UM-SJTU Joint Institute
Physics Laboratory
(Vp241)

Laboratory Report

Exercise 2
The Hall Probe:
Characteristics and Applications

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1 Abstract

In this experiment, we will have the basc understand of Hall Effect. We find proper working voltage 5V through the mearsurement of K_H, which equals 33V/T±3V/T. We verify the fact that Hall voltage is proportional to the magnetic field, while the slope represents the sensitivity of the center of an integrated Hall probe K_H, 31.7±0.7V/T, with -3.94% relative error to K_H under 5V working voltage and 1.44% relative error with the theoretical value. Also, we measure the magnetic field distribution along the axis of the solenoid and found its distribution similar to the corresponding theoretical curve which is higher and more stable in the center and symmetric about x=0cm.

2 Introduction

2.1 Motivation

The Hall effect has large application in the measurement of many important physics quantities. So, it's important for an engineer to study the basic knowledgement of the Hall effect and understand its usage. For example, the Hall devices can monitor and measure the variation of operating parameters of various parts of the automobile by detecting magnetic field change and converting it into electrical signal output. Position, displacement, Angle, angular velocity, rotational speed can be quadratic transformation to further detect mass, liquid level, flow rate to improve the safety and comfort level of an automobile.[2] And it also has many other useful applications to ensure the life security and enhance life quality.

2.2 Theoratical Background

2.2.1 Hall Effect

When a conducting sheet (matal, an semiconductor) is placed in a magnetic field which direction is perpendicular to the plane of the sheet while an electric current I parallelly passes through the sheet as shown in Fig.1, an electric potential difference may appear between the sides a and b of the sheet. This effect is called the Hall effect and the potential difference is known as the Hall voltage U_H.

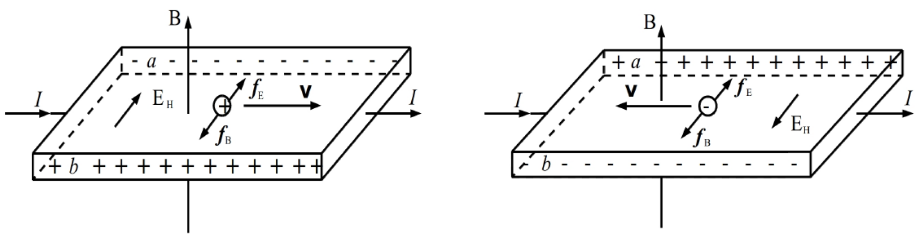

Figure 1: the illustration of the Hall effect [1]

The Hall effect caused by the Lorentz force. When charges moving in a magnetic field, the Lorentz force F_B make the moving charges to deflect and accumulate on one side of the sheet, which will also increases the transverse electric filed E_H(the Hall field). This field will in turn produce an electric force F_E which acts on moving charges with opposite direction to F_B. When F_E and F_B reach in their balance state, the charges no longer deflect and U_H stabilizes. When B is upward and I is to the right. If the sheet carries positive charge, then the voltage of a is lower than b. We can analyze the sign of U_H and determine the type of the charge carriers in semiconductors.

When the B is somehow weak, the Hall voltage can be presented as:

$$U_H = R_H \frac{IB}{d} = KIB \quad [1] \tag{1}$$

Where R_H is the Hall coefficient and $K = \frac{R_H}{d} = \frac{K_H}{I}$ [1], where K_H is the sensitivity of the Hall element.

2.2.2 Integrated Hall Probe

When K_H and I are fixed, B can be found by measuring the Hall voltage with a Hall probe. Amplifer should be used to magnify the small Hall voltage.

The Hall probe and the circuit are designed using silicon. A device called integrated Hall probe is a single device combining both the Hall probe and the electric circuit. "The integrated Hall probe SS495A consists of a Hall sensor, an amplifier, and a voltage compensator(Fig.2)[1]." Regardless of residual voltage, we can directly read the output voltage U. The relation between U and the magnitude of B is:

$$B = \frac{U - U_0}{K_H} \quad [1] \tag{2}$$

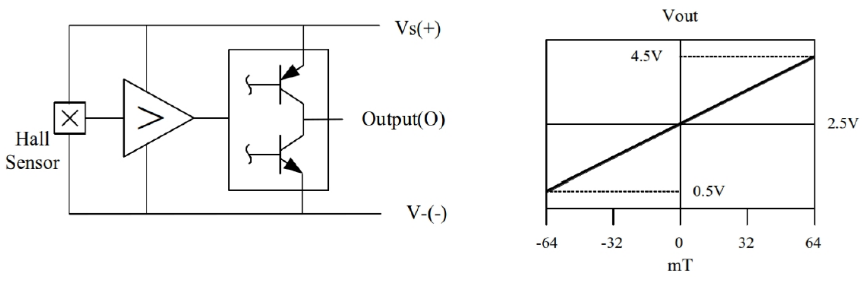

Figure 2: The integrated Hall probe SS495A (right) The relation between the output voltage U and B (left) [1]

2.2.3 Magnetic Field Distribution Inside a Solenoid

On the axis of a single layer solenoid, the magnetic field distribution can be represented as

$$B(x) = \mu_0 \frac{N}{L} I_M \left(\frac{L + 2x}{2[D^2 + (L + 2x)^2]^{\frac{1}{2}}} + \frac{L - 2x}{2[D + (L - 2x)^2]^{\frac{1}{2}}} \right) = C(x) I_M \quad [1] \tag{3}$$

where N is the turns number of the solenoid, I_M is the passing through current, L is the length, and D is the diameter of solenoid. "The magnetic permeability of vacuum is $\mu_0 = 4\pi \times 10^{-7} H/m$." [1]

In this lab, the solenoid has ten layers, and B(x) for each layer can be presented by the equation above. Then the net magnetic on the axis of the solenoid can be calculated by integrating B of all layers. The theoretical value are presented in Table 1.

x [cm]	B [mT]	x [cm]	B [mT]
±0.0	1.4366	±8.0	1.4057
±1.0	1.4363	±9.0	1.3856
±2.0	1.4356	±10.0	1.3478
±3.0	1.4343	±11.0	1.2685
±4.0	1.4323	±11.5	1.1963
±5.0	1.4292	±12.0	1.0863
±6.0	1.4245	±12.5	0.9261
±7.0	1.4173	±13.0	0.7233

Table 1: Theoretical value of the magnetic field inside the solenoid. [1]

3 Discription of Experiment

3.1 Apparatus

Fig.3 shows the "integrated Hall probe SS495A, a solenoid, a power supply, a voltmeter, a DC voltage divider, and a set of connecting wires." [1]

Figure 3: Experimental setup [1]

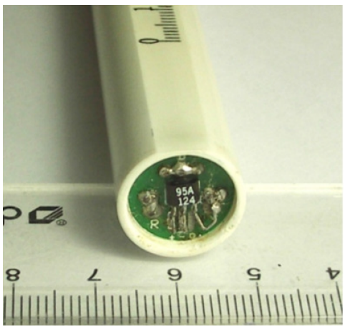

Figure 4: Integrated Hall probe SS495A [1]

3.2 Device Information

The information of each measurement device is shown in Table 2.

Apparatus	Range	Minimum scale of value	Maximum uncertainty
Voltage source	/	0.01V	0.5%
Voltimeter	/	0.001V or 0.0001V	0.05%+6×10^{-3} or 6×10^{-4}
Current Source	/	0.01A	2%
Graduated Ruler	0∼30cm	0.1cm	±0.05cm

Table 2: Information of Each Measurement Device

3.3 Measurement Procedure

3.3.1 Relation Between Sensitivity K_H and Working Voltage U_S

First, place the integrated Hall probe, make the reading exactly 15cm. Open all the source and set the voltage source to 5V. Then measure the output voltage both when current source equal to 0mA and 250mA. Take the theoretical value of $B(x = 0)$ from Equation 3 and calculate K_H by using Equation 2. Then, change the voltage source from 2.8V to 10V, repeat the output voltage test above 18 times. "Calculate K_H/U_S and plot the curve K_H/U_S vs. U_S." [1]

3.3.2 Relation between Output Voltage U and Magnetic Field B

Close all the source and voltmeter, use an voltage divider to amplify the output voltage when B=0, voltage source equal to 5V. By switching the button, change the output voltage to approximately 0V. Place the integrated Hall probe, make the reading exactly 15cm. Change the current source from 0mA to 500mA by 11 times. Record the output voltage. Find the theoratical relation of B and U_H. Then "plot the curve U vs. B and find the sensitivity K_H by a linear fit (use a computer)". Then analyze the output.

3.3.3 Magnetic Field Distribution Inside the Solenoid

Make the circuit still, change the current source to 250mA. Change the position of hall probe and record the certain position with its corresponding output voltage. Then plot B by the supporting table of previous part. Plot the theoretical and the experimental curve in one figure and analyze the output.

3.3.4 Caution

We did followed things to make the result more accurate.

Turn off all the sources after one sub experimentand wait until the saturate state for next usage; let the electronic device leave as far as we can from the probe to reduce some disturbance; wait for a while after changing the magnitude of the sources and only record the stable readouts.

4 Result

4.1 Relation Between Sensitivity K_H and Working Voltage U_S

4.1.1 Calculation of K_H

U_S[V]±0.5%[V]	5.00±0.03
$U_0(I_M{=}0)$[V]±0.05%+6×10^{-3}[V]	2.511±0.007
$U_S(I_M{=}250\text{mA})$[V]±0.05%+6×10^{-3}[V]	2.630±0.007

Table 3: Data for U_0 and U with U_S=5V

$$u_{U_S} = U_S \times 0.5\% = 5 \times 0.005 = 0.03V$$

$$u_{U_0} = U_0 \times 0.05\% + 6 \times 10^{-3} = 0.007V$$

$$u_{U_S} = U_S \times 0.05\% + 6 \times 10^{-3} = 0.007V$$

From Table 1 we get when x=0cm, $I_M = 0.1A$, B_0=1.4366mT
Now I=250mA. Since B is propotional to I, we can calculate B:

$$B = B_0 \times \frac{I}{I_M} = 1.4366 \times 10^{-3} \times \frac{250 \times 10^{-3}}{0.1} = 3.5915 \times 10^{-3}T$$

Using Equation 2, we can calculate K_H:

$$K_H = \frac{U - U_0}{B} = \frac{2.630 - 2.511}{3.5915 \times 10^{-3}} = 33V/T \pm 3V/T$$

The uncertainty is calculated as follow

$$\frac{\partial K_H}{\partial U} = \frac{1}{B} = \frac{1}{3.5915 \times 10^{-3}} = 278.44$$

$$\frac{\partial K_H}{\partial U_0} = -\frac{1}{B} = -\frac{1}{3.5915 \times 10^{-3}} = -278.44$$

$$u_{K_H} = \sqrt{\left(\frac{\partial K_H}{\partial U}\right)^2 u_U^2 + \left(\frac{\partial K_H}{\partial U_0}\right)^2 u_{U_0}^2} = \sqrt{(278.44)^2 \times 0.007^2 + (-278.44)^2 \times 0.007^2} = 3 \text{ V/T}$$

Take 31.25V/T±1.25V marked on the apparatus as the theoretical value for K_H:

$$u_{K_H} = \frac{33 - 31.25}{31.25} = 5.6\%$$

4.1.2 Measurement of U_0 and U under different U_S

U_s(V)	U_0(V)	U(V)	u_{U_S}	u_{U_0}	u_U
2.80	1.4040	1.4702	0.014	0.0013	0.0013
3.20	1.6051	1.6815	0.016	0.0014	0.0014
3.60	1.8109	1.8977	0.018	0.0015	0.0015
4.00	2.0087	2.1050	0.02	0.0016	0.0017
4.40	2.211	2.317	0.02	0.007	0.007
4.88	2.447	2.563	0.02	0.007	0.007
5.33	2.670	2.796	0.03	0.007	0.007
5.73	2.878	3.013	0.03	0.007	0.008
6.12	3.066	3.206	0.03	0.008	0.008
6.50	3.259	3.406	0.03	0.008	0.008
6.95	3.478	3.633	0.03	0.008	0.008
7.48	3.738	3.900	0.04	0.008	0.008
7.97	3.981	4.148	0.04	0.008	0.008
8.40	4.193	4.364	0.04	0.008	0.008
8.83	4.406	4.581	0.04	0.008	0.008
9.19	4.579	4.756	0.05	0.008	0.008
9.66	4.809	4.989	0.05	0.008	0.008
9.96	4.959	5.140	0.05	0.008	0.009

Table 4: Data for U_0 and U with different U_S

We change different value of U_S, U_0 is measured when I_M=0mA, U is measured when I_M=250mA. The measured data are recorded in Table 4

4.1.3 Relation between K_H and U_S

Then we calculate $\frac{K_H}{U_S} = \frac{U-U_0}{BU_S}$. The values of different U_S and their uncertainties are shown in Table 5. Take the 1$^{\text{st}}$ row of data for example:

$$u_{K_H} = \sqrt{\left(\frac{\partial K_H}{\partial U}u_U\right)^2 + \left(\frac{\partial K_H}{\partial U_0}u_{U_0}\right)^2} = \sqrt{\left(\frac{u_U}{B}\right)^2 + \left(\frac{-u_{U_0}}{B}\right)^2}$$

$$\frac{\partial \frac{K_H}{U_S}}{\partial \mathrm{U}} = \frac{1}{BU_S} \quad \frac{\partial \frac{K_H}{U_S}}{\partial U_0} = \frac{-1}{BU_S} \quad \frac{\partial \frac{K_H}{U_S}}{\partial U_S} = \frac{U_0-U}{BU_S^2}$$

$$\begin{aligned} u_{\frac{K_H}{U_S}} &= \sqrt{\left(\frac{\partial \frac{K_H}{U_S}}{\partial \mathrm{U}}\right)^2 u_U^2 + \left(\frac{\partial \frac{K_H}{U_S}}{\partial U_0}\right)^2 u_{U_0}^2 + \left(\frac{\partial \frac{K_H}{U_S}}{\partial U_S}\right)^2 u_{U_S}^2} \\ &= \sqrt{\left(\frac{1}{BU_S}\right)^2 u_U^2 + \left(\frac{-1}{BU_S}\right)^2 u_{U_0}^2 + \left(\frac{U_0-U}{BU_S^2}\right)^2 u_{U_S}^2} \end{aligned}$$

$$K_H = \frac{U-U_0}{B} = \frac{1.4702-1.4040}{0.00359} = 18.4V/T \qquad \frac{K_H}{U_S} = \frac{18.4}{2.80} = 6.58T^{-1}$$

$$u_{K_H} = \sqrt{(\frac{0.0013}{3.5915\times10^{-3}})^2 + (\frac{-0.0013}{3.5915\times10^{-3}})^2} = 0.5V/T$$

$$u_{\frac{K_H}{U_S}} = \sqrt{\left(\frac{0.0013}{3.5915\times10^{-3}\times2.80}\right)^2 + \left(\frac{-0.0013}{3.5915\times10^{-3}\times2.80}\right)^2 + \left(\frac{1.4040-1.4702}{3.5915\times10^{-3}\times2.80^2}\right)^2 \times 0.014^2}$$
$$= 0.19T^{-1}$$

U_s(V)	K_H[V/T]	$\frac{K_H}{U_S}(T^{-1})$	u_{U_S}(V)	u_{K_H}[V/T]	$u_{\frac{K_H}{U_S}}(T^{-1})$
2.800	18.4	6.58	0.014	0.5	0.19
3.200	21.3	6.65	0.016	0.5	0.18
3.600	24.2	6.71	0.018	0.5	0.17
4.00	26.8	6.7	0.02	0.6	0.16
4.40	30	6.7	0.02	3	0.6
4.88	32	6.6	0.02	3	0.6
5.33	35	6.6	0.03	3	0.5
5.73	38	6.6	0.03	3	0.5
6.12	39	6.4	0.03	3	0.5
6.50	41	6.3	0.03	3	0.5
6.95	43	6.2	0.03	3	0.4
7.48	45	6.0	0.04	3	0.4
7.97	46	5.8	0.04	3	0.4
8.40	48	5.7	0.04	3	0.4
8.83	49	5.5	0.04	3	0.4
9.19	49	5.4	0.05	3	0.4
9.66	50	5.2	0.05	3	0.3
9.96	50	5.1	0.05	3	0.3

Table 5: Us and KH and KH/Us

Then we plot the dots, shown in Fig.5

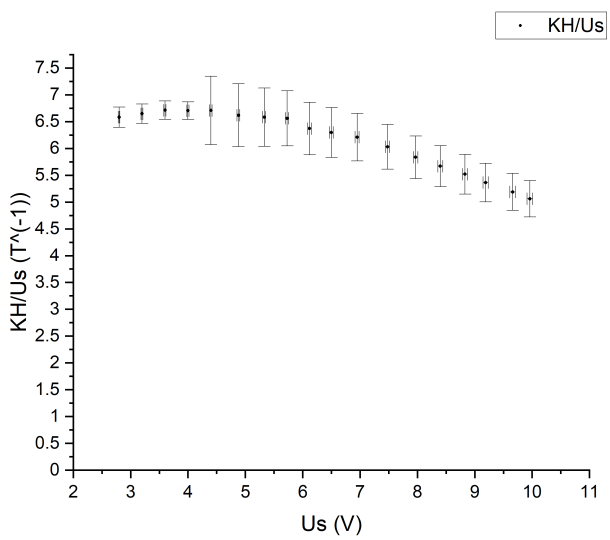

Figure 5: Plot of KH/Us and Us

4.2 Relation between Output Voltage U and Magnetic Field B

4.2.1 Measurement of I_M and U

We measure output voltage U under different I_M, and record the results in Table 6:

I_M[A]	U_{I_M}[A]	U[V]	u_U[V]
0.000	0	0.0001	0.0006
0.050	0.001	0.0279	0.0006
0.100	0.002	0.0519	0.0006
0.150	0.003	0.0751	0.0006
0.200	0.004	0.0982	0.0006
0.250	0.005	0.1170	0.0007
0.300	0.006	0.1426	0.0007
0.350	0.007	0.1648	0.0007
0.400	0.008	0.1857	0.0007
0.450	0.009	0.2098	0.0007
0.50	0.01	0.2299	0.0007

Table 6: Measurement data for the I_M vs. U relation

From Table 1 we get when x = 0 cm, $I_M = 0.1$ A, $B_0 = 1.4366$mT Now I = I_M. since B is proportional to I, we calculate B. Take $I_M = 0.05$ A for example:

$$B = B_0 \times \frac{I_M}{I_0} = 1.4366 \times 10^{-3} \times \frac{0.05}{0.1} = 0.00072 \pm 0.00001T$$

$$u_B = 1.4366 \times 10^{-2} \times U_{I_M} = 1.4366 \times 10^{-2} \times 0.001 = 0.00001$$

We arrange the data and the uncertainty in Table 7:

U[V]	u_U[V]	B[T]	u_B[T]
0.0001	0.0006	0.00000	0.00000
0.0279	0.0006	0.00072	0.00001
0.0519	0.0006	0.00144	0.00003
0.0751	0.0006	0.00215	0.00004
0.0982	0.0006	0.00287	0.00006
0.1170	0.0007	0.00359	0.00007
0.1426	0.0007	0.00431	0.00009
0.1648	0.0007	0.00503	0.00010
0.1857	0.0007	0.00575	0.00011
0.2098	0.0007	0.00646	0.00013
0.2299	0.0007	0.00718	0.00014

Table 7: Relation of U and B

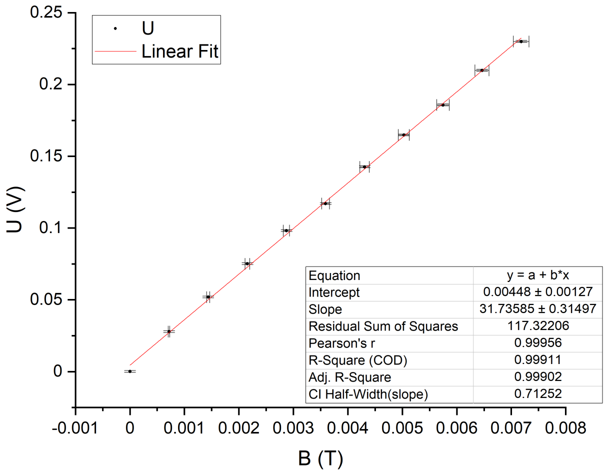

Figure 6: Linear Fit of U and B

Then we apply linear fit to U and B, shown in Fig.6

The slope of the line is 31.7±0.7 V/T, which shows the magnitude of K_H. The relative error with the value calculated in 4.1 is:

$$u_{r,K_H,1} = \frac{31.7 - 33}{33} = -3.94\%$$

We take K_H=31.25±1.25V marked on the apparatus as the theoretical value, the relative error compared with the theoretical value is

$$u_{r,K_H,2} = \frac{31.7 - 31.25}{31.25} = 1.44\%$$

4.3 Magnetic Field Distribution Inside the Solenoid

We measured the magnetic field inside the Solenoid along the axis at different distance. The experimental data is shown in Table 8.

Based on the value of U, we calculate the corresponding B by the equation:

$B = \frac{U}{K_H}$ For example, $B = \frac{0.0114}{31.7} = 0.00036T$

$$B = \frac{U}{K_H}$$
$$\frac{\partial B}{\partial U} = \frac{1}{K_H} = \frac{1}{31.7} = 0.0315$$
$$\frac{\partial B}{\partial K_H} = -\frac{U}{K_H^2}$$
$$u_B = \sqrt{\left(\frac{\partial B}{\partial U}\right)^2 u_U^2 + \left(\frac{\partial B}{\partial K_H}\right)^2 u_{K_H}^2} = \sqrt{(0.0315)^2 u_U^2 + \left(-\frac{U}{K_H^2}\right)^2 u_{K_H}^2}$$

Take the 1st row of data for example:

$$u_B = \sqrt{(0.0315)^2 \times 0.0006^2 + \left(-\frac{0.0114}{31.7^2}\right)^2 \times 0.7^2} = 0.00002T$$

(x-15)[cm]±0.05[cm]	U[V]	u_U[V]	B[T]	u_B[T]
-15.00	0.0114	0.0006	0.00036	0.00002
-14.70	0.0131	0.0006	0.00041	0.00002
-14.40	0.0152	0.0006	0.00048	0.00002
-14.10	0.0182	0.0006	0.00057	0.00002
-13.90	0.0204	0.0006	0.00064	0.00002
-13.60	0.0247	0.0006	0.00078	0.00002
-13.30	0.0312	0.0006	0.00098	0.00002
-13.00	0.0381	0.0006	0.00120	0.00002
-12.70	0.0464	0.0006	0.00146	0.00002
-12.40	0.0565	0.0006	0.00178	0.00002
-12.10	0.0672	0.0006	0.00212	0.00002
-11.80	0.0756	0.0006	0.00238	0.00002
-11.50	0.0845	0.0006	0.00266	0.00002
-11.00	0.0947	0.0006	0.00299	0.00002
-10.00	0.1064	0.0007	0.00336	0.00002
-9.50	0.1095	0.0007	0.00345	0.00002
-9.00	0.1114	0.0007	0.00352	0.00002
-8.50	0.1128	0.0007	0.00356	0.00002
-8.00	0.1136	0.0007	0.00358	0.00002
-7.00	0.1150	0.0007	0.00363	0.00002
-6.00	0.1158	0.0007	0.00365	0.00002
-5.00	0.1163	0.0007	0.00367	0.00002
-4.00	0.1166	0.0007	0.00368	0.00002
-3.00	0.1168	0.0007	0.00369	0.00002
-1.80	0.1168	0.0007	0.00368	0.00002
-0.50	0.1167	0.0007	0.00368	0.00002
0.00	0.1167	0.0007	0.00368	0.00002
1.00	0.1167	0.0007	0.00368	0.00002
2.00	0.1174	0.0007	0.00370	0.00002
3.00	0.1175	0.0007	0.00371	0.00002
4.00	0.1172	0.0007	0.00370	0.00002
5.00	0.1166	0.0007	0.00368	0.00002
6.00	0.1162	0.0007	0.00367	0.00002
7.00	0.1158	0.0007	0.00365	0.00002
8.00	0.1153	0.0007	0.00364	0.00002
9.00	0.1140	0.0007	0.00360	0.00002
10.00	0.1120	0.0007	0.00353	0.00002
11.00	0.1083	0.0007	0.00342	0.00002
11.50	0.1048	0.0007	0.00331	0.00002
12.00	0.0998	0.0006	0.00315	0.00002
12.30	0.0959	0.0006	0.00303	0.00002
12.60	0.0902	0.0006	0.00284	0.00002
12.90	0.0832	0.0006	0.00262	0.00002
13.20	0.0753	0.0006	0.00237	0.00002

13.50	0.0652	0.0006	0.00206	0.00002
13.80	0.0547	0.0006	0.00172	0.00002
14.00	0.0485	0.0006	0.00153	0.00002
14.20	0.0421	0.0006	0.00133	0.00002
14.40	0.0364	0.0006	0.00115	0.00002
14.60	0.0317	0.0006	0.00100	0.00002
14.80	0.0274	0.0006	0.00086	0.00002
15.00	0.0240	0.0006	0.00076	0.00002

Table 8: U and B with different x

We then calculate the theoretical value of B using the data from Table1:

$$B_{theo} = B_{std} \times \frac{I}{I_M}$$

The x we take is the scale on the ruler, but the true x should be the distance from the center of the solenoid. Therefore, when we plot the figure, the horizontal coordinate should be x-15cm.

From the figure, we could see that two plots are very closed to each other. This shows that the experimental value verify the theoretical value.

x[cm]	B_{std}[mT]	B_{theo}[T]	x[cm]	B_{std}[mT]	B_{theo}[T]
-13	0.7233	0.0018	1	1.4363	0.0036
-12.5	0.9261	0.0023	2	1.4356	0.0036
-12	1.0863	0.0027	3	1.4343	0.0036
-11.5	1.1963	0.0030	4	1.4323	0.0036
-11	1.2685	0.0032	5	1.4292	0.0036
-10	1.3478	0.0034	6	1.4245	0.0036
-9	1.3856	0.0035	7	1.4173	0.0035
-8	1.4057	0.0035	8	1.4057	0.0035
-7	1.4173	0.0035	9	1.3856	0.0035
-6	1.4245	0.0036	10	1.3478	0.0034
-5	1.4292	0.0036	11	1.2685	0.0032
-4	1.4323	0.0036	11.5	1.1963	0.0030
-3	1.4343	0.0036	12	1.0863	0.0027
-2	1.4356	0.0036	12.5	0.9261	0.0023
-1	1.4363	0.0036	13	0.7233	0.0018
0	1.4366	0.0036			

Table 9: Theoretical value of B

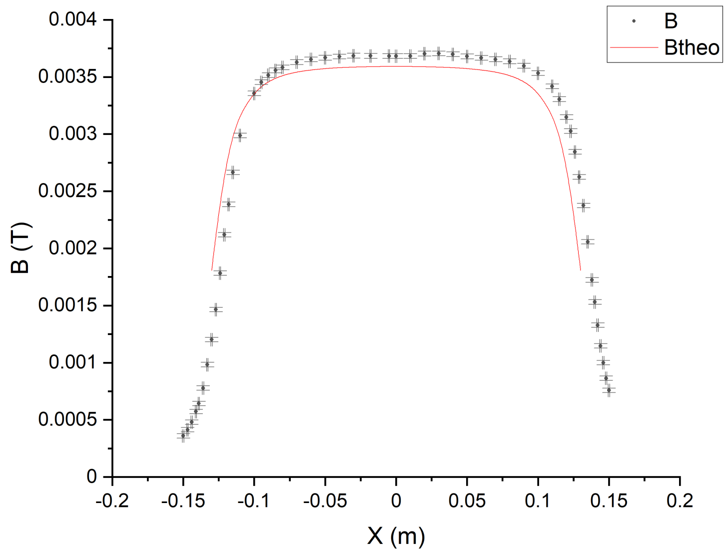

Figure 7: Bexp and Btheo with x

5 Conclusions and Discussions

In this lab, we can achieve the following goals:

- We have a preliminary understand of the Hall effect's principle and applications by making three experiments with a Hall probe.
- We measured the sensitivity K_H based on the experimental data we got both through formula or fitting. Also, we compare it with the value printed on the Hall probe.
- Make linear fit to Hall voltage U_H and magnetic field B. Find their propotional relationship.
- We measure the solenoid's magnetic field distribution along the axis. Then we compare the output with the corresponding theoretical curve which was calculated through the data given.

In 4.1.1, when Us=5V, we measured $K_H* = 33 \pm 3$V/T.

In 4.1.3, we plot $\frac{K_H}{U_S}$ vs. U_S and found that $\frac{K_H}{U_S}$ almost remains the same although U_S is changing. This shows that K_H is proportional to U_S. However, from the plot we can see $\frac{K_H}{U_S}$ has an incline to decrease when U_S is increasing, and this error will be analyzed in next part.

In 4.2, we measured the output voltage U with different I_M. Since I_M is proportional to B, we get the relation between U and B. We find that U is proportional to B. The slope indicates that $K_H = 31.7 \pm 0.7$V/T. We take $K_H = 31.25\pm$ 1.25V marked on the apparatus as the theoretical value. Also, in 4.1.1 we measured $K_H* = 33.13 \pm 3V/T$. Therefore, K_H from linear fit has a relative error of -1.44% compared with K_H* and has a relative error of 3.94% compared with the theoretical value. In 4.3, we measured the magnetic field B at different x along the axis of the solenoid. From Table 1 we obtain the theoretical distribution of the magnetic field, and we plot them in Fig.7 and compare them. Their shapes coincide but there is a slight position deviation of the two shape, but the uncertainty is fine due to the uncertainty of the apparatus.

The uncertainty may caused by the following reasons.

- In 4.1, the reason why $\frac{K_H}{U_S}$ has an incline to decrease when U_S is increasing might be the wrong experimental procedure. I first set $I_M = 0A$, change the Us from 2.8 to 10V, finish this round of measurement and then set $I_M = 250mA$, set the Us equal to the round1 values and then did the second round of measurement. Therefore, with the same Us, U0 and U are measured under a large time interval, which results in deviations in these two factors.
- Instability of displaying of U_0 and U; In procedure 4.2.1, U_0 is very hard to be adjusted to completely 0.
- The Hall probe might move its position when measuring
- Rise of temperature causing R to change.
- The surrounding students' solenoid may cast inteference on the measured quantities.

Since we have to change U_S and I_M by switching the channel, it's hard to obtain the value we want. I suggest the source value can be set digitally and students should be seperate apart.

6 Reference

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[2] Kang, Shuai. "Application of Hall Effect in Semiconductor Material." Advanced Materials Research, vol. 986-987, 2014, pp. 21–24., doi:10.4028/www.scientific.net/amr.986-987.21.

APPENDIX

A Data Sheet