Hall Effect in Semiconductors

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Contents

1 AIM

To measure the Hall coefficient in both P and N type semiconductors.

2 INTRODUCTION

The Hall effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. It was discovered by Edwin Hall in 1879.

The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current.

3 APPARATUS

Two solenoids, Constant current supply, Four probe, Digital gauss meter, Hall effect apparatus (which consist of Constant Current Generator (CCG), digital milli voltmeter and Hall probe).

4 DIAGRAM

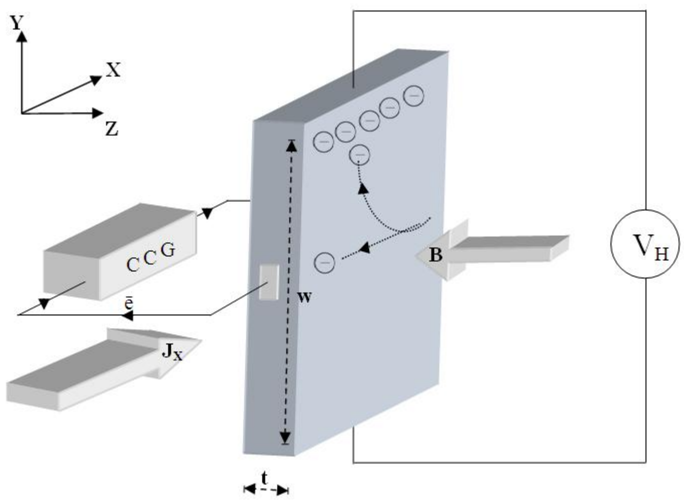
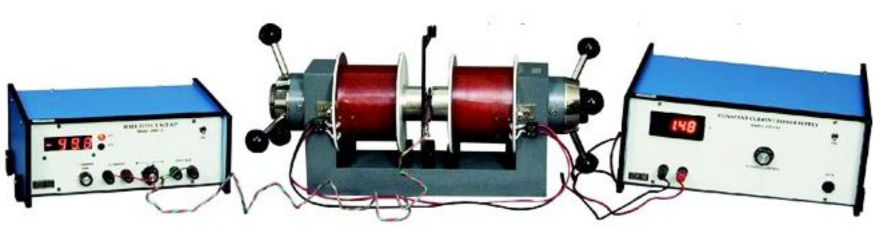


Fig.1 Schematic representation of Hall Effect in a conductor. CCG Constant Current Generator, JX current density
electron, B applied magnetic field
t thickness, w width
VH Hall voltage



full setup.HALL EFFECT

5 THEORY

If a current carrying conductor placed in a perpendicular magnetic field, a potential difference will generate in the conductor which is perpendicular to both magnetic field and current. This phenomenon is called Hall Effect. In solid state physics, Hall effect is an important tool to characterize the materials especially semiconductors. It directly determines both the sign and density of charge carriers in a given sample.

Consider a rectangular conductor of thickness t kept in XY plane. An electric field is applied in X-direction using Constant Current Generator (CCG), so that current I flow through the sample. If w is the width of the sample and t is the thickness. There for current density is given by

Jx=I/wt (1)

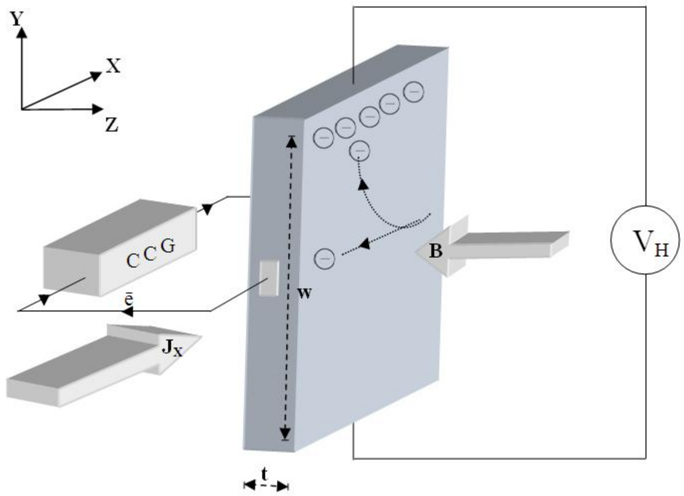


Fig.1 Schematic representation of Hall Effect in a conductor.
CCG Constant Current Generator, JX current density
electron, B applied magnetic field
t thickness, w width
VH Hall voltage

If the magnetic field is applied along negative z-axis, the Lorentz force moves the charge carriers (say electrons) toward the y-direction. This results in accumulation of charge carriers at the top edge of the sample. This set up a transverse electric field Ey in the sample. This develop a potential difference along y-axis is known as Hall voltage VH and this effect is called Hall Effect.

A current is made to flow through the sample material and the voltage difference between its top and bottom is measured using a volt-meter. When the applied magnetic field B=0,the voltage difference will be zero. We know that a current flows in response to an applied electric field with its direction as conventional and it is either due to the flow of holes in the direction of current or the movement of electrons backward. In both cases, under the application of magnetic field the magnetic Lorentz force,

$$F_m = q(vxB)$$

causes the carriers to curve upwards. Since the charges cannot escape from the material, a vertical charge imbalance builds up. This charge imbalance produces an electric field which counteracts with the magnetic force and a steady state is established. The vertical electric field can be measured as a transverse voltage difference using a voltmeter. In steady state condition, the magnetic force is balanced by the electric force. Mathematically we can express it as

eE=evB (2)

Where 'e' the electric charge, 'E' the hall electric field developed, 'B' the applied magnetic field and 'v' is the drift velocity of charge carriers. And the current 'I' can be expressed as,

I=neAv (3)

Where 'n' is the number density of electrons in the conductor of length l ,breadth 'w' and thickness 't'. Using (1) and (2) the Hall voltage VH can be written as,

$$V_H = Ew = vBw = IB/net$$
$$V_H = R_H(IB/T)\ (4)$$

by rearranging eq(4) we get

$$R_H = V_H T/IB\ (5)$$

Where RH is called the Hall coefficient.

RH=1/ne (6)

6 MEASUREMENTS AND CALCULATION

6.1 CALIBRATION

magnetic field is noted corresponding to supplied current which generate required magnetic field.

Sl.No.	I(in amp)	B(in gauss)	B(in tesla)
1	0	0	0
2	0.50	21	0.0023
3	1.00	43	0.0043
4	1.5	66	0.0066
5	2.0	87	0.0087
6	2.5	109	0.0109
7	3.00	134	0.0134
8	3.5	152	0.0152
9	4.0	178	0.0178
10	4.14	183	0.0183

6.2 For n-type semiconductor:

6.2.1 Magnetic field being constant at 0.0087 tesla

When Hall current is along+X direction

when all connections in direct bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	1.0	2.3
2	2.04	4.9
3	3.02	7.5
4	4.0	10.0
5	5.01	12.8
6	6.0	15.6
7	7.0	18.3
8	8.02	21.1
9	10.16	26.3
10	12.04	31.1
11	14.27	37.8
12	16.15	41.4
13	18.04	43.7

6.3 For n-type semiconductor:

6.3.1 Magnetic field being constant at 0.0087 tesla

When Hall current is along-X direction

And when all connections in reverse bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	2.07	-7.5
2	4.05	-14.5
3	6.02	-21.4
4	8.09	-28.4
5	10	-34.6
6	12	-40.9
7	14.17	-48
8	16.07	-53.4
9	18.03	-59.2

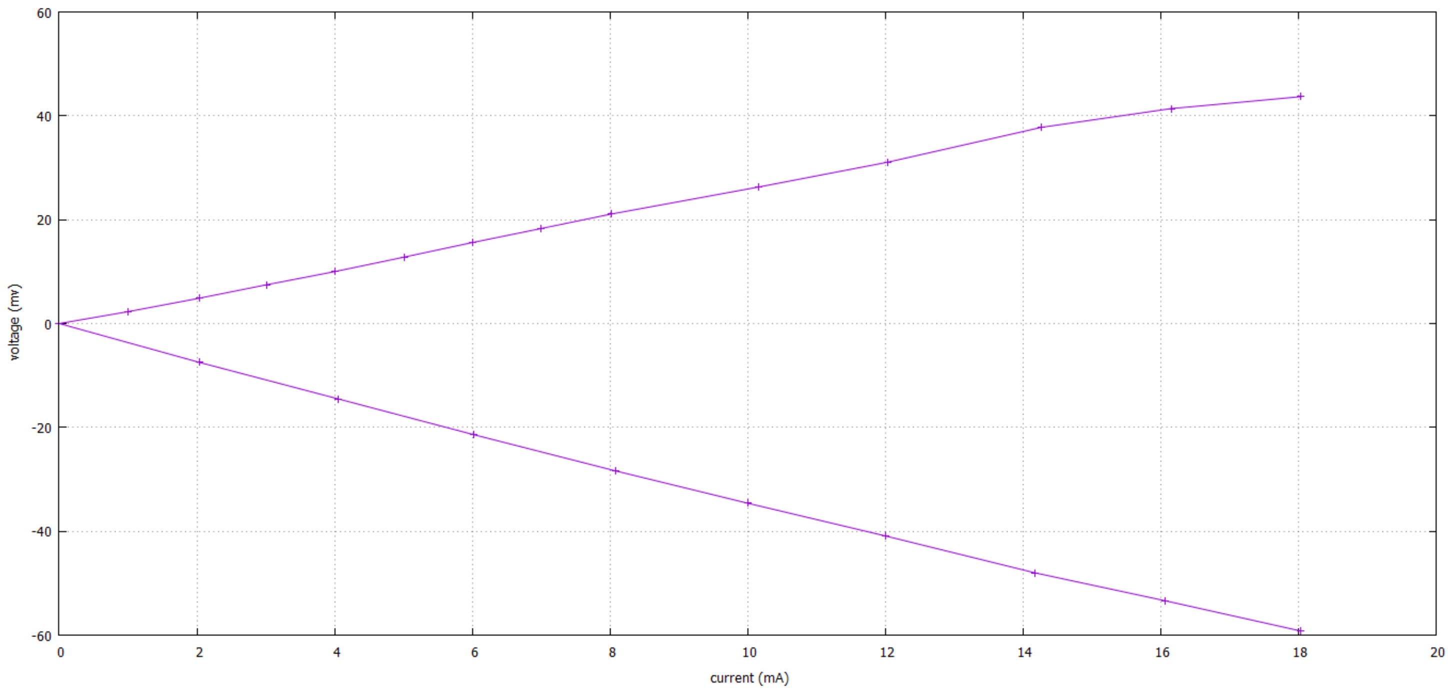


Fig:1 graph for both reverse and direct bias at magnetic field 0.0087 tesla in n-type semiconductor

Calculation

$$R_H = |(slope)|d/B$$

slope of hall voltage and hall current =2.709mV/mA

$$R_H = \frac{2.709\times5\times10^{-4}}{0.0087}\frac{m^3}{C} = 0.1557\frac{m^3}{C}$$

6.4 For n-type semiconductor:

6.4.1 Magnetic field being constant at 0.0180 tesla

When Hall current is along+X direction

And when all connections in reverse bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	1.98	10.2
2	4.00	21.0
3	6.02	31.8
4	8.19	43.6
5	10	53.3
6	12.08	64.4
7	14.03	74.5
8	16.05	84.5
9	18.20	94.6

6.5 For n-type semiconductor:

6.5.1 Magnetic field being constant at 0.0180tesla

When Hall current is along-X direction

And when all connections in reverse bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	2.04	-13.03
2	4.02	-26.40
3	6.46	-39.6
4	8.06	-51.9
5	10.30	-66.0
6	12.07	-76.8
7	14.08	-88.7
8	16.08	-100.2
9	18.07	-111

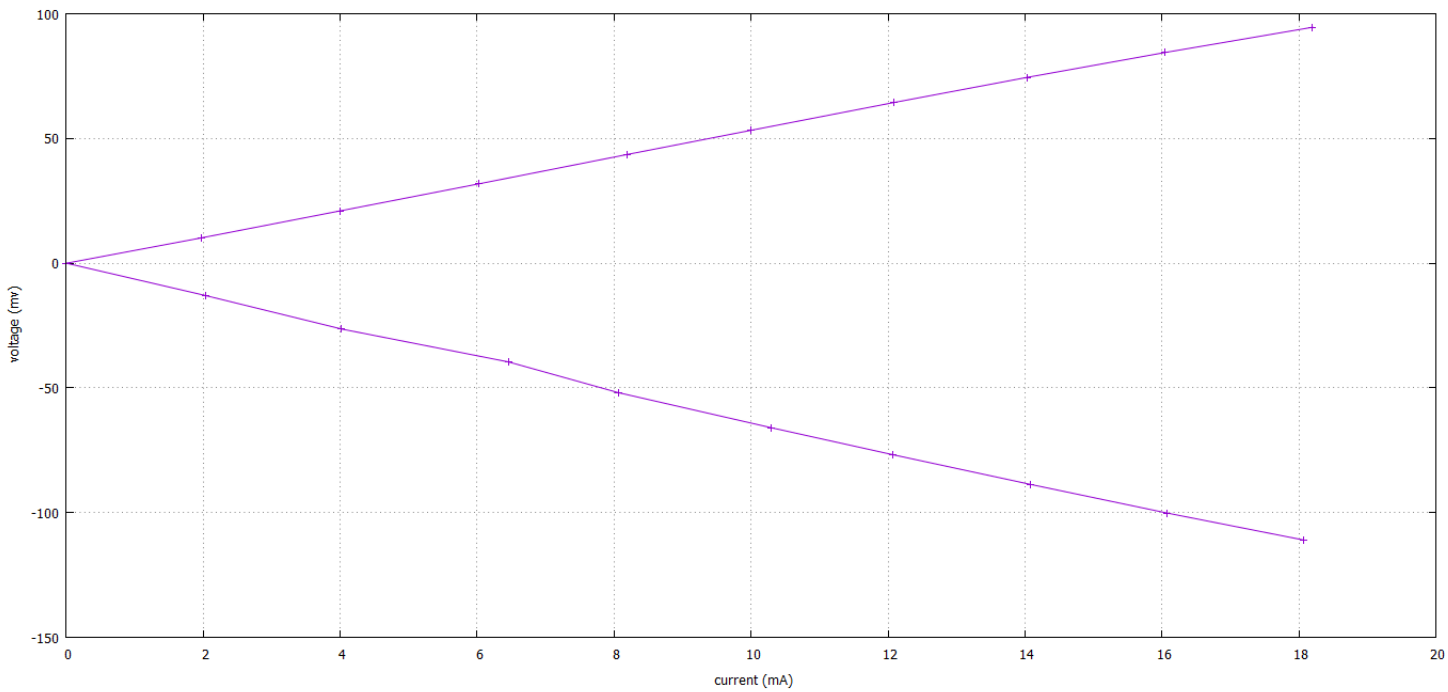


Fig:2 graph for both reverse and direct bias at magnetic field 0.0180 tesla in n-type semiconductor

Calculation

$$R_H = |(slope)|d/B$$

slope of hall voltage and hall current =5.37mV/mA

$$R_H = \frac{5.37\times5\times10^{-4}}{0.0180}\frac{m^3}{C} = 0.1492\frac{m^3}{C}$$

6.6 For p-type semiconductor:

6.6.1 Magnetic field being constant at 0.0087 tesla

When Hall current is along+X direction

when all connections in direct bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	1.02	12.2
2	2.11	25.3
3	3.09	36.8
4	4.05	47.7
5	5.04	58.5
6	6.08	69.0
7	7.03	76.5
8	8.01	85.3
9	9.08	94.7
10	10.09	101.3

6.7 For p-type semiconductor:

6.7.1 Magnetic field being constant at 0.0087 tesla

When Hall current is along-X direction

And when all connections in reverse bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	1	-2.3
2	2.05	-4.4
3	3.09	-7.6
4	4	-9.7
5	5.09	-12
6	6.02	-13.4
7	7.06	-14.8
8	8	-15.4

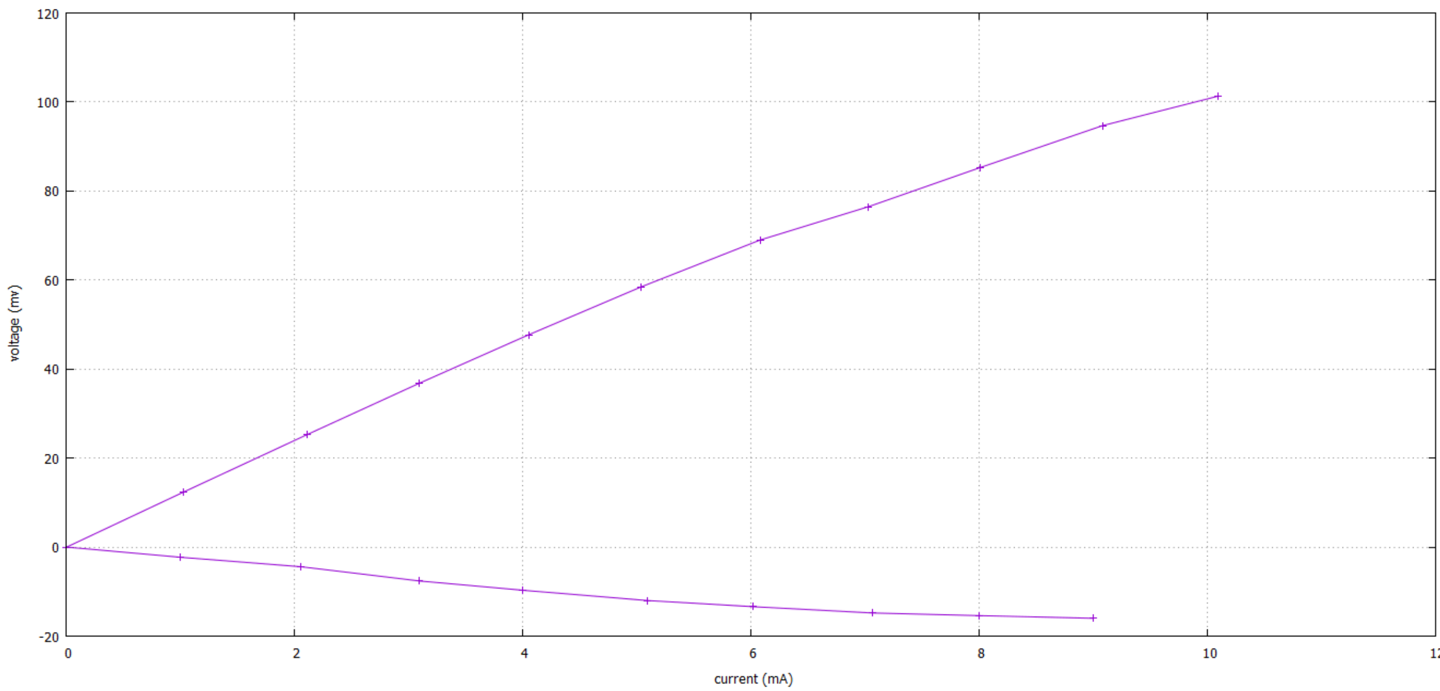


Fig:3 graph for both reverse and direct bias at magnetic field 0.0087 tesla in p-type semiconductor

Calculation

$$R_H = |(slope)|d/B$$

slope of hall voltage and hall current =10.457mV/mA

$$R_H = \frac{10.457 \times 5 \times 10^{-4}}{0.0087} \frac{m^3}{C} = 0.6010 \frac{m^3}{C}$$

6.8 For p-type semiconductor:

6.8.1 Magnetic field being constant at 0.0180 tesla

When Hall current is along+X direction

when all connections in direct bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	1.02	18.7
2	2	36.8
3	3.02	55.7
4	4.09	74.9
5	5	90
6	6	106.4
7	7.07	122.8
8	8	135.7
9	9.09	148.6
10	10.01	157.4
11	11.07	167.5

6.9 For p-type semiconductor:

6.9.1 Magnetic field being constant at 0.0180 tesla

When Hall current is along-X direction

And when all connections in reverse bias

Sl.No.	Hall current(in mA)	Hall voltage(in mV)
1	1.04	-9
2	2.02	-17.5
3	3.08	-26.4
4	4.05	-41.7
5	5.07	-41.7
6	6.01	-48.1
7	7	-53.8
8	8.01	-59.3
9	9	-64.1
10	10	-67.7
11	11	-70.5
12	12	-72.7
13	13.07	-74.5

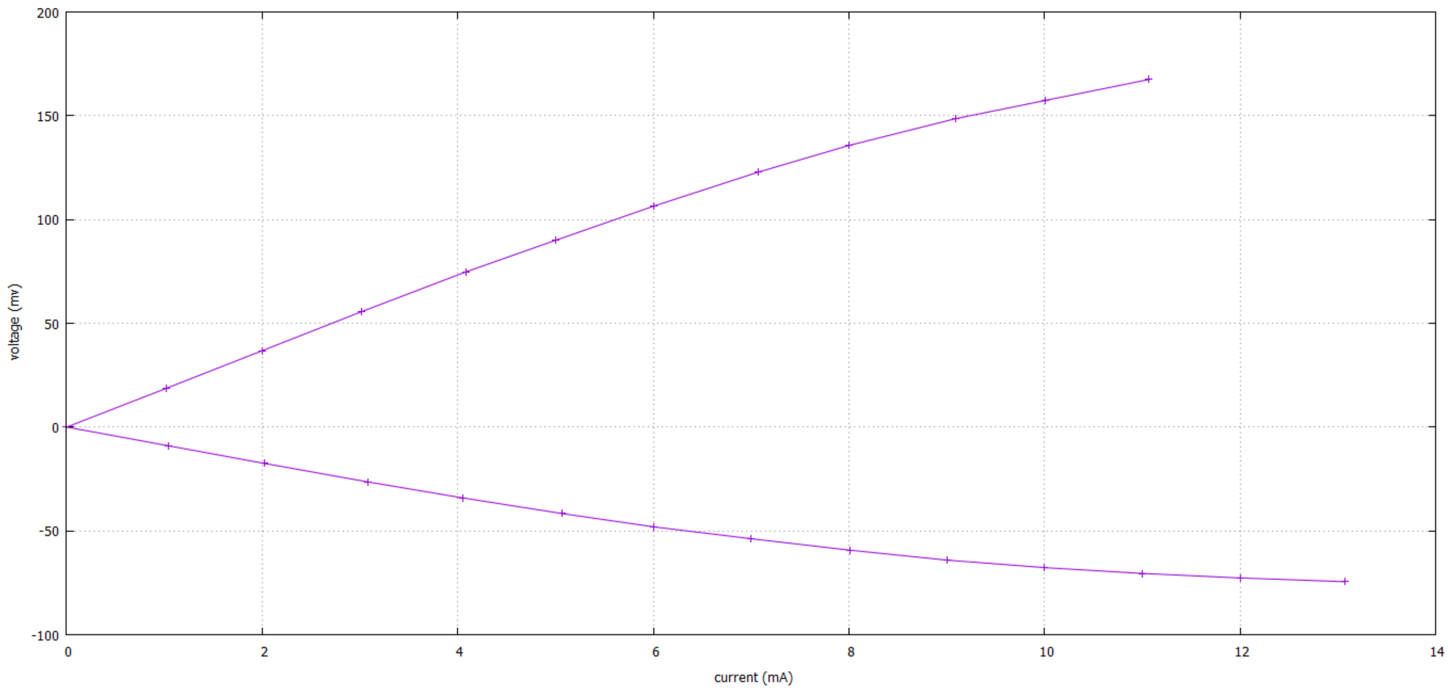


Fig:4 graph for both reverse and direct bias at magnetic field 0.0180 tesla in p-type semiconductor

Calculation

$$R_H = |(slope)|d/B$$

slope of hall voltage and hall current =17.2mV/mA

$$R_H = \frac{17.2\times5\times10^{-4}}{0.0180}\frac{m^3}{C} = 0.4777\frac{m^3}{C}$$

7 CONCLUSION

7.1 Results

from plotting graphs between hall voltage and magnetic eld while hall current is constant and the average values we have found are$R_H = 0.15245\frac{m^3}{C}$ for n-type semiconductor and$R_H = 0.53935\frac{m^3}{C}$ for p-type semiconductor.

8 REFERENCES

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3.http://vlab.amrita.edu
4.https://sites.google.com/a/iitgn.ac.in/ph102/home/pg-experiments