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ENGS124 Electricity and Magnetism Lab Section B Electric currents and magnetic fields of a coil

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1 Theory

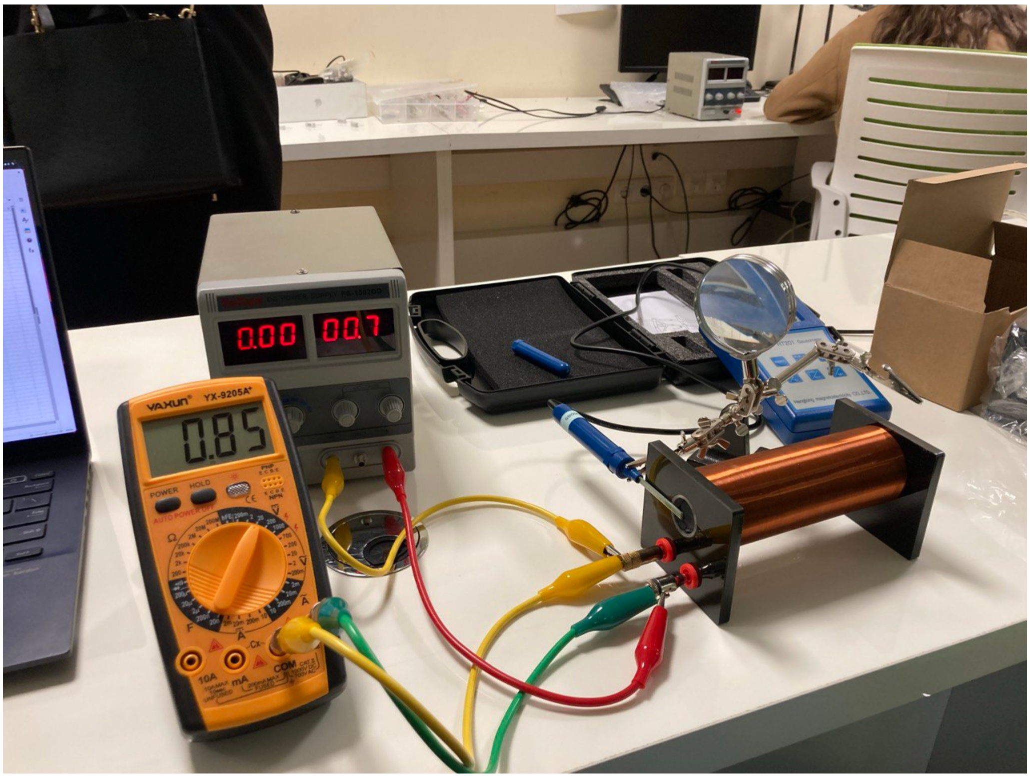
Ampere's law states that a magnetic field is created by an electric current, which is proportional to the size of that electric current, with a constant of proportionality equal to the permeability of free space. Now if we consider a coil of wire, we get the following equation in the axis of the coil:

$$B = \frac{\mu_0 I N}{l}$$

where μ_0 is the vacuum magnetic permeability, I is the current running throught the coil, N is the number of turns and l is the length of the coil. Several experiments were carried out to test the dependence of magnetic field on current, the influence of ferromagnetic material and the superposition of magnetic fields.

2 Field dependence on the current

A lab bench power supply was connected to a coil and the voltage was measured with a multimeter. The resistance of the coil was measured beforehand. A hall effect sensor was used to measure the magnetic field on the tip of the coil through the axis of the coil. The resistance of the coil is $R = 306\Omega$. An iron core was placed inside the coil.



Instrument or material	Description
Lab power supply	Large voltage range
Multimeter	Voltage and resistance measurement functionality
Hall sensor	Able to measure a in the order of mT
Solenoid	A solenoid with iron rod
Cables	For the multimeter and battery

Table 1: List of instruments and materials

Variable	Value	Resolution
Voltage across coil	Controlled	$0.01V$
Magnetic field strength	Measured	$0.01mT$

Table 2: List of variables

V (V)	I (mA)	B (mT)
1.00	3.27	1.22
2.00	6.54	2.29
3.00	9.80	3.39
4.00	13.07	4.53
5.00	16.34	5.68
6.00	19.61	6.80
7.00	22.88	7.93
8.00	26.14	9.07
9.00	29.41	10.20
10.00	32.68	11.33
11.00	35.95	12.41
12.00	39.22	13.56
13.00	42.48	14.62
14.00	45.75	15.68
15.00	49.02	16.76

Table 3: Experiment data

Source of error	Type of error	Countermeasures
Variable hall effect position	Random	If the hall effect sensor was moved, it would measure the magnetic field strength of a different point. The sensor was fixed with a stand to minimize movement.

Table 4: Estimated errors

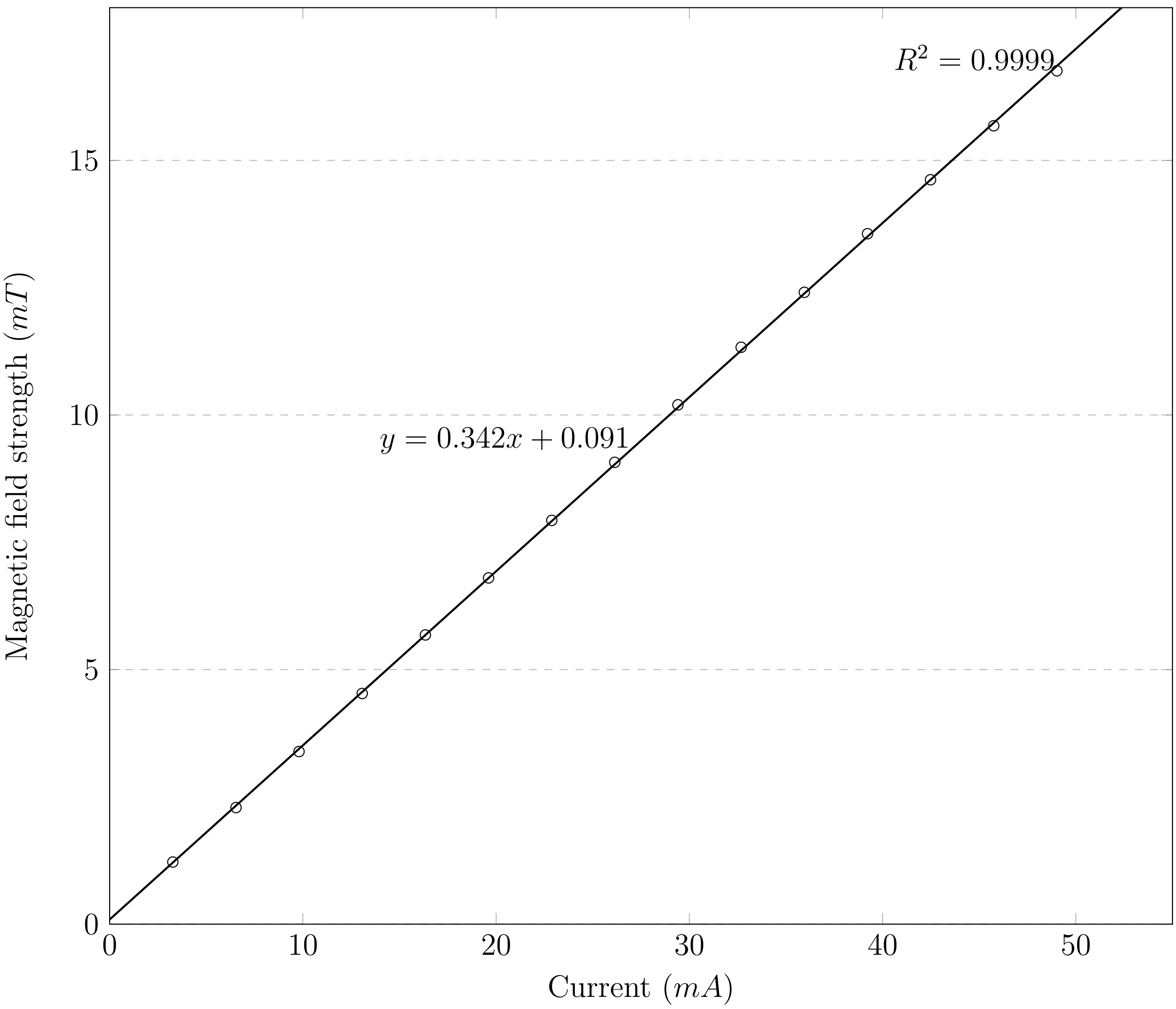


Figure 1: Plot of dependence of magnetic field strength from current (with iron core)

It was deduced that the magnetic field strength of the coil is linearly dependent from the current running through it.

3 Magnetic permeability of the rod

The same experiment was carried out, however the iron core was removed from the coil. All the diagrams, materials, instruments, variables and error sources were the same. The position of the hall effect sensor was not altered.

V (V)	I (mA)	B (mT)
1.00	3.27	0.09
2.00	6.54	0.19
3.00	9.80	0.29
4.00	13.07	0.40
5.00	16.34	0.51
6.00	19.61	0.61
7.00	22.88	0.71
8.00	26.14	0.80
9.00	29.41	0.90
10.00	32.68	1.01
11.00	35.95	1.12
12.00	39.22	1.21
13.00	42.48	1.31
14.00	45.75	1.42
15.00	49.02	1.51

Table 5: Experiment data

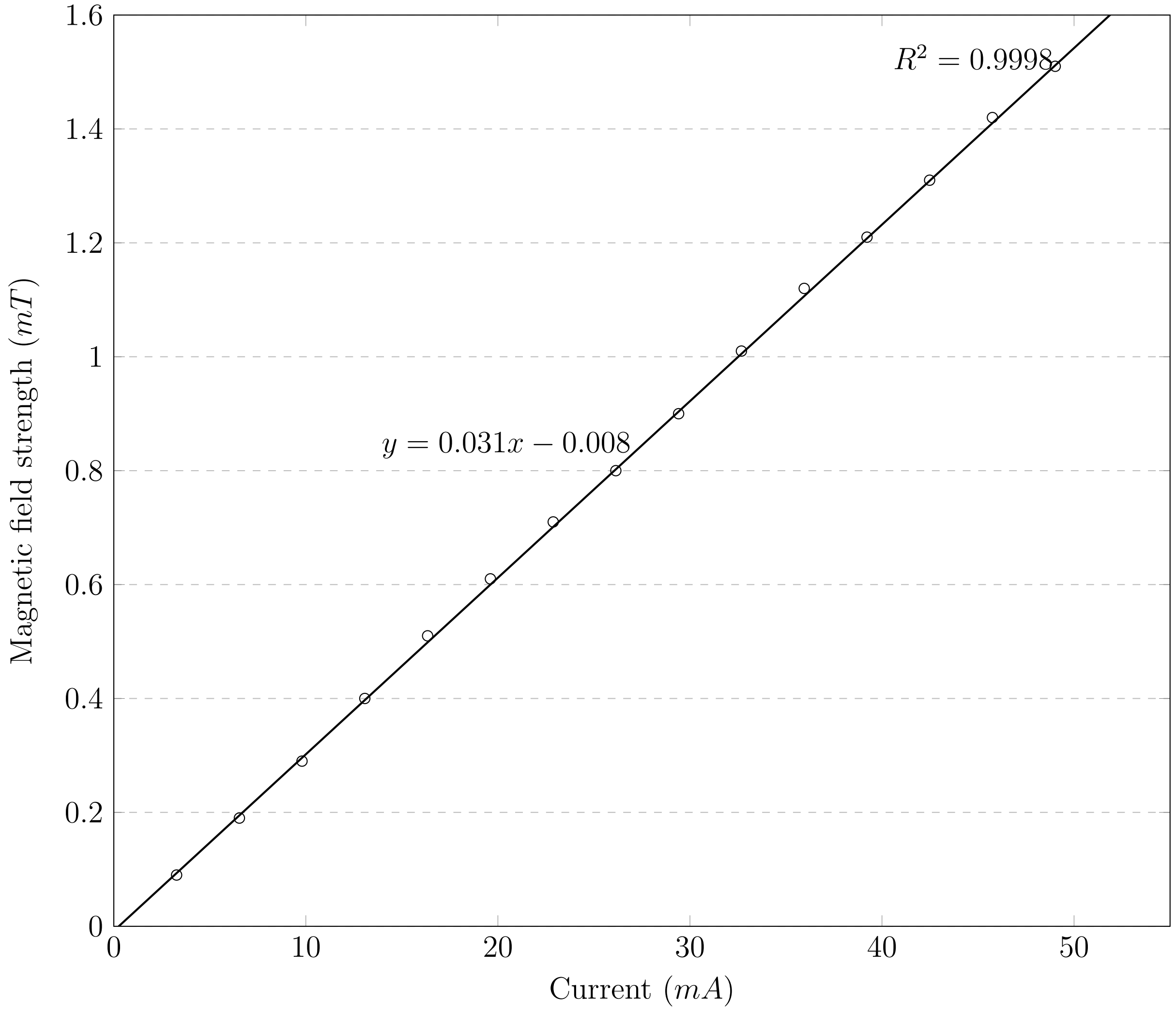


Figure 2: Plot of dependence of magnetic field strength from current (without iron core)

The magnetic field strength is still linearly dependent from the current, however it was much less, as the iron was used to concentrate the magnetic fields through the axis of the coil. The magnetic field strength as 11 times stronger with the rod, therefore the magnetic permeability is $\mu \approx 11$.

4 Magnetization of the rod

The same experiment was carried out, however the position of the iron rod was varied and the part that was left outside the coil was measured.

Instrument or material	Description
Lab power supply	Large voltage range
Multimeter	Voltage and resistance measurement functionality
Hall sensor	Able to measure a in the order of mT
Solenoid	A solenoid with iron rod
Ruler	To measure the iron rod
Cables	For the multimeter and battery

Table 6: List of instruments and materials

Variable	Value	Resolution
Part of rod outside	Controlled	$1mm$
Magnetic field strength	Measured	$0.01mT$

Table 7: List of variables

V (V)	I (mA)	x (mm)	B (mT)
10.00	32.68	137	1.01
10.00	32.68	110	1.03
10.00	32.68	100	1.03
10.00	32.68	90	1.06
10.00	32.68	80	1.10
10.00	32.68	70	1.14
10.00	32.68	60	1.21
10.00	32.68	50	1.30
10.00	32.68	40	1.48
10.00	32.68	30	1.76
10.00	32.68	20	2.34
10.00	32.68	10	3.07
10.00	32.68	0	6.63

Table 8: Experiment data

Source of error	Type of error	Countermeasures
Position measurement	Random	It was difficult to maintain consistent measurements of the rod.

Table 9: Estimated errors

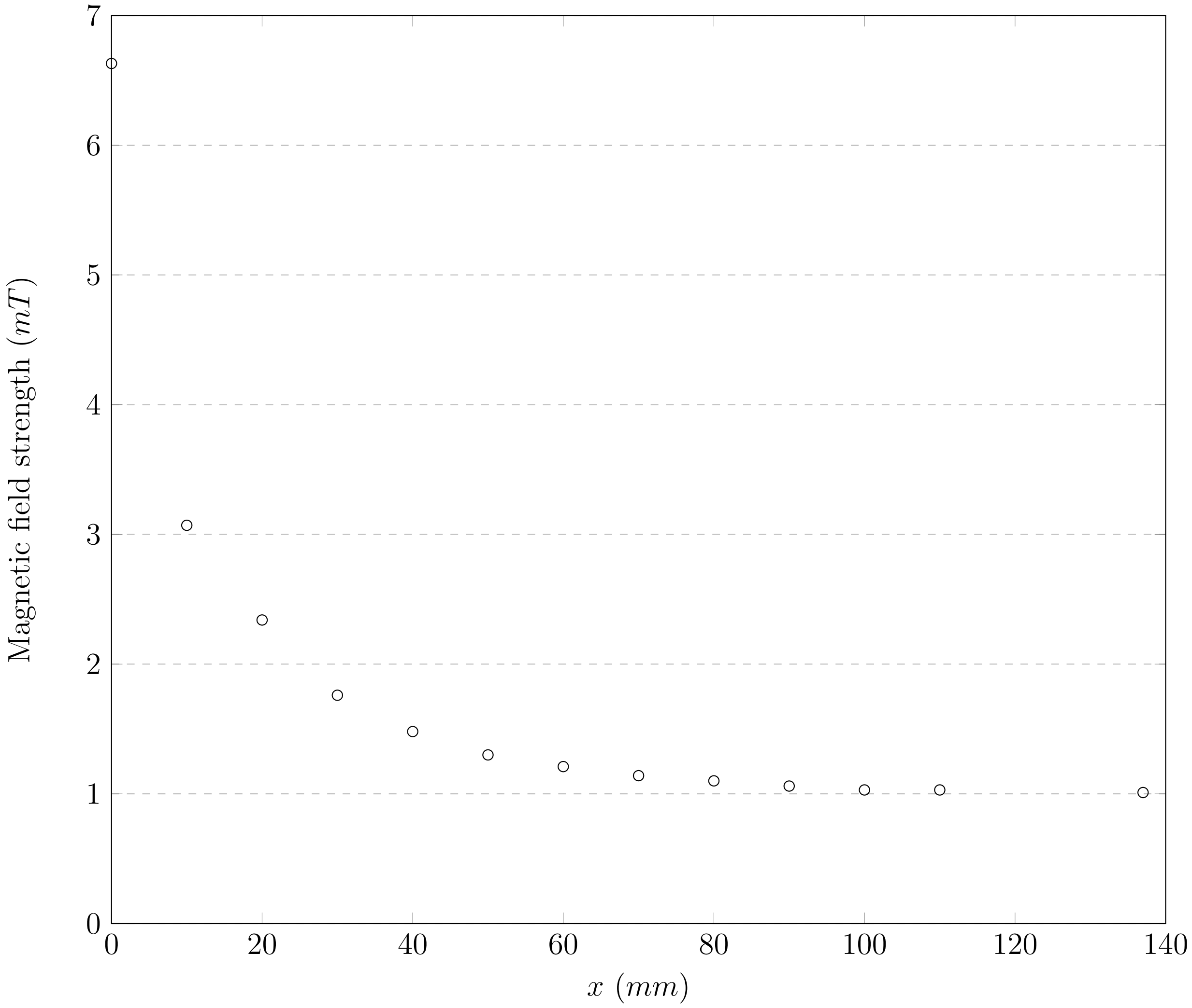


Figure 3: Plot of dependence of magnetic field strength from current (without iron core)

The magnetic field strength is inversely proportional from the part that is outside the coil.

5 Superposition principle

The data got lost, however the superposition principle was confirmed.