PHYSICS PRESENTATION

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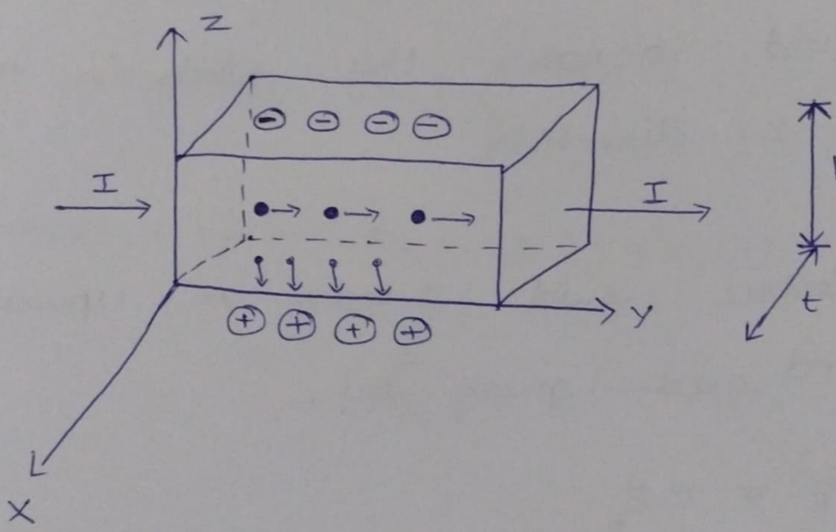
THEORY AND DERIVATION OF HALL EFFECT :-

* consider a rectangular slab of a p-type semiconductor material that carries a current I along the positive - y direction

* In a p-type semiconductor, holes are the majority charge carriers.



* Let a magnetic field B be applied along the positive x direction. Under the influence of this magnetic field, the holes experience a force called Lorentz force given by,

$$F_M = BeV_d = e|\vec{V_d} \times \vec{B}| \quad \left(\begin{array}{c} \text{As } \vec{V_d} \perp \vec{B}, \\ |\vec{V_d} \times \vec{B}| = V_d B \end{array} \right)$$

Here, e is the magnitude of a charge of hole and V_d is the drift velocity.

* This Lorentz force is exerted on the holes in the negative z- direction. Thus, the holes are deflected downward and collected at the bottom. surface.

* On the other hand, the top edge of the specimen becomes negatively charged due to the loss of holes. Hence, a potential called the Hall Voltage V_H is developed between the lower and upper surface, which establishes an electric field E called the Hallfield across the slab in the positive z- direction.

* This electric field exerts an upward force and is given by,

$$F_E = e E_h$$

* An equilibrium is reached between magnetic force and electric force and after that point, holes will travel undeflected.

$$F_E = F_M$$

$$e E_h = B e v_d$$

$$E_h = B v_d \longrightarrow (1)$$

* Here, b is taken as the distance between upper and lower surfaces.

$$V_H = E_h (b)$$

$$V_H = B v_d b \longrightarrow (2)$$

* If J is the current density, and bt is the area of the slab normal to the current flow.

$$J = I/bt$$

$$\cancel{n_h e v_d = I/bt}$$

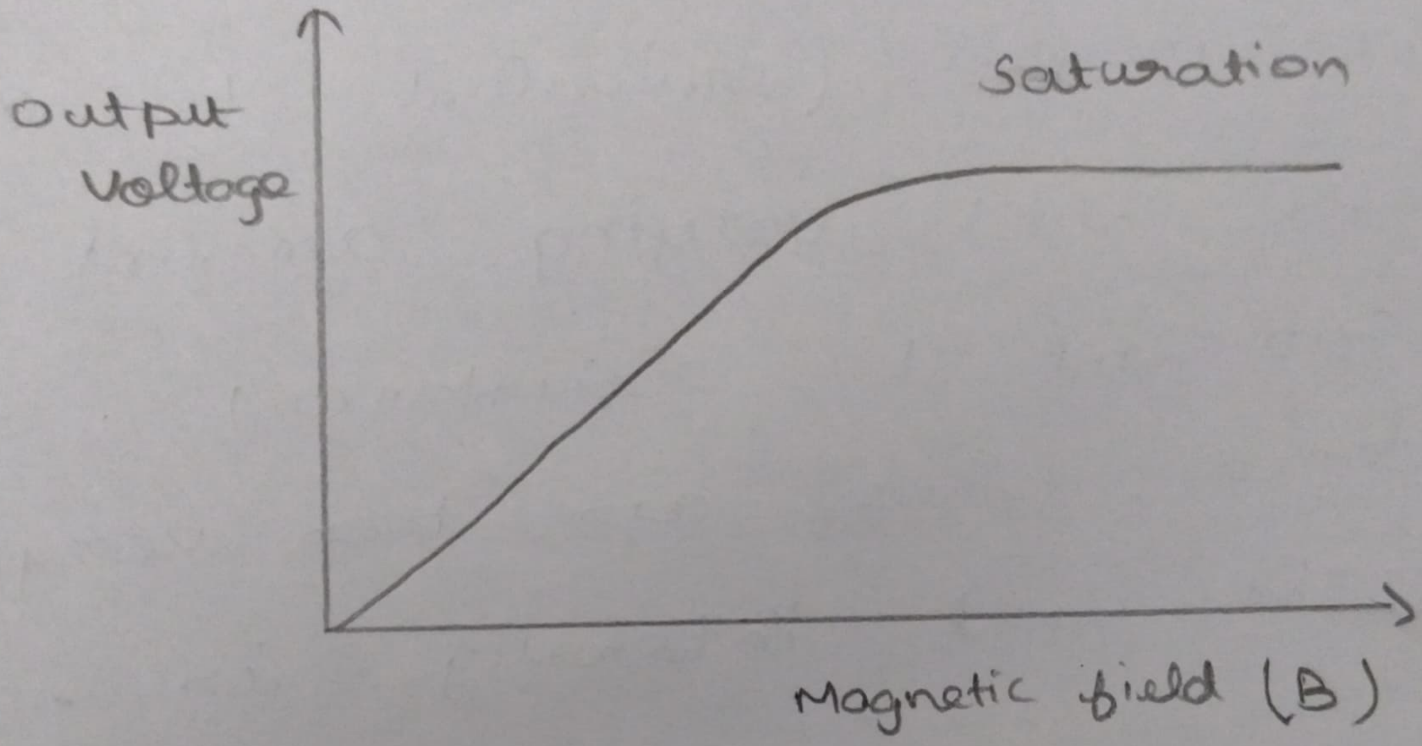
* Also, $J = n_h e v_d \longrightarrow (3)$

$$v_d = \frac{J}{n_h e} \longrightarrow (4)$$

* Substituiting (4) in (2)

$$V_H = B\left(\frac{J}{n_h e}\right) b$$

$$V_H = \frac{IB}{n_h e t}$$



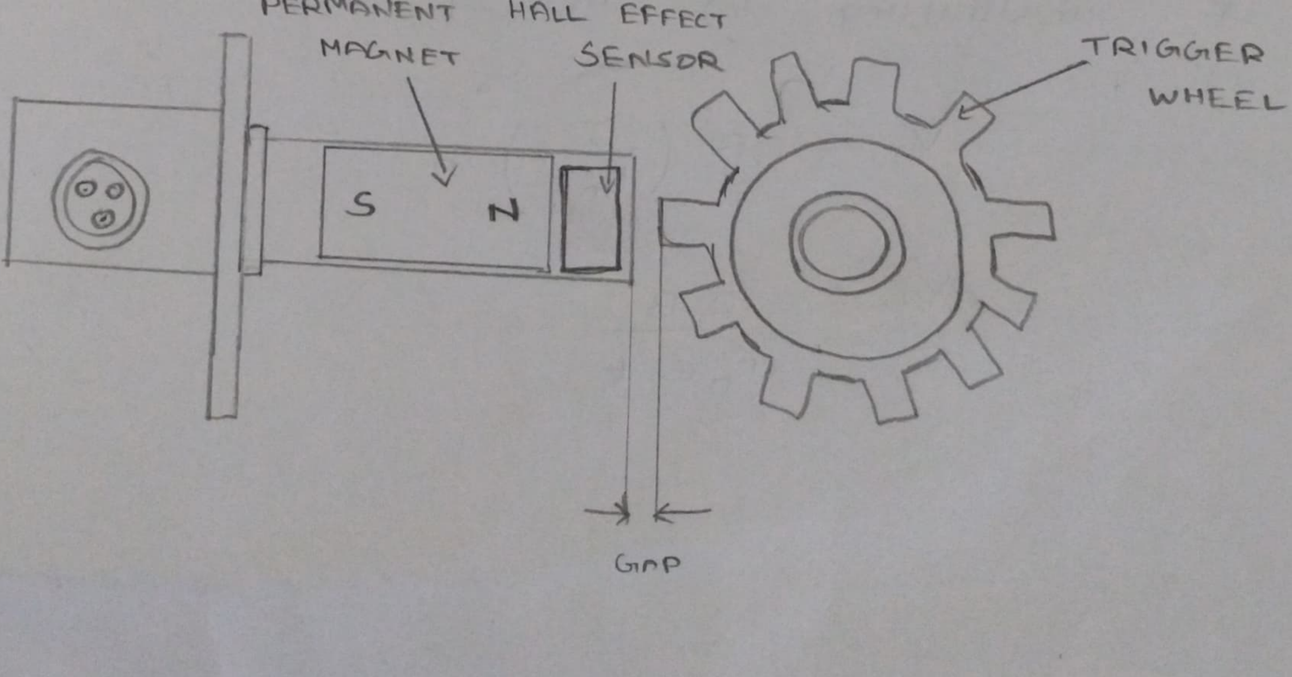
Output Voltage
Saturation
Magnetic field (B)

APPLICATIONS :-

This hall effect is used in making Hall sensors and these sensors are used in sensing speed of wheels, fuel level indicator, etc.

* Speed sensors in wheels :-

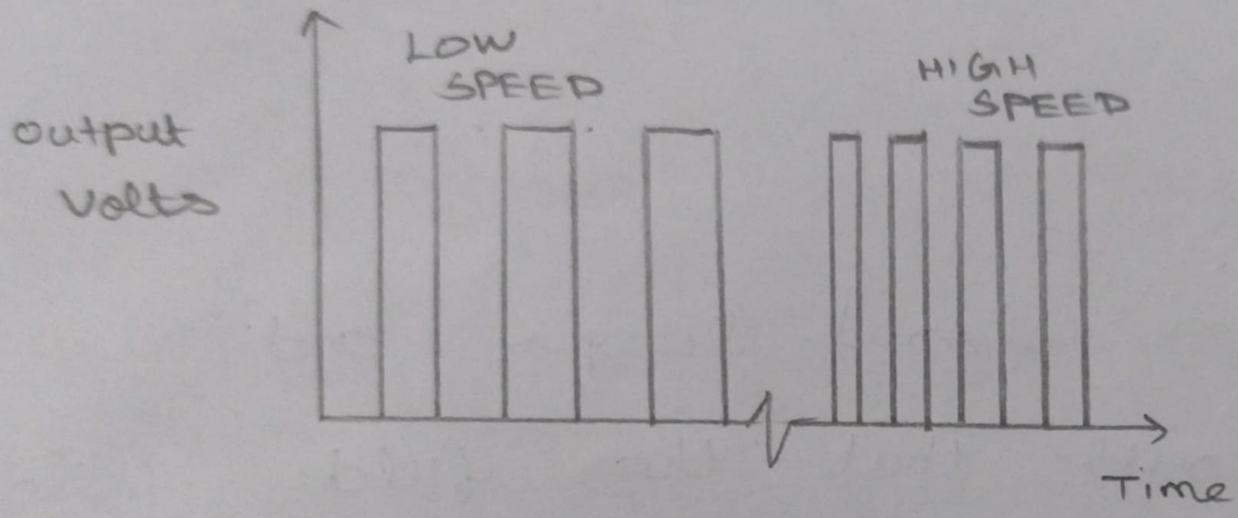
These sensors are composed of a Hall element and a permanent magnet which are placed near a toothed disk attatched on the rotating shaft. The basic hall element of the sensor provides very small voltage of only a few micro volts per Gauss, so these devices are manufactured with built-in-high gain amplifiers.



This type of sensor is known as 'variable reluctant sensor".

Magnetic fields form closed loops and we can think of the path that the field follows as a 'magnetic circuit'. This circuit includes a permanent magnet (equivalent to a battery) and materials with varying amount of reluctance (equivalent to resistance). Steel has low reluctance, while air has very high reluctance. The field intensity is equivalent to current.

In this case, the circuit includes the magnet, the gear, and other steel structures that hold them relative to each other. The gap between the sensor and the teeth of the disk is very small so each time a tooth pass near the sensor, it periodically increases and reduces the air gap in the magnetic circuit, which directely decreases and increases, respectively, the field intensity passing through the sensor. So, the output of the sensor is a square wave signal which can be easily used for calculating the RPM of the rotating shaft.



LOW SPEED
HIGH SPEED
output volts
Time