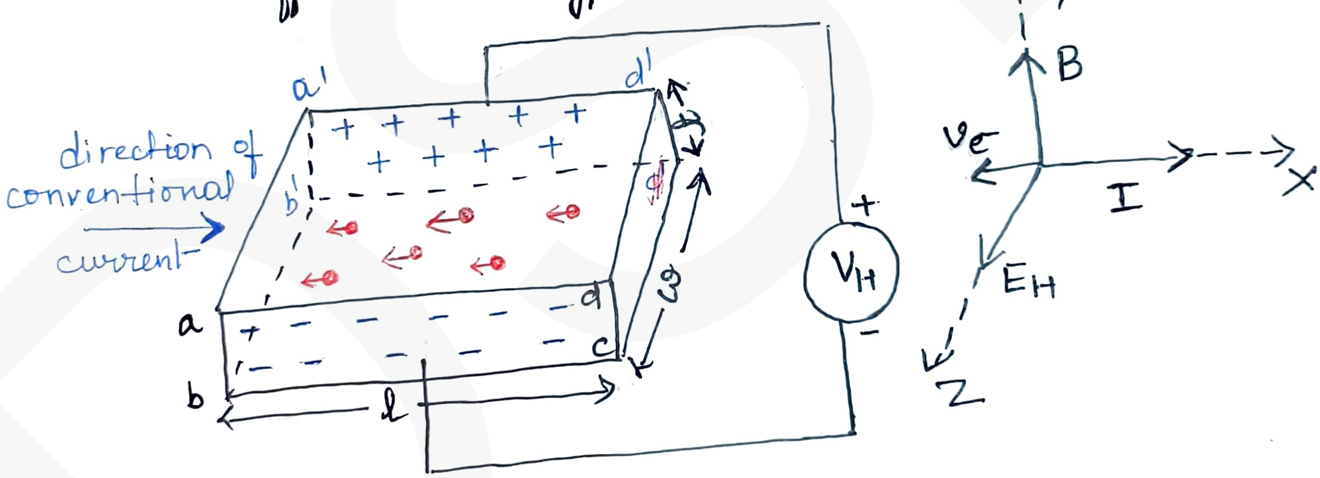
Hall Effect

When a magnetic field is applied perpendicular to a current carrying conductor, a voltage is developed in the specimen, across the width of the specimen which generates electric field perpendicular to both the current and the magnetic field. This phenomenon is called as " Hall Effect" and the generated voltage is called " Hall voltage". The corresponding transverse electric field is " Hall field".

Hall effect in n type semiconductor



* Consider a rectangular shaped semiconductor material with width w, thickness t and length l, through which current I is flowing along +ve x axis.
* It is placed in magnetic field acting along y axis.
* A voltmeter is connected across the front & back face of semiconductor i.e. along Z- axis.

The carriers of negative charge (electrons) moving with an average velocity v, feels the action of Lorentz force given by $\vec{F}_L = q(\vec{v} \times \vec{B})$

or $|\vec{F}_L| = evB$ — ① [∵ $q = -e$ for n type semiconductor & we are taking magnitude alone]

Due to the force acting on electrons, they are deflected outwards and accumulate on face abcd of slab.

Due to polarity opposite face of abcd is positively charged.

A potential difference is created between the plates, which is Hall voltage V_H.

Due to Hall effect transverse electric field E_H develops along Z axis.

Force due to E_H is given by $\vec{F}_H$ &

$$|F_H| = eE_H \quad \text{— ②}$$

To prevent further accumulation of charge, $\vec{F}_H$ produced due to $\vec{E}_H$ balances force $\vec{F}_L$.

∴ ① = ② ⇒ $|F_H| = |F_L|$

or $evB = eE_H$.

or $\boxed{v = \frac{E_H}{B}}$ — ③

Further, to obtain relation between Hall coefficient and Hall voltage,

Current density $\vec{J}$ given by I/A where I is the current flowing in the slab and A is the cross section area i.e. area $\perp$r to the flow of current is given by —.

$\vec{J} = nqv$. or $J = -nev$ [$\because q = -e$ for n type semi cond]

or $\dfrac{I}{A} = \dfrac{-neE_H}{B}$ [from (3)]

or $\dfrac{I}{w \times t} = \dfrac{-neE_H}{B}$.

or $\dfrac{I}{w \times t} = \dfrac{-neV_H}{B \times w}$ $\left[\because E_H = \dfrac{V_H}{w}\right]$

or $$\boxed{V_H = -\frac{1}{ne}\frac{IB}{t}}$$

Here $-\frac{1}{ne}$ is R_H the Hall coefficient for n type semiconductor.

$$\therefore \boxed{V_H = R_H \frac{IB}{t}}$$

Hall effect in p type semiconductor (refer fig 1)

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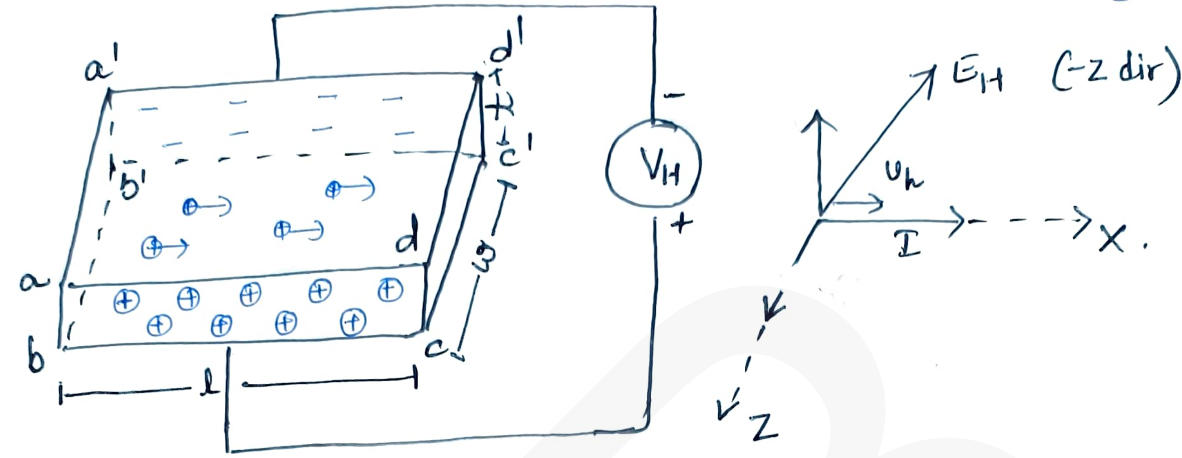

* Consider a rectangular shaped semiconductor material with width w, thickness t and length l, through which current I is flowing along +ve x axis.

* It is placed in magnetic field acting along y axis.

* A voltmeter is connected across the front & back face of the semiconductor i.e. along z-axis.

* The carriers of positive charge, holes moving with an average velocity v, feels the action of Lorentz force given by $\vec{F_L} = q(\vec{v} \times \vec{B})$.

$$\text{or } |\vec{F_L}| = evB \quad \text{——} \ (1)$$

* Due to The force acting on ~~at~~ holes, They are deflected outwards and accumulate on face abcd of slab.

* Due to polarity opposite face is negatively charged.

* A potential difference is created between the plates, which is Hall voltage V_H.

* Due to Hall effect transverse electric field E_H developes along $-Z$ axis.

Force due to E_H is given by $\vec{F}_H$ &.

$$|F_H| = eE_H \quad \text{——} (2)$$

To prevent further accumulation of charge, $\vec{F}_H$ produced due to $\vec{E}_H$ balances force $\vec{F}_L$.

$\therefore$ (1) = (2) $\Rightarrow |F_H| = |F_L|$

or $evB = eE_H$.

or $\boxed{v = \frac{E_H}{B}}$ ——(3)

To obtain relation between Hall coefficient & Hall voltage -

Current density $\vec{J}$ given by I/A where I is the current flowing in the slab and A is the cross section area i.e. area $\perp$r to the flow of current is given by -

$\vec{J} = nqv$ or $J = nev$ [$\because q = e$ for p type semi cond]

or $\frac{I}{A} = +\frac{neE_H}{B}$ (from (3))

or $\frac{I}{w \times t} = \frac{neV_H}{B \times w}$. [$\because E_H = \frac{V_H}{w}$]

or $\boxed{V_H = \frac{1}{ne}\frac{IB}{t}}$

Here $\frac{1}{ne}$ is R_H - the Hall coefficient for p type semiconductor.

$\therefore \boxed{V_H = R_H \frac{IB}{t}}$.

APPLICATIONS OF HALL EFFECT

* Hall effect is used to find whether a semiconductor is N type or P type.
* Hall effect is used to find carrier concentration.
* Hall effect is used to calculate the mobility of charge carriers (free e^{-}s and holes)
* Hall effect is used to measure conductivity.
* Hall effect is used to measure strength of magnetic field.
* Hall effect is used in an instrument called Hall effect multiplier which gives the output proportional to the product of two I/P signals.