08 February 2024

Winter 2024

experiment 5

Magnetic Field

University of Wollongong in Dubai

SUBMITTED BY:

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PHYS143
Physics for Engineers

Purpose

Measure the magnetic field in coils with variable number of turns and compare the measured value to the theoretical value.

Hypothesis Statement

The number of turns in a coil is directly proportional to its magnetic field strength. The measured value must be in accordance with the theoretical value, which is to be calculated using $B = \mu_0 n I$.

Materials

- Coil wire
- Coil bobbin
- DC Power supply
- Computer
- Magnetic field sending equipment

Procedure

1. Clamp the wire on the coil at its ends and lock it. Loosen the lock to adjust the length as required.
2. Connect the power supply to the two clamps.
3. Connect the magnetic field sensor to the magnetic field sensor box. Then connect the magnetic field sensor box to the computer to read field strength values on the *PASCO Capstone* application.
4. Place the magnetic field sensor near the middle of the coil. It should be perpendicular to the wires and equidistant from the ends of the coil.
5. Turn on the power supply and set the current to 3A.
6. Read the values shown on the computer through the *PASCO Capstone* application.
7. Repeat the procedure for varying lengths of the coil.

Data & Graphs

Length of coil (m)	Experimental Magnetic Field (G)	Theoretical Magnetic Field (T)
0.10	9.52	1.13×10^{-3}
0.15	7.54	7.54×10^{-4}
0.20	6.99	5.65×10^{-4}
0.25	5.95	4.52×10^{-4}

$B_{theoretical} = \mu_0 \frac{N}{L} I$

e.g. $B = (4\pi \times 10^{-7}) \frac{30 \times 3}{0.1} = 1.13 \times 10^{-3}\ T$

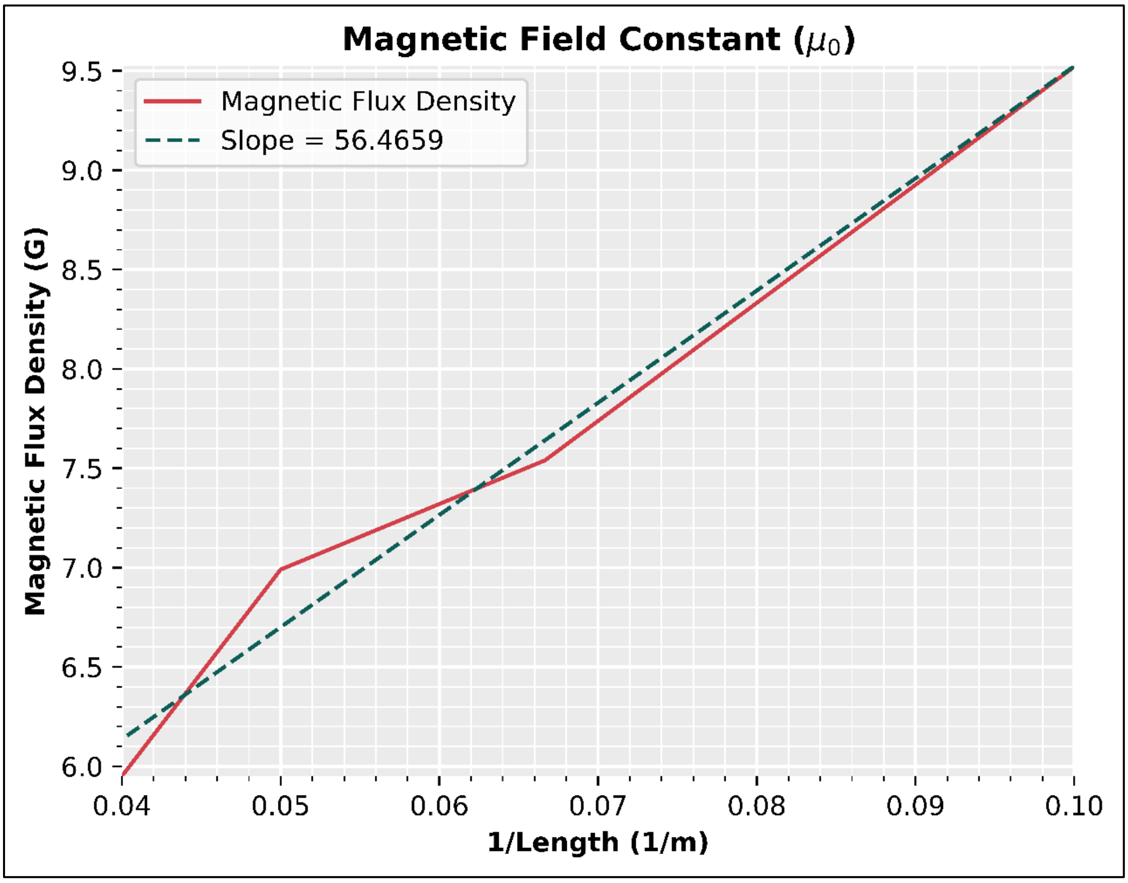

Figure 1: Determining Magnetic Field Constant

Calculation of μ_0

Gradient of graph: 56.4659 = y/x

y = B, x = 1/L. ∴ y/x = BL

$\mu_0 = 4\pi \times 10^{-7} = 1.257 \times 10^{-6}\, {}^{N}/_{m^2}$

From equation, $BL = \mu_0 nI$

Experimental value of $\mu_0 = \frac{BL}{nI} = \frac{56.4659}{30 \times 3} = 0.6274\, {}^{N}/_{m^2}$

Observations

We investigated the relationship between the solenoid's coil length and the strength of the magnetic field that results in the first phase of the laboratory investigation. By means of careful observation and analysis, we discovered a correlation: changes in the coil's length by 5 cm steps resulted in identical variations in the strength of the magnetic field. This phenomenon followed the well-established formula ($B_{theoretical} = \mu_0 \frac{N}{L} I$), in which the coil's length (L) and magnetic field strength (B) were inversely related. Therefore, there was a noticeable drop in the solenoid's magnetic field strength as its length increased.

Conclusion

1. What was the purpose of this lab?

Measure the magnetic field in coils with variable number of turns and compare the measured value to the theoretical value.

2. How does the lab we performed relate to what we are studying in class?

We have learnt in class that the number of turns in a coil is directly proportional to its magnetic field. The magnetic field of a coil is proportional to the square of the number of turns in the coil, so increasing the number of turns will increase the magnetic field.

3. Give a brief recap of the procedure used.

Clamp the wire ends on the coil, adjust as needed, connect the power supply, link the magnetic field sensor to the computer via the sensor box, position the sensor centrally, perpendicular to the wires, equidistant from ends, set the current to 3A, and record readings for different coil lengths.

4. What problems did you have during the lab? Did you have to modify your procedure?

Fortunately, the team faced no problems with the experiment conducted. We immediately grasped the concept and encountered no issues with practical understanding. Therefore, there was no need to modify the procedure, as it was executed with ease.

5. Do your results make sense? What are the sources of error?

The results align with the established formula: coil length (L) inversely affects magnetic field strength (B). Lab findings mirrored this, with shorter coils yielding stronger fields. However, the value of μ_0 deviated from theory, likely due to unit disparities between lab and theoretical calculations.

The sources of error are systematic errors, such as the possibility of the magnetic field sensor being poorly calibrated, or the wires not being firmly attached.

6. What did you learn from this lab?

This experiment taught us that experimenting with coils that have a variable number of turns per unit length aids in understanding the connection between the coil's magnetic field and turn count. You can see how the magnetic field varies with the number of turns by varying the number of turns and measuring the magnetic field.

7. If you were to repeat this lab in the future, how would you modify or improve the procedure?

If attempting this experiment for a second time, we will take precautions such as not exceeding the current, not touching the wire when the power supply is on, and modifying the lengths of the coil when power supply is switched off.

Purpose

Examine the magnetic field produced by current in a pair of Helmholtz coils.

Hypothesis Statement

The magnetic field (B) produced by a pair of Helmholtz coil is stronger and more rigid, in comparison with other sources and is given by $B = \frac{8\mu_0 nI}{5\sqrt{5R}}$

Materials

- Helmholtz Coil
- DC Power supply
- Computer
- Magnetic field sensing equipment
- Multimeter

Procedure

1. Measure the radius of the Helmholtz coil and record the number of turns.
2. Connect the Helmholtz coil to the DC power supply. Connect an ammeter or a multimeter to accurately measure the current.
3. Use the magnetic field sensing probe to measure the field at the center of the Helmholtz coil for current values between 0 A to 1 A, in 0.2 A increments.

Data & Graphs

[Table title here]

	Run #1	
	Magnetic Field Strength (Axial) (G)	Time (s)
101	1.13	10.000
102	1.25	10.100
103	1.28	10.200
104	1.30	10.300
105	1.34	10.400
106	1.46	10.500
107	1.52	10.600
108	1.58	10.700
109	1.65	10.800
110	1.65	10.900
111	1.62	11.000
112	1.69	11.100
113	1.70	11.200
114	1.68	11.300
115	1.68	11.400
116	1.64	11.500
117	1.66	11.600
118	1.55	11.700
119	1.49	11.800
120	1.48	11.900
121	1.37	12.000
122	1.34	12.100
123	1.32	12.200
124	1.28	12.300
125	1.29	12.400
126	1.34	12.500
127	1.35	12.600

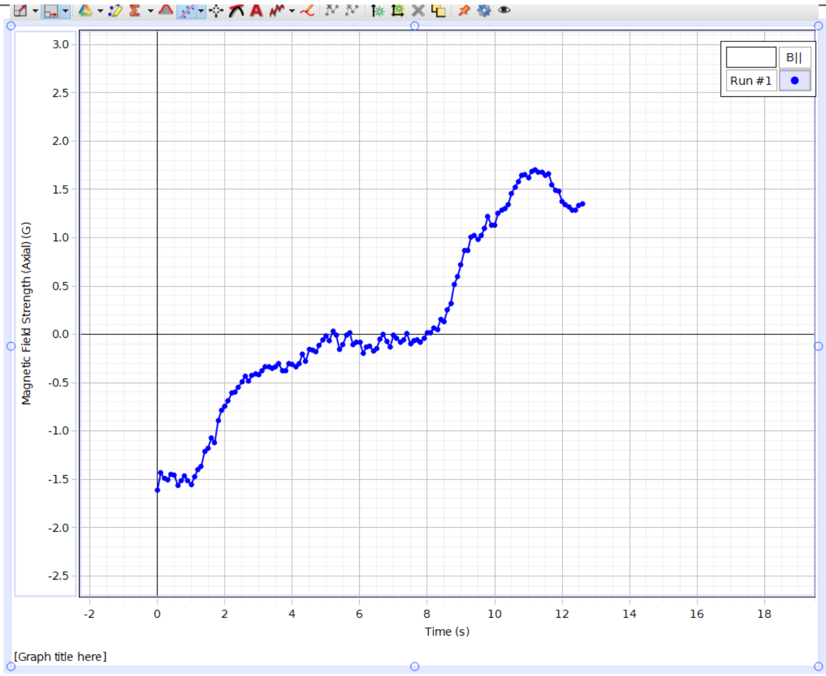

Figure 2: Magnetic Field in Helmholtz coil at I = 0.2A

[Table title here]

	Run #1	
	Magnetic Field Strength (Axial) (G)	Time (s)
147	2.07	14.600
148	2.07	14.700
149	2.15	14.800
150	2.11	14.900
151	2.31	15.000
152	2.38	15.100
153	2.63	15.200
154	2.65	15.300
155	2.84	15.400
156	2.89	15.500
157	2.85	15.600
158	2.89	15.700
159	2.85	15.800
160	2.76	15.900
161	2.49	16.000
162	2.55	16.100
163	2.40	16.200
164	2.38	16.300
165	2.32	16.400
166	2.34	16.500
167	2.35	16.600
168	2.33	16.700
169	2.33	16.800
170	2.36	16.900
171	2.32	17.000
172	2.34	17.100
173	2.35	17.200

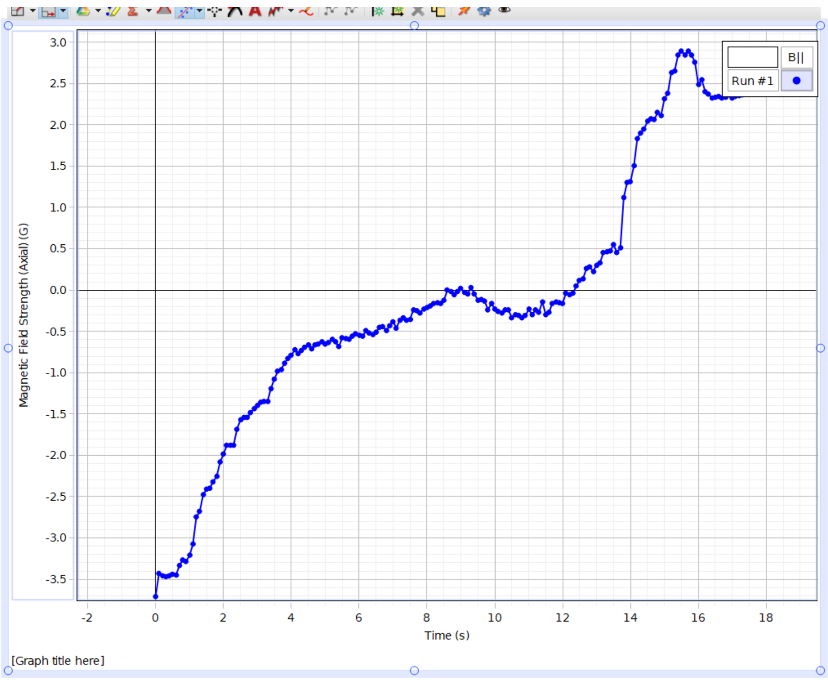

Figure 3: Magnetic Field in Helmholtz coil at I = 0.4A

[Table title here]

	Run #1 Magnetic Field Strength (Axial) (G)	Time (s)
210	5.35	20.900
211	5.38	21.000
212	5.41	21.100
213	5.44	21.200
214	5.47	21.300
215	5.44	21.400
216	5.45	21.500
217	5.54	21.600
218	5.59	21.700
219	5.56	21.800
220	5.28	21.900
221	5.09	22.000
222	5.23	22.100
223	5.11	22.200
224	4.76	22.300
225	4.39	22.400
226	2.58	22.500
227	0.95	22.600
228	0.04	22.700
229	-0.28	22.800
230	-0.42	22.900
231	-0.47	23.000
232	-0.45	23.100
233	-0.40	23.200
234	-0.44	23.300
235	-0.42	23.400
236	-0.46	23.500

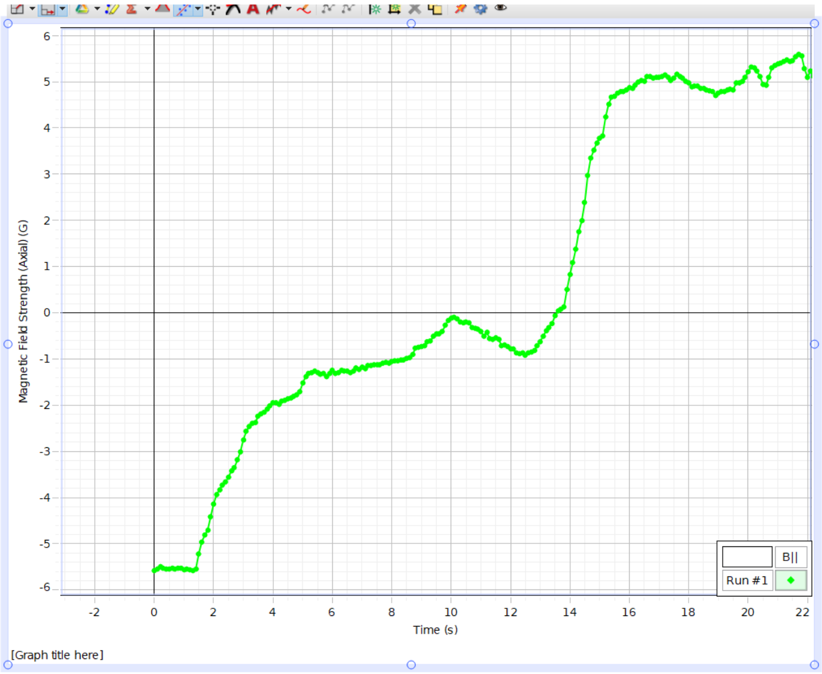

Figure 4: Magnetic Field in Helmholtz coil at I = 0.6A

[Table title here]

	Run #1 Magnetic Field Strength (Axial) (G)	Time (s)
139	7.04	13.800
140	7.02	13.900
141	7.13	14.000
142	7.07	14.100
143	7.08	14.200
144	7.04	14.300
145	6.94	14.400
146	6.78	14.500
147	6.61	14.600
148	6.41	14.700
149	6.14	14.800
150	5.82	14.900
151	5.76	15.000
152	5.63	15.100
153	5.55	15.200
154	5.49	15.300
155	5.52	15.400
156	5.52	15.500
157	5.52	15.600
158	5.52	15.700
159	5.60	15.800
160	5.60	15.900
161	5.65	16.000
162	5.65	16.100
163	5.70	16.200
164	5.66	16.300
165	5.64	16.400

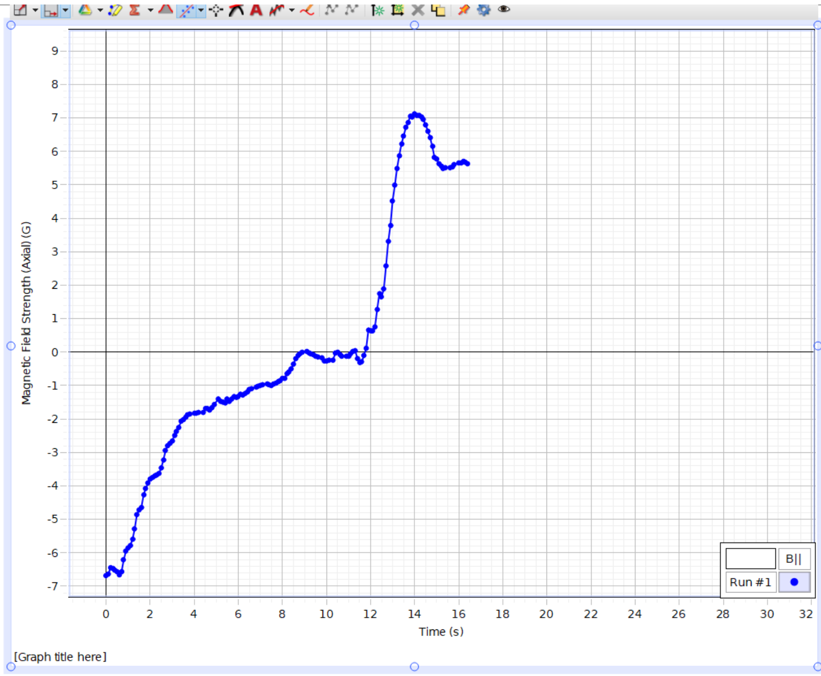

Figure 5: Magnetic Field in Helmholtz coil at I = 0.8A

[Table title here]

	Run #1	
	Magnetic Field Strength (Axial) (G)	Time (s)
88	0.42	8.700
89	2.27	8.800
90	4.24	8.900
91	5.76	9.000
92	6.94	9.100
93	7.64	9.200
94	8.42	9.300
95	8.61	9.400
96	8.78	9.500
97	8.81	9.600
98	8.71	9.700
99	8.68	9.800
100	8.55	9.900
101	8.50	10.000
102	8.31	10.100
103	8.11	10.200
104	7.92	10.300
105	7.61	10.400
106	7.53	10.500
107	7.44	10.600
108	7.27	10.700
109	7.14	10.800
110	7.04	10.900
111	6.93	11.000
112	6.83	11.100
113	6.81	11.200
114	6.78	11.300

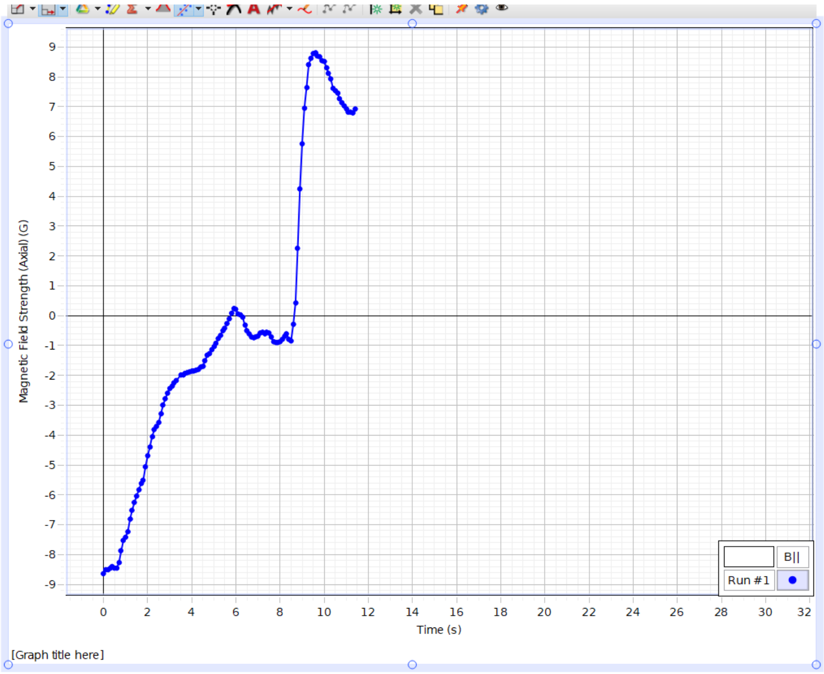

Figure 6: Magnetic Field in Helmholtz coil at I = 1.0A

Observations

From the observations of our experimental graphs, we can depict an image of how the magnetic field looks like around a solenoid. In our experiment, as we moved away from the center of the solenoid from the right side of the Helmholtz coil to the left side, we saw the value of the magnetic field strength start to decrease. However, once we started to approach and enter the left side of the solenoid we saw the exact strength of the magnetic field equal in value but opposite in direction to the one on the right. With this information we can deduce that:

- The magnetic field strength is greatest in the center of the solenoid.
- Magnetic Field strength decreases as you move away from the center of the solenoid
- There is polarity in magnetic field strength in accordance with the flow of current.

Conclusion

1. What was the purpose of this lab?

To examine the magnetic field produced by current in a pair of Helmholtz coils.

2. How does the lab we performed relate to what we are studying in class?

The experiment on the Helmholtz coil demonstrated the principles of magnetic fields generated by current and the effectiveness of using Helmholtz coils to produce uniform magnetic fields.

3. Give a brief recap of the procedure used.

Measure the Helmholtz coil, connect it to a DC power supply, attach a current-measuring device, and use a magnetic field probe to measure field strength at the coil's center for currents between 0 A to 1 A, in 0.2 A steps.

4. What problems did you have during the lab? Did you have to modify your procedure?

The team was well-oriented with the concept of Helmholtz coils and was quick to proceed with the experiment. Thankfully, they did not have to modify the procedure and swiftly completed it.

5. Do your results make sense? What are the sources of error?

The results do make sense as the experiment performed relates to the theory which explains that the magnetic field is greatest around the center of the solenoid and decreases as it moves away from it. It was also indicated that the magnetic field is equal in magnitude but opposite in direction on different sides of the solenoid.

The sources of error include human errors, such as the magnetic field not being measured consistently in terms of time and distance from the coil, and systematic errors, such as the ammeter or multimeter being poorly calibrated.

6. What did you learn from this lab?

By positioning a tiny magnetic field probe or a compass at the coil's center and measuring the field, we learned how to determine how uniform the magnetic field the coil is producing.

7. If you were to repeat this lab in the future, how would you modify or improve the procedure?

If attempting this experiment for a second time, we will take precautions such as not touching the wire when the power supply is on and operating the coils with low voltages to avoid damaging the coils.