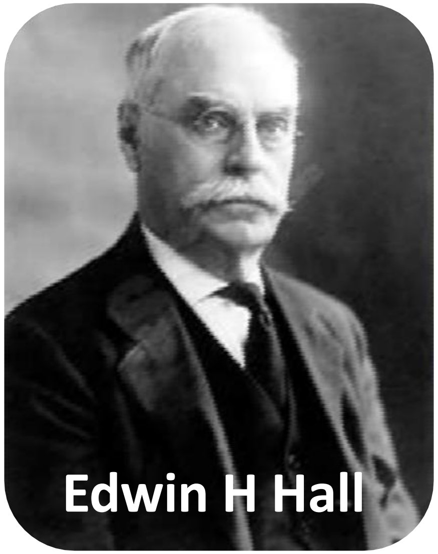
HALL EFFECT

DISCOVERY of Hall Effect

- *The Hall effect was discovered in 1879 by Edwin Herbert Hall while he was working on his doctoral degree at Johns Hopkins University in Baltimore, Maryland, USA. His measurements of the tiny effect produced in the apparatus he used were an experimental tour de force, accomplished 18 years before the electron was discovered and published under the name "On a New Action of the Magnet on Electric Currents"*

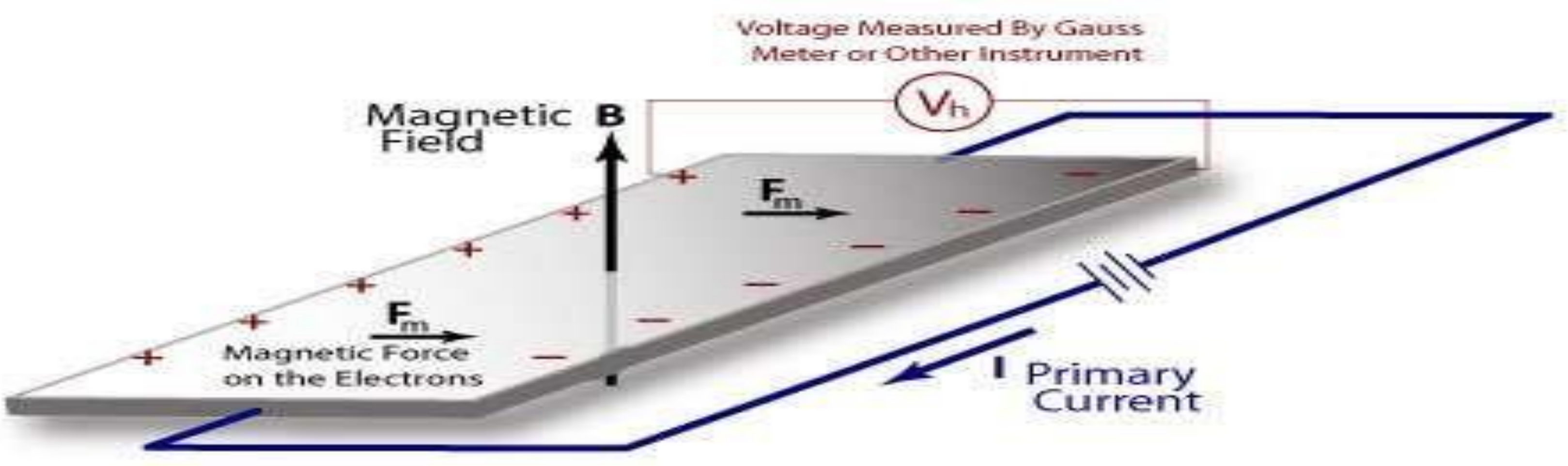


HALL EFFECT:

When a current carrying conductor is placed in a magnetic field perpendicular to the flow of current then it is observed an electric field is created perpendicular to both flow of charge carriers and magnetic field, this field is know as Hall field and corresponding effect is called Hall effect.

THEORY

- When a perpendicular magnetic field is present. A Lorentz force is exerted on the electron. Due to which Electron moves in perpendicular direction to both current and Magnetic Field. And develop a Potential difference across the conductor or semiconductor.



Consider a charged particle of charge'**q**'moving with a velocity of '**v**' in an uniform magnetic field '**B**', then the MAGNETIC LORENTZ force is given by,

$$F = q(\vec{v} \times \vec{B})$$

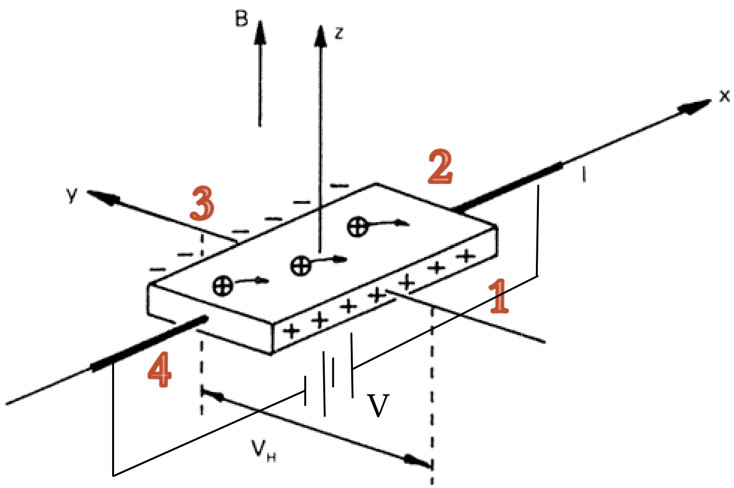
Or in scalar form as,

$$F = Bqv \sin\theta$$

Lorentz force equation in the presence of electric as well as magnetic field

$$\mathbf{F} = q\,(\mathbf{E} + \mathbf{v} \times \mathbf{B})$$

Theory:



Let us consider a P-Type semiconductor Sample placed in a magnetic field as shown in the figure,

The magnetic field simultaneously exerts a force called, LORENTZ force = $q\ (v_x \times B_Z)$ acting on holes and deflecting them towards side1.

As a consequence, holes completely accumulate on side 1 creating a NET POSITIVE charge, as side3 is depleted of holes and is negatively charged.

Let us consider a sample of a p-type semiconductor having width(w), thickness(t) and length(L).

The magnitude of these charges collected on opposite faces is such that the electric field E_y (=V_{AB}/w) created by these charges exactly counterbalances the LORENTZ force on these charges due to the magnetic field and forms an EQUILIBRIUM.

And at this stage NO further accumulation of HOLES takes place on the side1 and HALL FIELD(E_y) reaches a steady value.

The contacts 1(A) and 3(B) are called as HALL contacts and E_y and V_{AB} are called as HALL electric field and HALL voltage respectively.

DERIVATION:

Under equilibrium conditions , the force on the charges due to HALL electric field and LORENTZ force counterbalances each other, that is

$$qE_y = q\, v_x\, B_z \quad \text{------------- (1)}$$

$$E_y = v_x\, B_z \quad \text{------------- (2)}$$

We know that the CURRENT DENSITY 'J_x' is given by

$$J_x = p\, q\, v_x \quad \text{------------- (3)}$$

$$v_x = \frac{J_x}{pq} \quad \text{------------ (4)}$$

Where p = concentration of current carriers i.e. holes

Now substituting v_x from 4 into 2, we get

The HALL effect is generally by means of HALL COEFFICIENT R_h defined in terms of J by,

$$E_y = \frac{J_x}{pq\, B_z} \quad \text{------------ (5)}$$

$$E_y = \frac{J_x}{pq\,B_z} = J_x R_H B_z \quad \ldots\ldots\ldots\ldots\ldots(6)$$

Where R_H is Hall coefficient.

$$R_H = \frac{1}{pq} \quad \text{----------} \; (7)$$

Now let us express equation 6 in terms of measurable parameters

$$V_{AB}/w = \frac{I_x/wt\,B_z}{pq} \quad \ldots\ldots\ldots\ldots\ldots(8)$$

$$p = \frac{I_x B_z}{V_{AB}\,t} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (9)$$

We know that resistance (R) and resistivity (ρ) are correlated by the relation-

$$R = \rho \frac{l}{A} \quad \ldots\ldots\ldots\ldots\ldots \ (10)$$

For the sample in our case above expression can be written as I_x V_{CD}

$$\rho = \frac{V_{CD}}{I_x} \frac{wt}{L} \quad \ldots\ldots\ldots\ldots\ldots\ldots (11)$$

Also we know that –

$$\sigma = pq\mu_p$$

$$\mu_p = \frac{\sigma}{pq}$$

$$\mu_p = \sigma R_H = \frac{R_H}{\rho} \quad \ldots\ldots\ldots\ldots\ldots (12)$$

Applications of HALL effect:

1) Determination of semiconductor type:

- If HALL coefficient =>
- POSITIVE→ p-type semiconductor
- NEGATIVE→ n-type semiconductor

2) *Calculation of carrier concentration:*

- By measuring the V_H and R_H the carrier concentration of ELECTRONS in n-type
- semiconductor and HOLE concentration in p-type semiconductor is measured

3) *Determination of mobility of charge carriers:*

- The mobility of charge carriers is found by 3 and 4 eqn in the previous derivation.

4) *Measurement of magnetic flux density*

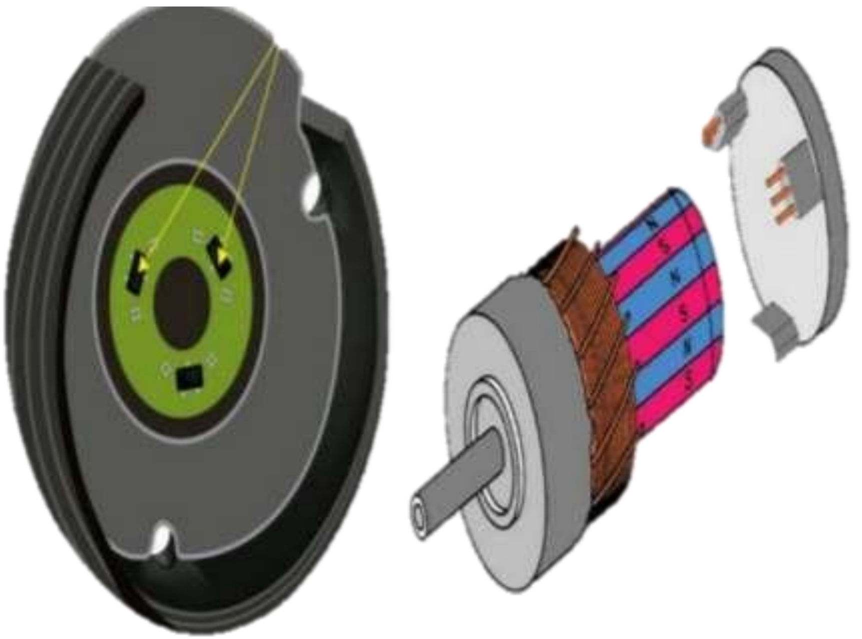
- HALL voltage V_H is directly proportional to the magnetic flux density B for a given current I for a semiconducting sample and is used in MAGNETIC FLUX DENSITY METER.

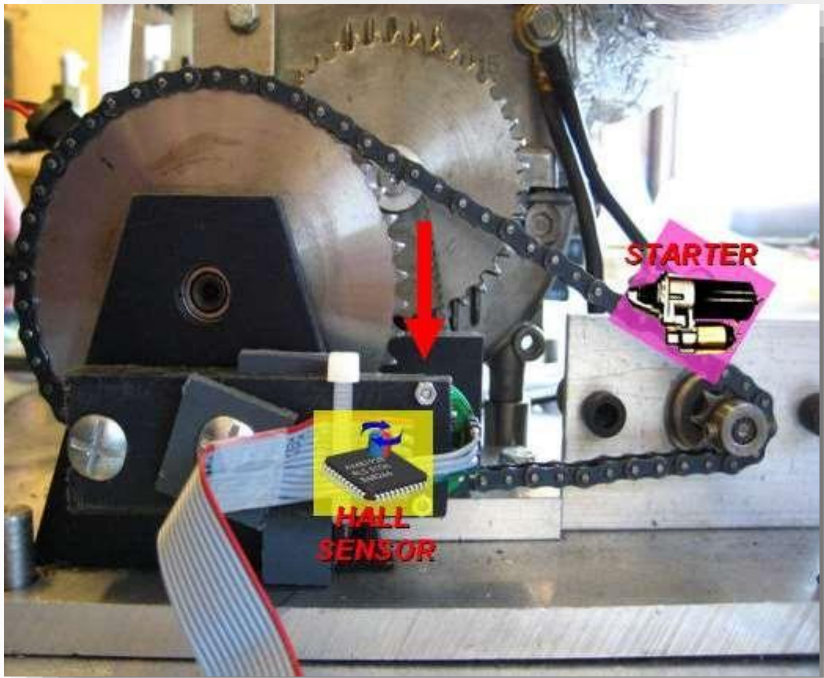
MAGNETOMETERS

- Smart phones are equipped with magnetic compass.
- These compass measure Earth's magnetic field using 3-axis magnetometer.
- These magnetometer are sensors based on Hall Effect.
- These sensors produce a voltage proportional to the applied magnetic field and also sense polarity.

POSITION SENSING IN BRUSHLESS DC ELECTRIC MOTORS

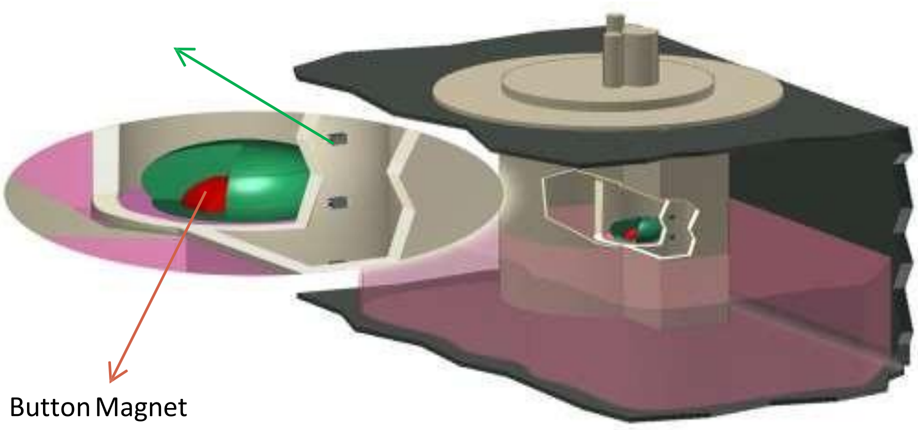
- Some types of brushless DC electric motors use Hall effect sensors to detect the position of the rotor and feed that information to the motor controller. This allows for more precise motor control.





AUTOMOTIVE FUEL LEVEL INDICATOR

- The main principle of operation of such indicator is position sensing of a floating element.
- When Button magnet is mounted on the surface of a floating object. The current carrying conductor is fixed on the top of the tank lining up with the magnet.
- As level of fuel rises, an increasing magnetic field is applied on the current resulting in higher Hall voltage.
- The fuel level is indicated and displayed by proper signal condition of Hall voltage.



THANKS FOR WATCHING