# 8. HALL EFFECT

## AIM:

(i) To study Hall effect and determine
  Hall voltage, $V_H$
  Hall coeffecient, $R_H$

(ii) To determine the type of minority carriers i.e, whether the Semiconductor crystal is of n-type or p-type.

(iii) To determine the charge carrier density or carrier concentration per unit volume in the semiconductor crystal.

## APPARATUS:

1. Hall probe
2. Gauss meter
3. Power supply
4. Multimeter
5. Constant power source

## INTRODUCTION:

In 1879, E.H Hall observed that on placing a current carrying conductor perpendicular to a magnetic field, a voltage is observed perpendicular to both the magnetic field and the current. It was observed that the charge carriers, which were assumed to be electrons, experienced a sideways force opposite to what was expected.

The number of conducting charges and the sign of charge carriers cannot be determined by the measurement of conductivity of a specimen. In metals/conductors, the current carriers are only electrons wheareas in semiconductors, both electrons and holes act as current carriers.

Therefore, in semiconductor, it is quite necessary to determine whether a material is of n-type or p-type. The Hall effect can be used to distinguish the two types of charge carriers and also to determine the density of charge carriers.

THEORY:

When a magnetic field is applied perpendicular to a current carrying specimen, a voltage is developed in the specimen in a direction perpendicular to both the current and the magnetic field.

This phenomenon is called Hall effect. The voltage so generated is called Hall Voltage.

We know that a static magnetic field has no effect on charges unless they are in motion. When the charges flow, a magnetic field directed perpendicular to the direction of flow produces a mutually perpendicular force on the charges.

Cosequently, electrons and holes get seperated by opposite forces and produce on electric field $E_H$, thereby setting up a potential difference between the ends of a specimen. This is called Hall potential, $V_H$.

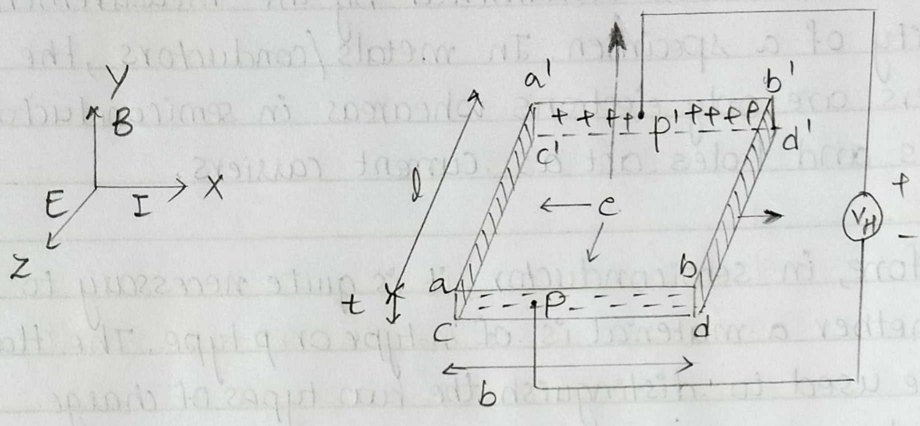


Fig. 1

Working Principle :-

Consider a semiconductor in the form of a flat strip. Let I be the current that flows through the strip along X-axis. If a millivoltmeter is connected between points P and P', it doesn't show any reading. This indicates that there is no potential difference setup between these points.

But when a magnetic field is applied along Y-axis, i.e perpendicular to the direction of current, a deflection is produced in the millivoltmeter.

As shown in Fig-1, if a current is passed along X-axis, then the electrons move along negative direction of X-axis.

The Force on electron due to the applied magnetic field B is given by,

$$F = e(V \times B)$$

$$F = evB\sin 90^\circ$$

$$F = evB \quad \text{---} \ (1)$$

Here, e = electron charge

v = drift velocity

B = magnetic field applied

F = Force.

Using Fleming's left hand rule, the force on electrons will be directed towards the face abcd, thereby making face abcd negative and a'b'c'd' positive.

If the current is carried by positively charged carriers i.e holes, the carriers move in the same direction as that of current.

The magnetic force causes positive charge carriers to move towards the face abcd, thereby making face abcd positive and a'b'c'd' negative.

Thus, by determining the polarities of the surface of the strip, we can determine the sign of the charge carriers.

At thermal equilibrium, the lorentz force exactly matches the force due to the electric field, $E_H$ (Hall voltage)

$$evB = eE_H$$

$$vB = E_H \quad — ②$$

We know that, the drift velocity $= \frac{I}{neA}$ where A is the area of cross section, n is the no. of charge carriers and current density $J = I/A$

equation ② $\Rightarrow \frac{I}{neA} B = E_H$

$A = bt$

$b \rightarrow$ breadth/width

$t \rightarrow$ thickness of specimen.

$$\frac{IB}{nebt} = E_H \quad — ③$$

As we know that, $V_H = E_H t \quad — ④$

Substitute, equation ④ in equation ③,

$$\frac{IB}{nebt} = \frac{V_H}{t}$$

$$\frac{IB}{neb} = V_H$$

$$\frac{R_H IB}{b} = V_H \qquad (\because R_H = \frac{1}{ne})$$

$$\boxed{R_H = \frac{V_H b}{IB}}$$

BLOCK DIAGRAM OF EXPERIMENTAL SET-UP:

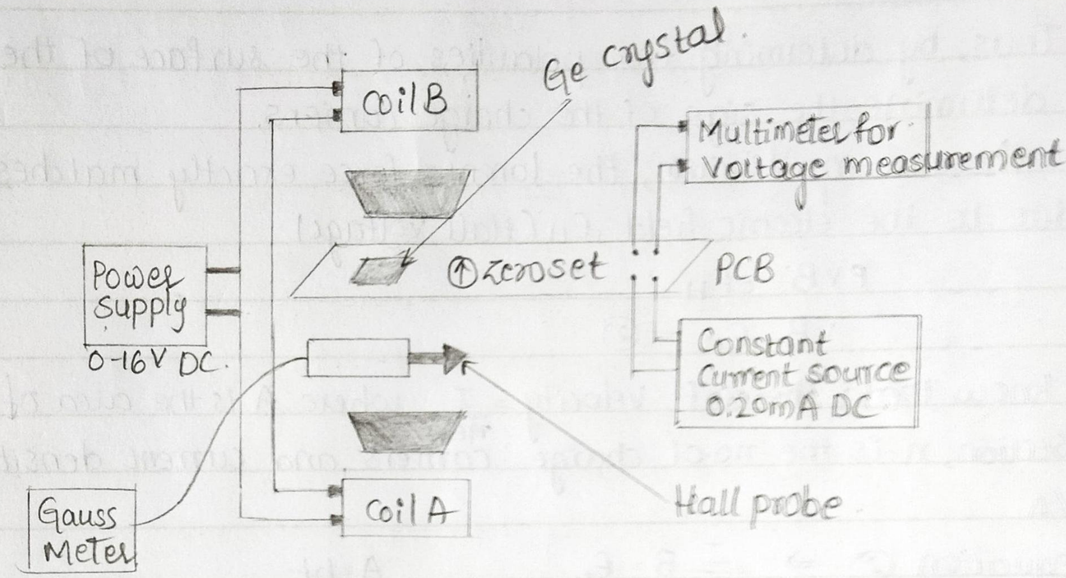


Fig-2

OBSERVATION TABLE :

| S No | Current (mA) | Hall Voltage (B and I in one direction) | Hall Voltage (B and I in Reverse direction) | Mean | $V_H$ (hall voltage) / I |
|---|---|---|---|---|---|
| 1 | 0.5 | 0.004 | 0.004 | 4 | 8 |
| 2 | 1 | 0.006 | 0.005 | 5.5 | 5.5 |
| 3 | 1.5 | 0.009 | 0.008 | 8.5 | 5.6667 |
| 4 | 2 | 0.012 | 0.009 | 10.5 | 5.25 |
| 5 | 2.5 | 0.014 | 0.012 | 13 | 5.2 |
| 6 | 3 | 0.017 | 0.015 | 16 | 5.3333 |
| 7 | 3.5 | 0.019 | 0.016 | 17.5 | 5 |
| 8 | 4 | 0.022 | 0.019 | 20.5 | 5.125 |
| 9 | 4.5 | 0.026 | 0.025 | 25.5 | 5.6667 |
| 10 | 5 | 0.027 | 0.022 | 24.5 | 4.9 |
| 11 | 5.5 | 0.029 | 0.026 | 27.5 | 5 |
| 12 | 6 | 0.033 | 0.027 | 30 | 5 |

CALCULATIONS :

Hall voltage,

$$V_H = \frac{4+5.5+8.5+10.5+13+16+17.5+20.5+25.5+24.5+27.5+30}{12}$$

$$= \frac{203}{12} = 16.9167 \text{ mV}$$

$$= 0.0169 \text{ V}$$

$\therefore$ Hall Voltage $= 0.0169$ V

# Graph for Record Book

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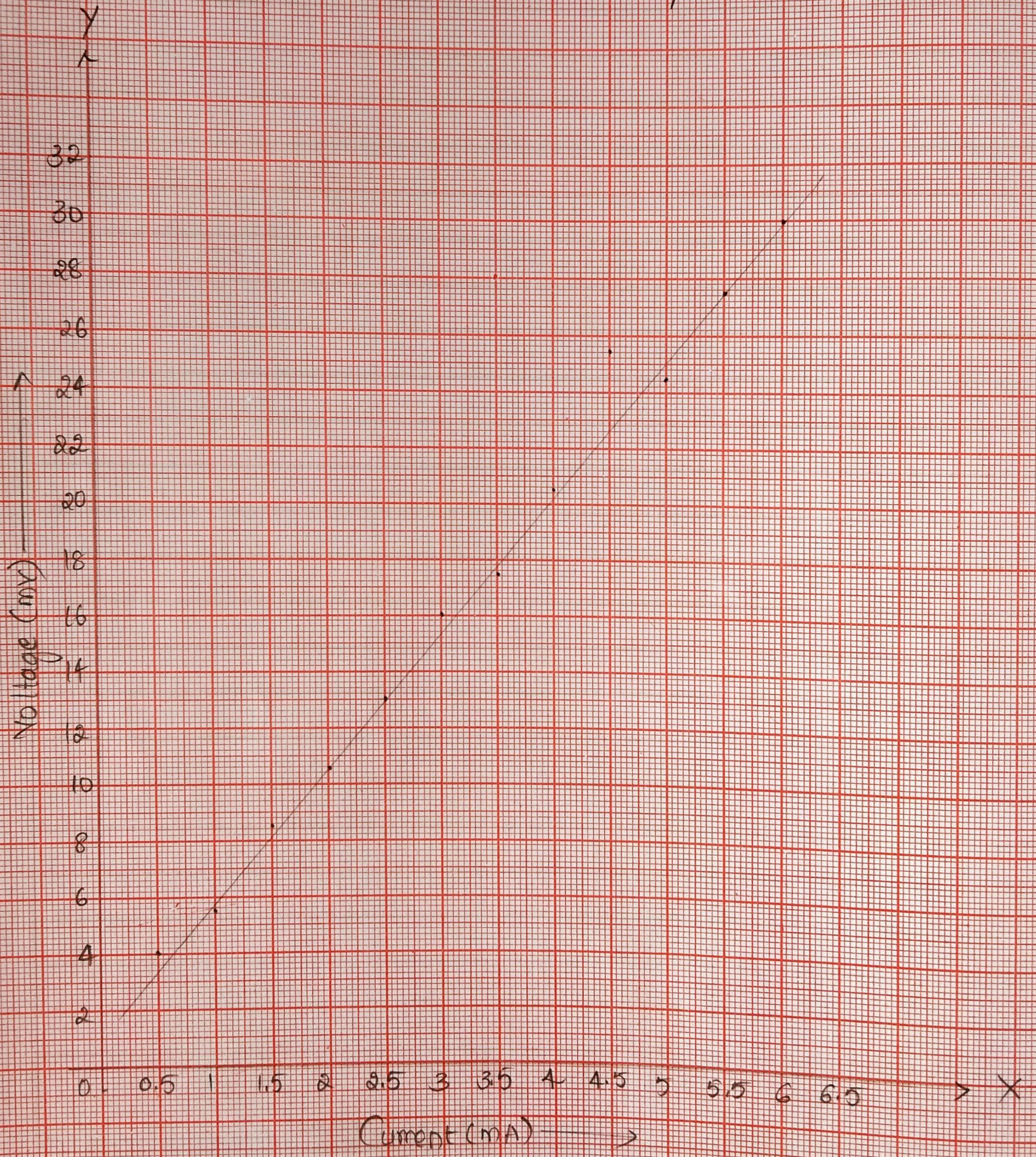
Scale:

X-axis, 1cm = 0.5 mA
Y-axis, 1cm = 2 mV



Hall Coefficient,

$$R_H = \frac{V_H b}{IB} \qquad b = 6\,mm = 6\times10^{-3}\,m$$

$$B = 2300 \text{ guass} = 2300\times10^{-4}\text{ Tesla}$$

$$\frac{V_H}{I} = \frac{\cancel{8.5}\ 8 + 5.5 + 5.6667 + 5.25 + 5.2 + 5.3333 + 5 + 5.125 + 5.6667 + 4.9 + 5 + 5}{12}$$

$$= \frac{65.6417}{12}$$

$$= 5.4701$$

$$R_H = \frac{5.4701\times6\times10^{-3}}{2300\times10^{-4}}$$

$$R_H = 0.1427\ m^3C^{-1}$$

Sign of hall coefficient is positive. Therefore the crystal is of "p-type".

From Graph, $\text{Slope} = \frac{25-13}{5-2.5} = \frac{12}{2.5} = 4.8$

$$R_H = \frac{4.8\times6\times10^{-3}}{2300\times10^{-4}} \qquad \left(R_H = \frac{\text{Slope}\times b}{B}\right)$$

$$R_H = 0.1252\,m^3C^{-1}$$

$$R_{avg} = \frac{R_H(\text{calculation}) + R_H(\text{graph})}{2}$$

$$= \frac{0.1427 + 0.1252}{2}$$

$$R_{H_{avg}} = 0.13395\ m^3C^{-1}$$

Carrier Concentration,

$$n = \frac{1}{R_{H_{avg}} e} = \frac{1}{0.13395 \times 1.6 \times 10^{-19}}$$

$$n = 4.6659 \times 10^{19} m^{-3}$$

where, $R_H$ = Hall coefficient
$V_H$ = Hall Voltage
$I$ = current
$B$ = Magnetic field
$b$ = Width of specimen

PROCEDURE :

1. Connect all the apparatus as shown in Fig-2
2. Then start keeping the current to be zero and also the voltage to be zero.
3. Fix a particular magnetic field.
4. By changing the values of the current note the corresponding values of the voltage
5. This voltage is called Hall voltage. Then Reverse the current direction and note the voltage in table.
6. Then, Find the hall coefficient value ($R_H$).

Draw graph between $V_H$ and $I$ which gives a straight line. We can also find $R_H$ from graph.

RESULT:

1) Hall Voltage, $V_H = 0.0169\,V$
2) Hall Coefficient, $R_H$ from table calculations $= 0.1427\, m^3C^{-1}$
$R_H$ from graph $= 0.1252\, m^3C^{-1}$
3) The Semiconductor crystal is p-type.
4) Carrier concentration per unit volume in the semiconductor crystal, $n = 4.6659 \times 10^{19} m^{-3}$

CONCLUSION:

Hall Voltage, $V_H$ and Hall coefficient, $R_H$ are found to be 0.0169 v and 0.13395 $m^3C^{-1}$ respectively. The semiconductor crystal is found to be p-type and the charge carrier density in the semiconductor crystal is found as $4.6659 \times 10^{19} m^{-3}$

APPLICATIONS:

1. Using magnetic flux leakage - In order to properly insepect items such as pipes or tubes, Hall effect probes work with something called magnetic flux leakage
2. Sensors to detect ~~ratio~~ rotation speed - A Hall effect probe can be used to in bicycle wheels, speedometers in the automotieve world.
3. Used to detected movement - we will often find a Hall effect used in smart phones as well as GPS systems.
4. Ferrite Toroid Hall effect current transducers - This is mainly used in electronic compasses, making use of the magnetic field to show direction.
5. Split-ring clamp-on sensors.