Hall effect

Aim :- 1) To determine the Hall coefficient (R_H)

2) To measure the unknown magnetic field (B_{Y1}) and to compare it with that measured by the Gaussmeter (B_{Y2}).

Apparatus :- 1) Gauss meter with probe

2) Electromagnet
3) Constant current source to Pass current through electromagnet
4) Specimen of semi-conducting material with connecting terminals to Pass current (I_X)through it [Green wire terminals] and to measure the Hall voltage (V_H) [Red wire terminals]
5) Constant current source to Pass current (I_X) through semiconductor specimen
6) Milli-ammeter to measure I_X
7) Voltmeter to measure Hall voltage (V_H) [5,6 &7 are fixed to Hall effect board]
8) Connecting terminals.

Formulae :- 1) Hall coefficient $R_H = \dfrac{V_H\, t}{I_X\, B_Y}$ $cm^3/Coulumb$

2) Magnetic induction $B_{Y2} = \dfrac{V_H\, t}{I_X\, R_H}$ $Gauss$

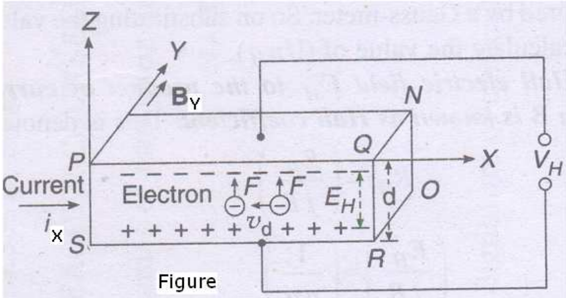
Where V_H = Hall voltage developed between the upper and lower faces of the specimen (V)

I_X = Current sent through the specimen (A)

t = Thickness of the specimen (Distance between the side faces) (cm)

Theory :- As per the statement of Hall effect "when a magnetic field is applied perpendicular to a current carrying current conductor, a potential difference is developed between the opposite faces of the conductor which is perpendicular to both current and magnetic field directions."

Consider a uniform thick semiconductor (or) metal strip (specimen) placed with its length parallel to X-axis. A current I_X is passed through the conductor along X-axis. A magnetic field B_Y is applied along Y – axis, then the charge carriers experience a force (F) perpendicular to X-Y plane i.e. along Z- axis as per the Fleming's Left Hand rule as shown in the figure. If electrons are the charge carriers, they accumulate at the upper surface. This surface acquires negative charge while the lower surface gets positive charge and some potential difference is developed between these two surfaces. This is electrostatic field. This voltage is called Hall Voltage (V_H) and the Electric field is called Hall electric field (E_H). (In this case the Hall voltage V_H is negative, this –ve sign indicates the charge carriers are negatively charged i.e. electrons. If it is +ve the charge carriers are holes.



Figure

These F and E_H act in opposite directions. i.e. The forces due to magnetic field and electrostatic field on charge carrier act in opposite direction. Ultimately, the net force on the charge carrier becomes zero.

$\therefore$ q ($\mathbf{V_d}$ X $\mathbf{B_Y}$) + q $\mathbf{E_H}$ = 0 (or) ($\mathbf{V_d}$ X $\mathbf{B_Y}$) + $\mathbf{E_H}$ = 0

Here $\mathbf{V_d}$ is the drift velocity of the charge carrier = J/nq.

Where J = Current density q = Charge of the carrier n = No. of charge carriers/cm^3

Here is another physical quantity called <u>Hall coefficient</u> which is equal to <u>the reciprocal of the amount of charge per unit volume.</u>

$$\text{Hall coefficient} \quad R_H = \frac{1}{nq} = \frac{E_H}{J\,B_Y} \quad \& \quad = (\frac{V_H}{d})\frac{1}{(I_X/A)\,B_Y}$$

$$R_H = (\frac{V_H}{d})\frac{1}{(I_X/td)\,B_Y} = \frac{V_H\,t}{I_X\,B_Y}$$

Where t = Thickness of the specimen d = Height A = Area of cross-section

This experiment can be used to find 1) the nature of the charge carrier 2) the Hall voltage 3) current through the specimen 4) applied magnetic field 5) Conductivity of the conductor etc. But for the present it is confined to measure the unknown magnetic field.

<u>Description</u> :- This experimental set-up consists of 3 main instrumental parts.

1) <u>Digital Gaussmeter with Hall probe</u> :- Hall probe cable is to be plugged-in to the socket of the digital gaussmeter and the power should be given to the gaussmeter. This probe also operates basing on the principle of Hall effect. A small current sent through the Hall probe develops a small Hall voltage when it is placed in a magnetic field and the Hall voltage is amplified by an amplifier whose output is calibrated in Gauss which directly gives the magnetic induction (B) value in the gaussmeter.

2) Electromagnet with constant current supply :- Two insulated Copper wires are wound on two soft iron bars whose faces are facing each other. When a D.C. current (in amperes) from a constant current source is sent through the coils, the faces of the iron bars acts as the two poles of a magnet (electromagnet) creating a magnetic field in between them. The gap between poles can be varied , in general, the gap should be 1 cm.

3) Hall effect board with Hall probe semi-conductor specimen mounted on sun mica PCB :- A specimen of rectangular semi-conductor slab in which Hall effect is to be studied is fixed to a printed circuit board (PCB) with the help of 4 supporting terminals. Out of 4 terminals, 2 terminals are along the length and these (Middle & green) terminals are connected to the current source of the Hall effect board. The other 2 terminals are along the width and these (Red) terminals are connected to the Voltmeter of the Hall effect board. The Hall effect board has 2 uses. A) To pass current (I_X) through the specimen & to measure that current. B) To measure the Hall voltage (V_H) developed across the specimen. To meet these two purposes a two mode switch is arranged to the digital meter of the board. First mode is to measure the current (I_X), sent through the specimen and the second mode is to measure the Hall voltage (V_H) developed across the specimen.

Procedure :- This experiment comprises of **two parts**

1) Measurement of Hall coefficient (R_H)

2) Measurement of applied magnetic field (B_y) by using Hall effect (Application of Hall effect)

Measurement of Hall coefficient (R_H)

In the 1st part give the power supply to the gaussmeter. Keep the range switch of the gaussmeter in minimum range and adjust the zero adjustment such that the reading in the gaussmeter shows zero. If the gaussmeter does not come to zero, then keep its value at minimum and take it as zero error. This zero error is to be corrected while taking the final reading of magnetic induction (B_Y).

Now adjust the distance between the poles of the electromagnet equal to 1cm & pass 1A current through the electromagnet from its constant current source, then some magnetic field (B_Y) is created between the poles of electromagnet. This magnetic field or magnetic induction (B_Y) is measured by the gaussmeter by keeping its probe between the poles of the electromagnet. The position of the probe is adjusted such that the flat faces of the probe are perfectly vertical and perpendicular to the magnetic field. Then the gaussmeter shows maximum value.

Keep the mode switch of the current source of the semiconductor specimen in the current mode (Here also the zero error and zero correction are to be made) and pass 0.5 mA (or) 1 mA current (I_X) through the specimen. Place this specimen between the poles of the electromagnet such that the faces of the specimen are perfectly vertical and note the voltage (V_1) developed between the upper and lower faces of the specimen after turning the mode switch of the current source of the specimen in to voltage mode. Now reverse the position of the specimen (up side down and vice versa) and keep it between the poles once again and measure the voltage (V_2) developed between the upper and lower faces of the specimen.

Now calculate the Hall voltage $$V_H = \frac{(V_2 \sim V_1)}{2}$$

Note the values of I_X, V_1, V_2 in the table – 1 and calculate V_H. Repeat the experiment for different values of I_X by increasing its value in equal intervals of 0.25 mA.

Graph :- Draw the graph by taking the current through the specimen I_X on X- axis and Hall voltage V_H on Y- axis. This gives a straight line passing through the origin. Take a particular value of I_X and note its corresponding value of V_H

Note the thickness (t) of the specimen which was noted on the board of the specimen.

Substitute the values of I_X, V_H, t and B_Y in the formula – 1 and calculate Hall coefficient (R_H)

Measurement of applied magnetic field (B_y)

In the 2nd part of the experiment keep the current through the semi-conductor specimen (I_X) at constant value of 1 mA and pass 1A current through the electromagnet and measure the voltages V_1 and V_2 by placing the specimen between the poles of the electromagnet & from that calculate the Hall voltage V_H (as measured in the 1st part). Also measure the magnetic induction (B_{Y1}) with gaussmeter by placing its probe between the poles of electromagnet.

Substitute the values of I_X, V_H, t and Hall coefficient R_H (as calculated in 1st part) in the formula – 2 and calculate value of applied magnetic field (B_{Y2}). The experiment is repeated by increasing the current through the electromagnet (it means by changing the magnetic field B_Y) in equal intervals of 0.5 A. Note the values in the table – 2.

In the 2nd part the experiment the magnetic field B_Y is measured with gaussmeter as B_{Y1} and also measured by using the Hall effect as B_{Y2}. These two are compared in the table – 2.

Precautions :- 1) Electromagnet power supply should be connected to a 3 pin main socket having good earth connection.

2) Switch "ON" or "OFF" the power supply at zero current position.

3) Adjust the distance between the poles of the magnet nearly 1 cm, then only the gaussmeter shows correct reading.

Results :-

Table - 1

Thickness of the semi-conductor specimen t = cm.

Current through the Electromagnet = 1 A

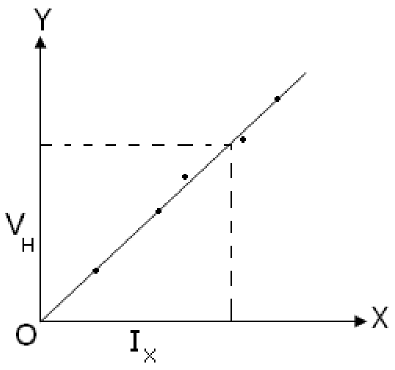
Applied magnetic field measured with gaussmeter B_Y =

S. No.	Current through The specimen I_X (mA)	Measurement of Hall Voltage V_H (V)		
		V_I	V_2	$V_H = \frac{(V_2 \sim V_1)}{2}$
1.				
2.				
3.				
4.				
5.				

Table - 2

Current through the semi-conductor specimen I_X = 1 mA

S. No.	Current through the electromagnet (A)	Measurement of Hall Voltage V_H (V)			Magnetic induction measured with Hall effect $B_{Y2} = \frac{V_H\, t}{I_X\, R_H}$ (Gauss)	Magnetic induction measured with gaussmeter (B_{Y1}) (Gauss)
		V_I	V_2	$V_H = \frac{(V_2 \sim V_1)}{2}$		
1.						
2.						
3.						
4.						
5.						



Graph

<u>More accurate method to measure V_H</u> :- In the above two parts of the experiment i.e. while measuring R_H and B_Y the Hall voltage (V_H) shall be measured first. In measuring V_H, the following is the accurate method. First some current (1A) is sent through the electromagnet to create the magnetic field between the poles of the magnet. Now the current I_X (1mA) is sent through the semiconductor specimen and put the specimen between the poles and measure the voltage (V_1) developed across the specimen (after switch over the mode switch in to voltage mode) as said above. Now the current in the specimen is reversed by interchanging the current leads of the specimen and measure the voltage (V_2). Then Hall voltage $V_{H1} = (V_1 \sim V_2)/2$. Now reverse the current direction in the electromagnet by interchanging its current leads. Once again measure the voltages (V_3 & V_4) developed across the specimen by placing the specimen between the two poles, before and after reversing the current direction in the specimen by inter changing its current leads. Now the Hall voltage $V_{H2} = (V_3 \sim V_4)/2$.

Then the Hall voltage $$V_H = \frac{(V_{H1} + V_{H2})}{2}$$

The above method is to be adopted while measuring V_H.