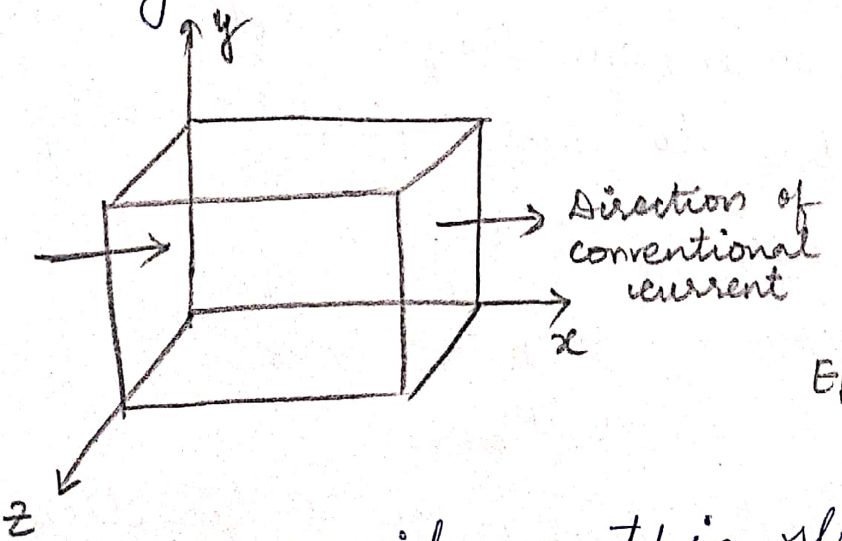
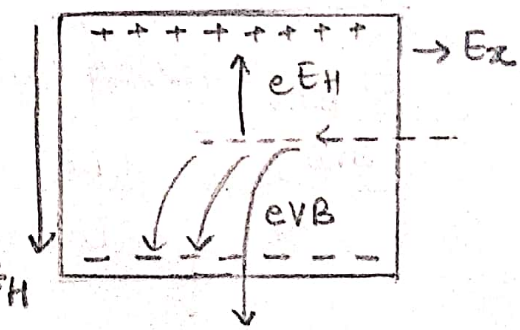
HALL EFFECT

It is used to distinguish the two type of carriers and also determines the density of charge carriers.

When a magnetic field is applied perpendicular to a current carrying conductor, 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" and the generated voltage is called "Hall voltage"





Let us consider a thin slab of conductor subjected to electric field E. This produces a current I and causes a force of magnitude eE to act on the charge carriers.

(2)

when this conductor is placed in magnetic field, a magnetic force is proportional to the strength of the magnetic field strength (B) and charge (e) and velocity (v) acts on the charge carriers.

This force is at right angle to the direction of B & v, Therefore each charge is deflected towards one side of the conductor. When charge reaches the surface of conductor, an electrical charge is built up there, which in turn gives rise to transverse field E_h called Hall field.

It causes a compensating drift, such that force due to hall field exactly balance the lorentz force.

At equilibrium, $eE_H = e v_x B_z$

$$E_H = v_x B_z$$

If J_x = current density in x-direction then

$$J_x = ne v_x$$

$$v_x = \frac{J_x}{ne}$$

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

$$\boxed{E_H = R_H J_x B_z} \quad \text{——} ①$$

$\therefore$ $R_H = \frac{1}{ne}$ = Hall coefficient

also $R_H = \frac{E_H}{J_x B_z}$ = Hall coefficient

ie Hall coefficient is negative for n-type semiconductor and positive for P-type semiconductor.

$\left\{ R_H = \frac{-1}{ne} = \frac{-E_H}{J_x B_z} \right.$ for e⊖

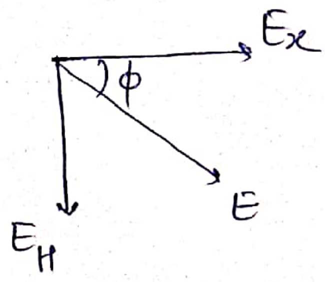
Relation between mobility and Hall angle

Mobility is defined as velocity of an electron per unit electric field.

$$\mu = \frac{v}{E_x} \Rightarrow v = \mu E_x$$

also $v = \frac{E_H}{B_z}$

$$\therefore \frac{E_H}{B_z} = \mu E_x \quad \text{——} (*)$$



$$\Rightarrow \mu = \frac{E_H}{E_x} \cdot \frac{1}{B_z}$$

ϕ = Hall angle

$$\mu = \tan\phi \cdot \frac{1}{B_z}$$

$$\Rightarrow \boxed{\tan\phi = \mu B_z}$$

Note: $\tan\phi = \frac{E_H}{E_x}$ = Ratio of Hall field and Applied field

$E_H = \mu E_x B_z$ from (*)

(4) and $E_H = R_H J_x B_z$ from (1)

$$\mu E_x B_z = R_H J_x B_z$$ equation (1) & (*)

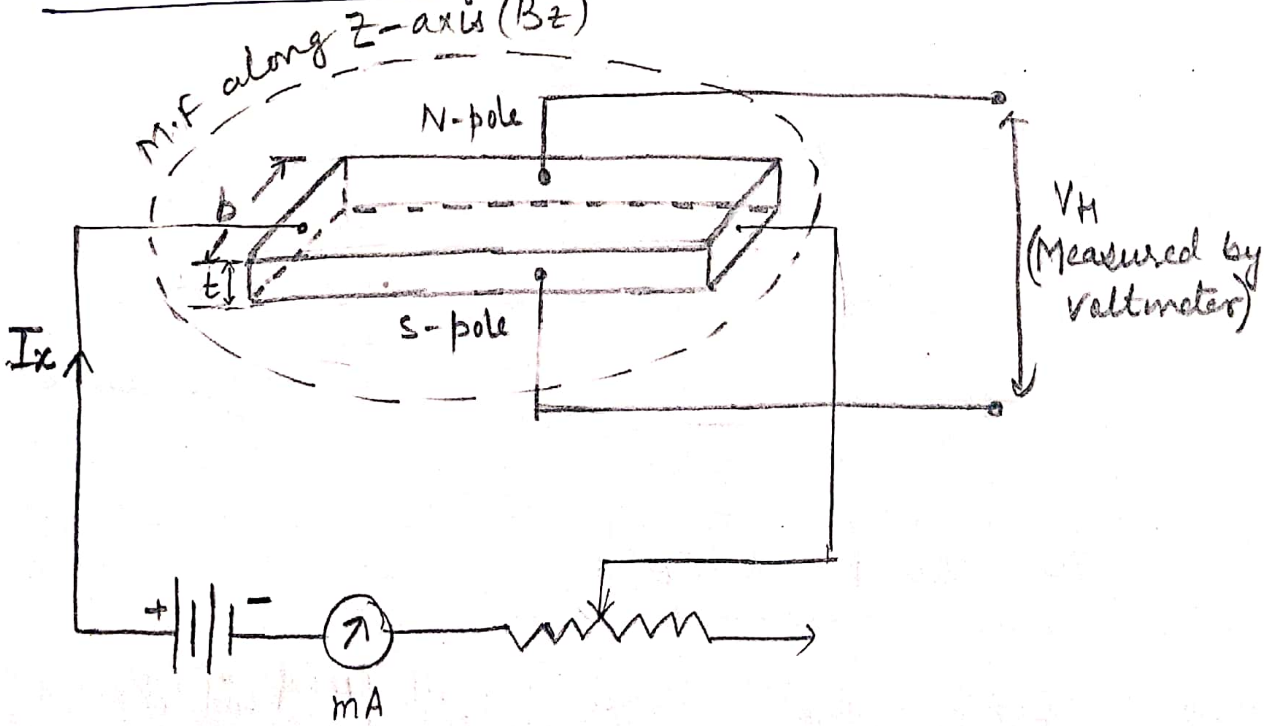
$$\boxed{\mu = \frac{R_H J_x}{E_x}}$$

$\frac{J_x}{E_x} = \sigma$ = electrical conductivity

$$\boxed{\mu = \sigma R_H}$$

$$\boxed{\tan\phi = \mu \cdot B = \sigma R_H B_z.}$$

Experimental set up and Determination of Hall constant :



The Hall coefficient is found by measuring hall voltage V_H, that generates the Hall field E_H.

If V_H is taken across the thickness 't' of the specimen, then

$$V_H = E_H \cdot t$$

$$V_H = R_H \cdot J_x \cdot B_z \cdot t$$

$$J_x = \frac{I_x}{b.t}$$

b = width of sample

$$V_H = \frac{R_H \, I_x \cdot B_z \cdot \cancel{t}}{b \cdot \cancel{t}}$$

$$\boxed{R_H = \frac{V_H \cdot b}{I_x \cdot B_z}}$$

V_H is measured by voltmeter, if width of specimen, magnitude of applied current and applied magnetic field are known, R_H can be calculated.

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APPLICATIONS OF HALL EFFECT :

1) Determination of type of Semiconductor
   If $R_H = -ve$ — n-type semiconductor
   $R_H = +ve$ — P-type semiconductor

2) Classification of Materials
   If R_H = large — semiconductor
   = small — Metal
   $\Rightarrow \infty$ — Insulators

(6)

3) Determination of carrier concentrations

$n = \frac{-1}{eR_H}$ $\downarrow$ Electron conc.

$p = \frac{1}{eR_H}$ $\downarrow$ Hole concentration

4) Determination of carrier mobility

$V_H \propto B_z$

∴ Knowing magnetic density, one can measure mobility.

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