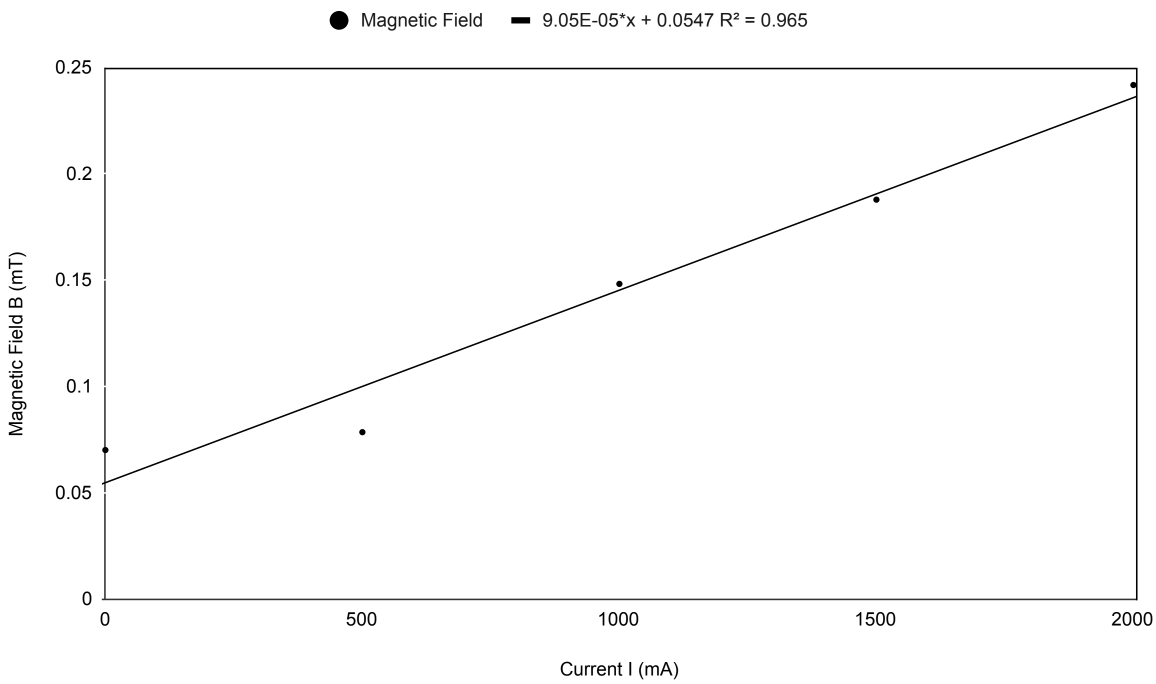

Figure 3.1: Graph

Q7. Determine the slope of the graph of B versus I and then calculate the value of μ_0.

Magnetic field vs. Current

Slope =	$9.05\times10^{-5} \pm 1\times10^{-6}$
Intercept =	0.0547 ± 0.0122
Length of solenoid (m) =	0.965
Number of turns =	72
Turns/m (m^{-1}) =	74.61
Permeability constant, μ_0 =	1.213×10^{-6}

Experiment 2:

Q8. Tabulate the results for the magnetic field versus the number of turns/meter.

Current I (A)	Length L (m)	Total no. of turns in coil	Turns per meter n (m^{-1})	Magnetic Field B (mT)
1	0.5 m	72	144	0.1531
1	1 m	72	72	0.0628
1	1.5 m	72	48	0.0913
1	2 m	72	36	0.0766

Q9. Plot a graph of magnetic field B (T) versus the number of turns/meter n (m^{-1}). What does the slope of this graph represent?

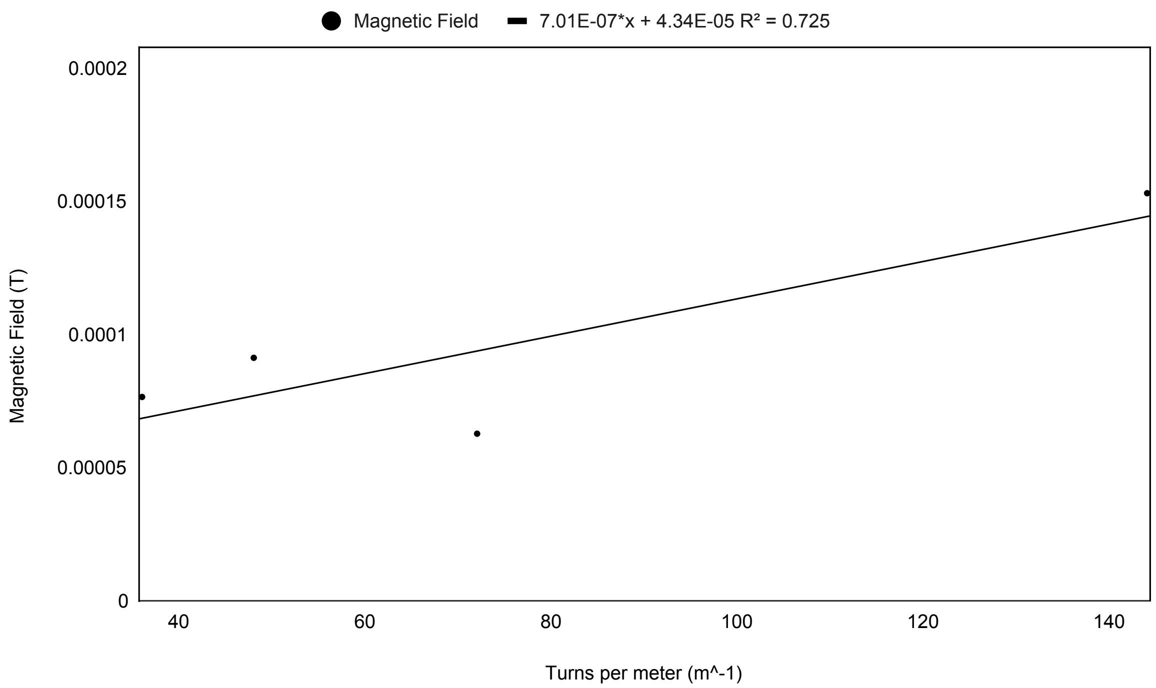

Figure 3.2: Graph

Q10. Determine the slope of the graph of B versus n and then calculate the value of μ_0.

Magnetic field vs. Number of turns/meter

Slope =	$7.01\times10^{-7} \pm 3\times10^{-7}$
Intercept =	$4.34\times10^{-5} \pm 2.62\times10^{-5}$
Current (A) =	1
Permeability constant, μ_0 =	7.01×10^{-7}

Q11. Compare your results from Q7 and Q10 to the accepted permeability.

	Measured Permeability μ_0 (T.m/A)	Accepted Permeability μ_0 (T.m/A)	Difference (%)
From Q7.	1.213×10^{-6}	1.26×10^{-6}	3.73 %
From Q10.	7.01×10^{-7}	1.26×10^{-6}	44.37 %

4 Discussion:

Despite taking every measure to ensure accuracy, some discrepancies still occur and our answers don't perfectly match up with the accepted permeability, we can speculate on reasons as to why. While carrying out the experiment, the first likely source of error we noticed was with the values recorded by the lab quest. As we moved the magnetic field sensor we noticed that the values were extremely unstable and would constantly fluctuate with almost no pattern, due to this we had to just pick a value which was displayed and take that as our data point despite the LabQuest not coming to a rest. It was also observed that the magnetic field would continue to increase almost indefinitely, everytime we wanted to record a new data point we were required to recalibrate the magnetic field value to zero in order to get an accurate reading.

A method for avoiding the first source of error we noticed is by increasing your sample size, hopefully if we record enough data points and increase the amount of values we can use in our average we can eliminate as many outliers as possible and hopefully end up with an answer that its closely representative of the value we would expect to obtain if these errors weren't present. Minimising the second source of error was just a matter of remembering to recalibrate the magnetic field to zero each time we wanted to take a reading, although this was time consuming it went a long way in increasing the accuracy of our values, and if we continued to practice this for even more data points would could be sure to reduce our percentage error even further.

5 Conclusion

After carrying out this experiment we were able to conclude that the relationship that exists between Current (A) and Magnetic Field (mT) is that as the Current in the circuit is increased, so too does the Magnetic Field inside the solenoid. We were able to determine that as the number of turns in a solenoid increases so too does the strength of the Magnetic Field. Finally we determined values for the permeability constant (μ) 1.213×10^{-6} T.m/A and 7.01×10^{-7} T.m/A, which had an error of 3.73 % and 44.37 % respectively.