EXPERIMENT NO.6

HALL EFFECT

OBJECT:

To study the Hall Effect and determine Hall coefficient(R_H) and carrier density $n(orp)$ of a given semiconductor material using Hall effect set-up.

APPARATUS:

A rectangular slab of semiconductor crystal, electromagnet, digital Gauss meter, constant current power supply, digital ammeter and millivoltmeter, connecting leads etc.

FORMULA USED:

(i) **Hall Coefficient** of a semiconductor is given by

$$R_H = \frac{V_H}{I_x}\frac{t}{B_z} \text{ meter}^3\text{/Coulomb}$$

Where V_H = Hall Voltage in volts.

I_x = Current in the specimen in Amperes.

t = Thickness of the specimen in meter.

B_z = Magnetic field in Gauss.

(ii) **Carrier Density**

The number of charge carriers per unit volume in a semiconductor (n- electron concentration in n-type and p-hole concentration in p-type semiconductor) is

$$n(orp) = \frac{1}{R_H e}$$

Theory:

When a piece of conducting material (metal or semiconductor) is placed in a transverse magnetic field and current is passed along the length of the conductor, a voltage is developed at right angles to both the direction of the current(I_x) and magnetic field(B_z). This phenomenon is known as Hall effect and the voltage developed across the specimen is Hall voltage. The Hall voltage is proportional to both the applied magnetic field and the current.

Consider a specimen in the form of a rectangular cross-section carrying a current I_x in the x-direction as shown in Fig.1.If the material is n-type then the Lorentz force,

$$F = eB_z v_x \qquad (1)$$

Where v_x is the velocity of electrons, as a result, electrons drift downward making the lower surface more negative than the upper one .The field created by the surface charges produces a force which opposes the Lorentz force.

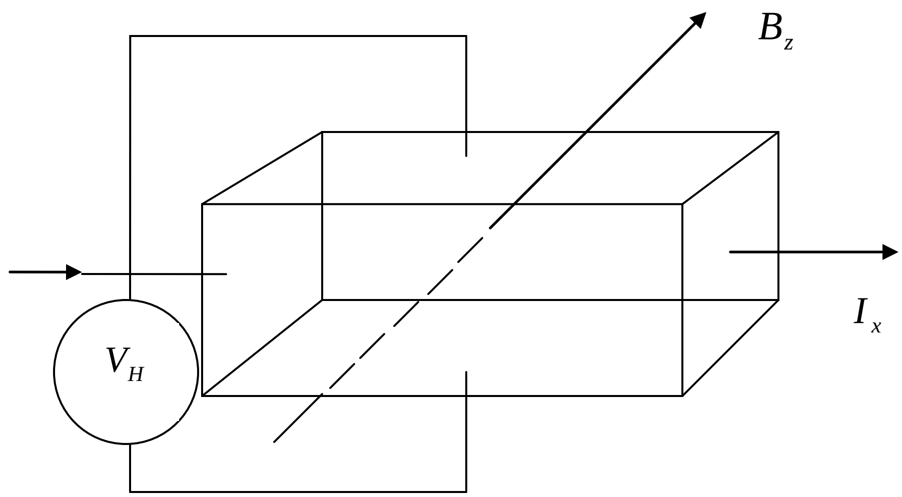


Figure.1 The direction of Hall Voltage (V_H), applied current (I_x) and magnetic field(B_z)

The drift of electrons continues until the hall force cancel the Lorentz Force. Thus in steady state,

$$eE_H = eB_z v_x$$

Where E_H is the Hall field, or,

$$E_H = B_z v_x \qquad (2)$$

If J_x be the current density in x direction, then

$$J_x = nev_x \qquad (3)$$

Where n is the concentration of charge carriers. Substituting the value of $v_x = (J_x / ne)$ from equation (3) in equation (2), we get,

$$E = \left(\frac{1}{ne}\right) B_z J_x$$

The Hall field is thus proportional to current and magnetic field. The proportionality constant, i.e., $(1/ne)$ is known as the Hall coefficient R_H for the material and defined in terms of current density J_x by the relation

$$R_H = \frac{E_H}{B_z J_x}$$

For n-type material,

$$R_H = -\frac{1}{ne}$$

Where n is the number of electrons as charge carriers and negative sign indicates that the field is developed along the negative y-axis.

Similarly, for p-type,

$$R_H = \frac{1}{pe}$$

Where n is the number of holes.

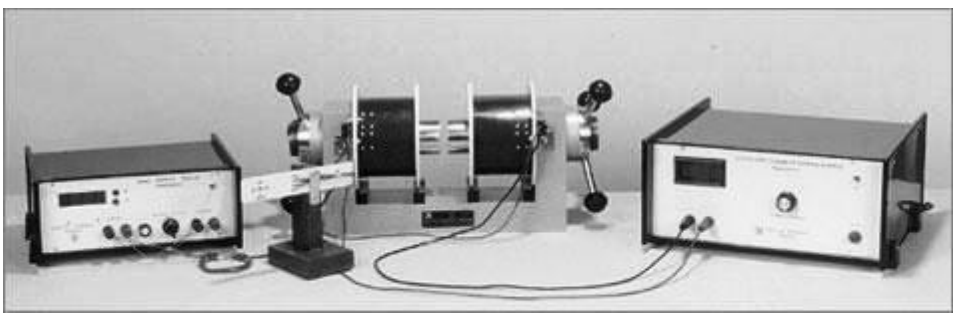
In terms of V_H and I_x one can write,

$$R_H = \frac{V_H/b}{B_z\left(I_x/bt\right)}$$

or

$$R_H = \frac{V_H t}{I_x B_z} \qquad (4)$$

Equation(4) is used to determine Hall coefficient.



PROCEDURE:

[A] Calibration of the Electromagnet

1. Allow some current I in the electromagnet from the constant current source.
2. Note the corresponding magnetic field B_Z using digital gauss meter.
3. Measure the magnetic field for different values of current.

[B] Measurement of Hall Voltage

1. Place the specimen between the pole pieces of the electromagnet and set a suitable current.

2. Allow some current (mA) through the semiconductor and note the corresponding Hall voltage (mV).
3. Measure Hall voltage for different values of Hall current.
4. Repeat the steps (2) and (3) for different values of current in the electromagnet.

OBSERVATIONS:

[A] Calibration of the Electromagnet:

S. No.	**Current in Ampere**	**Magnetic field in Gauss**
1.		
2.		
3.		

[B] Measurement of Hall Voltage:

S.No.	**For I = ….Amp**		**For I = ….Amp**		**For I = ….Amp**	
	Current through specimen I_x (mA)	**Hall Voltage V_H (mV)**	**Current through specimen I_x (mA)**	**Hall Voltage V_H (mV)**	**Current through specimen I_x (mA)**	**Hall Voltage V_H (mV)**
1.						
2.						
3.						
4.						
5.						

CALCULATIONS:

[A] Calibration of the Electromagnet

Plot a graph between I (Current) and B_Z (Magnetic field).

[B] Measurement of Hall Voltage

(1) Plot a graph between V_H and I_x for different values of I and calculate the slope of each line $\frac{V_H}{I_x}$ and the Hall coefficient

$$R_H = \frac{V_H}{I_x}\frac{t}{B_z}$$

Or

$$R_H = slope \times \frac{t}{B_z} \quad Meter^3/C$$

(2) The number of charge carriers in the specimen

$$n \ or \ (p) = \frac{1}{e\,R_H}$$

Substitute the value of R_H and calculate the concentration of carriers $n(or\ p)$.

RESULT:

(1) The Hall coefficient $R_H =$ ………………..Meter^3/C.
(2) The number of charge carriers =…………….
(3) The nature of given semiconductor material is ……….type.

PRECAUTIONS:

(1) Hall voltage developed is very small and should be measured accurately.
(2) The specimen should be kept properly in the magnetic field of electromagnet.
(3) Current through the semi-conducting crystal should be strictly with in limit as mentioned by manufactured.
(4) Electromagnet should not be touched during flow of current through it.
(5) Current through electromagnet should not reach more than 3.00 Ampere.
(6) Switch off the current through electromagnet after completion of observations.

REFERENCES:

(1) Solid State Physics by S.O.Pillai.
(2) Introduction to Solid State Physics by C.Kittel.

VIVA-VOCE

(1) What is Hall effect?
(2) What is Hall coefficient?
(3) What is Fleming’s left hand rule and its utility?
(4) What are semiconductors and name the type of them?
(5) What do you mean by mobility of charge carriers?
(6) What is the importance of Hall effect?
(7) Can Hall effect be observed in metals too?
(8) What is one Gauss?
(9) What are dimensions of the semi-conducting sample?
(10) What is an electromagnet and mention about its applications?