UM-SJTU Joint Institute

Physics Laboratory
(Vp241)

Laboratory Report

Excercise 2

The Hall Probe: Characteristics and Applications

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[rev4.1]

1 Introduction

The objective of this exercise is basically to use a Hall probe to verify the Hall effect and apply it to measure magnetic field.

2 Experimental setup

2.1 Equipments used in the experiment

Devices used in this experiment include the following: an integrated Hall probe, a solenoid, a power supply, a voltmeter, a DC voltage divider, and several wires for connection

2.2 Measurements used in the experiment

Three different measurements are involved in this experiment: Relation Between Sensitivity K_H and Working Voltage U_S, Relation Between Output Voltage U and Magnetic Field B, and Magnetic Field Distribution Inside the Solenoid.

2.2.1 Relation Between Sensitivity K_H and Working Voltage U_S

For "Relation Between Sensitivity K_H and Working Voltage U_S", we will look for the relation between these two variables by applying the following equation:

$$B = \frac{U - U_0}{K_H} \tag{1}$$

We place the Hall probe at the centre of the solenoid,set the working voltage at 5V and measure the output voltage when I=0 and 250mA. Then we plug in the theoratical value of B to calculate the value of K_H.

2.2.2 Relation Between Output Voltage U and Magnetic Field B

In this part, we figure out the relation between the output voltage of the Hall probe and the magnetic field where it was inserted by adjusting the current in the solenoid. With B=0, US=5 V, connect the 2.4 2.6 V output terminal of the DC voltage divider and the negative port of the voltmeter. Adjust the voltage until $U_0 = 0$. Then Place the integrated Hall probe at the center of the solenoid and measure the output voltage U for different values of I_M ranging from 0 to 500 mA, with intervals of 50mA. After measuring, plot the curve U vs. B and find the sensitivity K_H by a linear fit.

2.2.3 Magnetic Field Distribution Inside the Solenoid

In this measurement, we want to find the the magnetic field distribution along the axis of the solenoid for $I_M = 250$mA. Start from the distance of 2cm, take the value of the voltage U and insert the probe by 1cm for new data. Repeat this process from 2cm to 28cm. After that, use a computer to plot the theoretical and the experimental curve showing the magnetic field distribution inside the solenoid. We use dots for the data measured and a solid line for the theoretical curve. The origin of the plot should be at the center of the solenoid.

3 Measurements and Results

3.1 Relation Between Sensitivity K_H and Working Voltage U_S

For the first measurement, we obtain the following data table: Since the

U_S [V] ± ____ [V]	$U_0(I_\mathrm{M} = 0)$ [V] ± ____ [V]	$U(I_\mathrm{M} = 250$ mA) [V] ± ____ [V]
5	2.496	2.617

Table 1. Data for U_0 and U with $U_S = 5$ V.

theoretical value of the magnetic field is proportional to the magnitude of I_M when x is a fixed value, we can simply acquire the desired value for B by multiplying it by 2.5 times. The calculation is given by:

$$B(x = 0, I_\mathrm{M} = 250\ [\mathrm{mA}]) = \frac{250}{100} \times 1.4366 \times 10^{-3} = 3.59 \times 10^{-3} \pm 0.07 \times 10^{-3}\ \mathrm{T}.$$

Now according to the equation 1, we have the following:

$$K_\mathrm{H} = \frac{U - U_0}{B(x = 0, I_\mathrm{M} = 250\,[\mathrm{mA}])} = \frac{2.617 - 2.496}{3.59 \times 10^{-3}} = 32.86\,[\mathrm{V/T}].$$

Thus we get the value desired for the solenoid as K_H. It might be used for later calculations.

	I_{M} [mA] ± ____ [mA]	U [mV] ± ____ [mV]
1	0	0.16
2	50	23.5
3	100	44.5
4	150	66.1
5	200	89.6
6	250	112.7
7	300	135.5
8	350	155.4
9	400	178.4
10	450	200.3
11	500	223.4

Table 3. Measurement data for the I_M vs. U relation.

3.2 Relation Between Output Voltage U and Magnetic Field B

For the second measurement, we obtain the following data table:

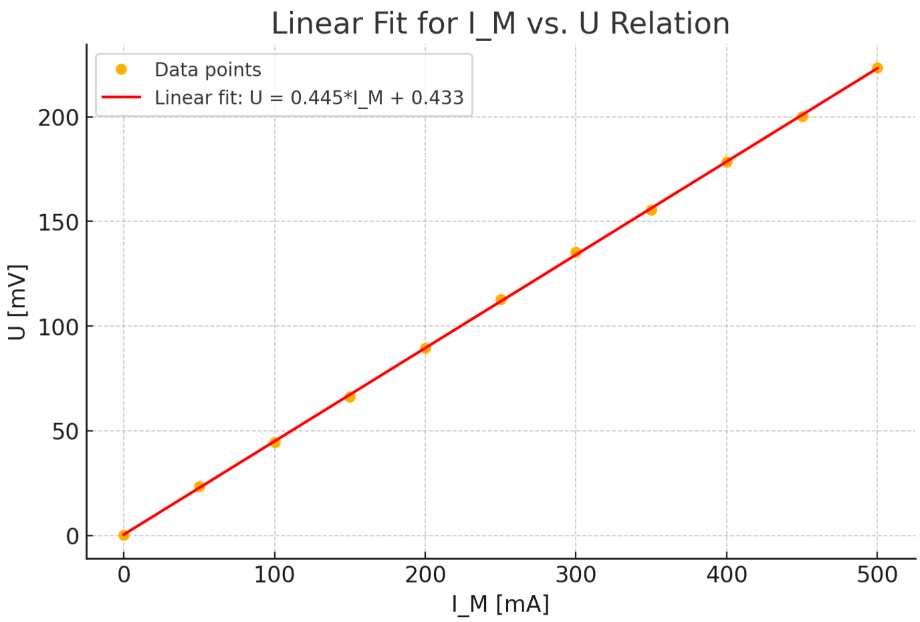
Here again, we notice that the theoretical value of the magnetic field is proportional to the magnitude of I_M when x is a fixed value, and since the measured U_out is the amplified output of U_H so we suppose that $U = kU_H$. Thus, we should derive a function given as below:

$$B(x = 0) = k \times \frac{U_H}{K_H} \tag{2}$$

We clearly see that B should be proportional to the Hall voltage U_H, and this is the relationship we wanted to discover in this part. To find the value of K_H, we can apply a linear fit to the data of I_M and U_H. Notice that we have the following equation:

$$B(x) = \mu_0 \frac{N}{L} I_{\mathrm{M}} \left(\frac{L + 2x}{2[D^2 + (L + 2x)^2]^{\frac{1}{2}}} + \frac{L - 2x}{2[D^2 + (L - 2x)^2]^{\frac{1}{2}}} \right) = C(x) I_{\mathrm{M}}$$

It is obvious that by moving the terms around, we will eventually have K_H as some multiple of slope of I_M v.s U_H The linear fit is shown below: We have



mentioned before that the magnitude of I_M is proportional to the magnitude of B at x=0, so we will have the following equation:

$$B(x=0) = \frac{I_M}{100} \times 1.4366 \times 10^{-3}$$

After transferring the original slope of I_M and U_H, we get the value of K_H to be around 33.01 [V/T].

3.3 Magnetic Field Distribution Inside the Solenoid

For the third measurement, we obtain the following data table:

Here we want to look at the distribution of magnetic field inside the tube, so we will use this equation for calculation:

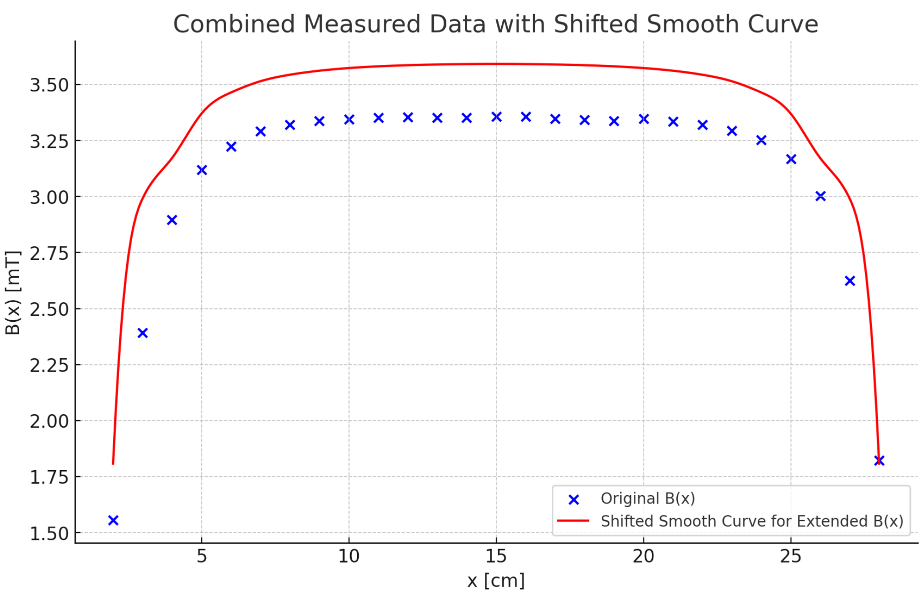
$$B(x) = \frac{U}{K_H} \tag{3}$$

In this equation, the value of K_H will be the value calculated in the section before. We wwill plot both the measured and theoratical values of magnetic field distribution in one single figure From the figure we see that the measured values are quite close to the theoratically desired value.

4 Conclusions and discussion

	x [cm] ± ____ [cm]	U [mV] ± ____ [mV]		x [cm] ± ____ [cm]	U [mV] ± ____ [mV]
1	2	51.35	27	28	60.17
2	3	79.99	28		
3	4	95.59	29		
4	5	102.96	30		
5	6	106.38	31		
6	7	108.62	32		
7	8	109.59	33		
8	9	110.13	34		
9	10	110.39	35		
10	11	110.66	36		
11	12	110.70	37		
12	13	110.65	38		
13	14	110.64	39		
14	15	110.83	40		
15	16	110.77	41		
16	17	110.51	42		
17	18	110.33	43		
18	19	110.13	44		
19	20	110.45	45		
20	21	110.12	46		
21	22	109.62	47		
22	23	108.73	48		
23	24	107.38	49		
24	25	104.58	50		
25	26	99.12	51		
26	27	86.63	52		

Table 4. Data for the U vs. x relation.



4.1 H-B Curve and desired values of data

In this experiment, we developed a rough idea about how to use integrated Hall probe and measured its sensitivity under different working voltages. We also measured two values for K_H using both direct calculation and linear fit, and compared them with each other. Also, we took the data needed to calculate the magnetic field distribution inside a solenoid.

From the results of the experiment, we can see that the sensitivity is decreasing as the working voltage increases. Also, the distribution of magnetic field inside a solenoid has the characteristic of having the maximum near the mid point, and gradually decreases along the axis with increasing rate. All these help us learn about the Hall probe better.

4.2 Discussion

There are still some errors with magnitude that can not be ignored, and we here briefly discuss some possible reasons. The most significant reason might be due to the errors generated by the equipments themselves. During the experiment, we noticed that the reading of some values such as the working voltage kept changing rapidly. This to some extent greatly affected the accurate reading of the working voltage. Other factors may also involve problems such as uneven probe etc. However, all the problems are minor issues and can be easily solved by small improvements to the experiment.

5 Works cited

Department of Physics, Shanghai Jiaotong University, Exercise 2 (The Hall Probe: Characteristics and Applications) - lab manual [rev. 3.9], 2024
Python Software Foundation. (2020). Python Language Reference, version 3.9. Available at http://www.python.org

All the figures displayed in the article (excluding the appendix) are given using Python 3.9.

A Datasheet

UM-SJTU Physics Laboratory Vp241
Data Sheet (Exercise 2)

Name: 王恺轩　　Student ID: 523370910219

Name: ______　　Student ID: ______

Group: 11　　Date: 30.10.2024

NOTICE. Please remember to show the data sheet to your instructor before leaving the laboratory. The data sheet will not be accepted if the data are recorded with a pencil or modified with a correction fluid/tape. If a mistake is made in recording a datum item, cancel the wrong value by drawing a fine line through it, record the correct value legibly, and ask your instructor to confirm the correction. Please remember to take a record of the precision of the instruments used. You are required to hand in the original data with your lab report, so please keep the data sheet properly.

U_S [V] ± ____ [V]	$U_0(I_M = 0)$ [V] ± ____ [V]	$U(I_M = 250\text{ mA})$ [V] ± ____ [V]
5	2.496	2.617

Table 1. Data for U_0 and U with $U_S = 5$ V.

	U_S [__] ± ____ [__]	U_0 [__] ± ____ [__]	U [__] ± ____ [__]
1			
2			
3			
4			
5			
6			
7			
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18			

Table 2. Data for U_0 and U with different U_S.

Instructor's signature: ______

1

	I_{M} [mA] ± ____ [mA]	U [mV] ± ____ [mV]
1	0	0.16
2	50	23.5
3	100	44.5
4	150	66.1
5	200	89.6
6	250	112.7
7	300	135.5
8	350	155.4
9	400	178.4
10	450	200.3
11	500	223.4

Table 3. Measurement data for the I_M vs. U relation.

Instructor's signature: ______________

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	x [cm] ± ____ [cm]	U [mV] ± ____ [mV]		x [cm] ± ____ [cm]	U [mV] ± ____ [mV]
1	2	51.35	27	28	60.17
2	3	79.99	28		
3	4	95.59	29		
4	5	102.96	30		
5	6	106.38	31		
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13	14	110.64	39		
14	15	110.83	40		
15	16	110.77	41		
16	17	110.51	42		
17	18	110.33	43		
18	19	110.13	44		
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25	26	99.12	51		
26	27	86.63	52		

Table 4. Data for the U vs. x relation.

Instructor's signature: ____________

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