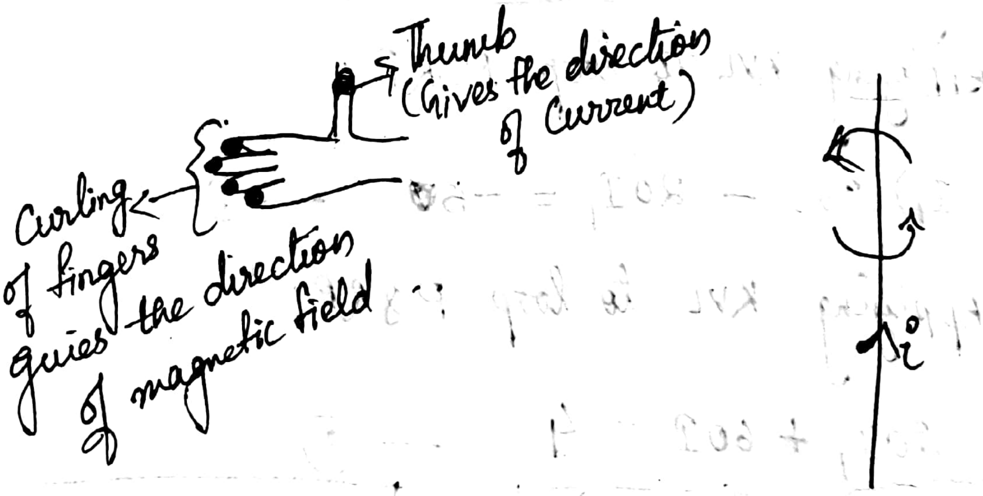
UNIT-II - Electromagnetism and Electromagnetic induction

Electromagnetism :- It is a process in which a magnetic field is created when a Current flows through a Conductor.

Right hand Thumb Rule :- This rule is used to find the direction of magnetic field due to Current in a Conductor.



Force acting on a Current carrying Conductor placed in a Uniform magnetic field :-

Consider a Conductor 'XY' placed in a Uniform magnetic field of magnetic induction $\vec{B}$ acting inward and perpendicular to the plane of paper.

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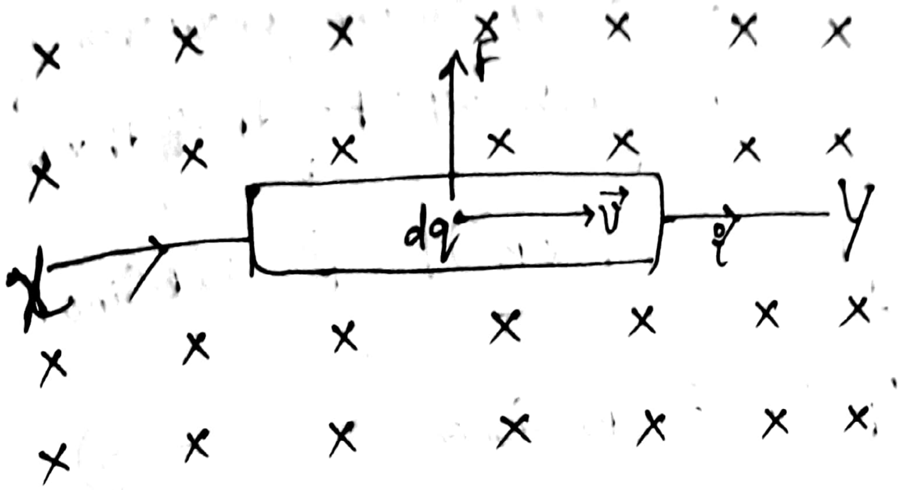


Let a current 'i' be flowing through the conductor from X to Y.

Let a small amount of positive charge 'dq' is moving from X to Y with a velocity 'V'.

The small amount of force acting on this charge is given by; $d\vec{F} = dq(\vec{V} \times \vec{B})$ —①

If the charge 'dq' moves a distance 'dl' in a time 'dt', then; $V = \frac{dl}{dt}$ —②

Substituting ② in ①;

$$d\vec{F} = dq\left(\frac{d\vec{l}}{dt} \times \vec{B}\right)$$

$$\Rightarrow dF = \frac{dq}{dt}(d\vec{l} \times \vec{B})$$

$$\Rightarrow dF = i(d\vec{l} \times \vec{B})$$

∴ Total force acting on the conductor of length 'l' is given by ; $F = \int dF = i \int_0^l (d\vec{l} \times \vec{B})$

$$\boxed{\vec{F} = i(\vec{l} \times \vec{B})} \Rightarrow \vec{F} = ilB\sin\theta\,\hat{n}$$

$$\boxed{|\vec{F}| = ilB\sin\theta} \quad \text{——— (3)}$$

The direction of $\vec{F}$ can be determined by using <u>Fleming's left hand Rule.</u>

<u>Case-1</u> When $\theta = 90°$, then from eqn (3)

$$|\vec{F}_{max}| = ilB.$$

∴ Maximum force is experienced by a charged particle which is moving at right angles to the direction of magnetic field.

<u>Case-2</u> When $\theta = 0°$ or $180°$, then from eqn (3) ; $F = 0$

∴ No force is experienced by a current carrying conductor when it is parallel to the lines of force (magnetic field).

<u>Electromagnetic Induction</u> :- The phenomenon by which a current is induced in a conductor due to change in magnetic field near the conductor is known as e.m induction.

Faraday's Laws of Electromagnetic Induction

① Whenever magnetic flux linked with a coil (circuit) changes an e.m.f is induced in the coil and current flows through the coil. The induced emf exists in the coil so long as the change in magnetic flux linked with the coil continues.

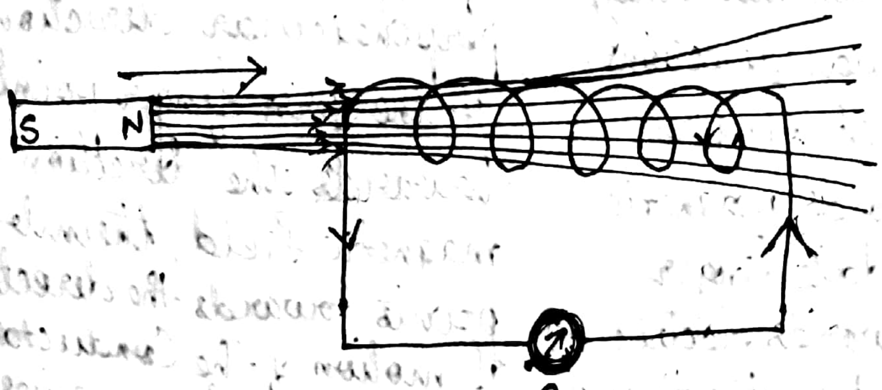
② The induced emf in the coil is directly proportional to the negative rate of change of magnetic flux linked with the coil.

i.e $E \propto -\frac{d\phi}{dt}$ $|E| = \frac{d\phi}{dt}$

$\Rightarrow E = -k\frac{d\phi}{dt}$

Taking $k = 1$; $\boxed{E = -\frac{d\phi}{dt}}$ $|\varepsilon| = \frac{d\phi}{dt}$

Negative sign is due to the direction of induced emf.



The direction of induced current is determined by Fleming's Right Hand Rule.

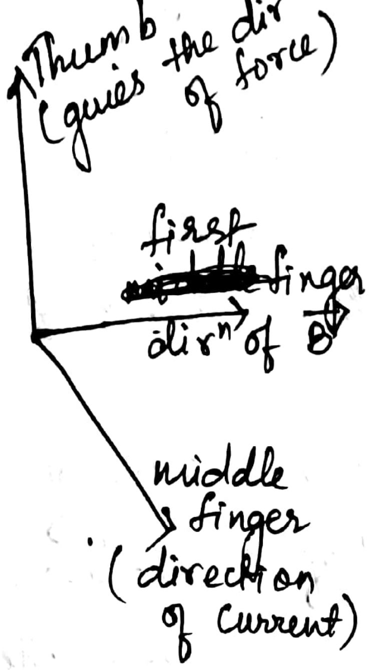
Lenz's Law:- It states that the direction of induced emf in a coil is such that it tends to oppose the cause which produces it.

$$\mathcal{E} = -\frac{d\phi}{dt}$$

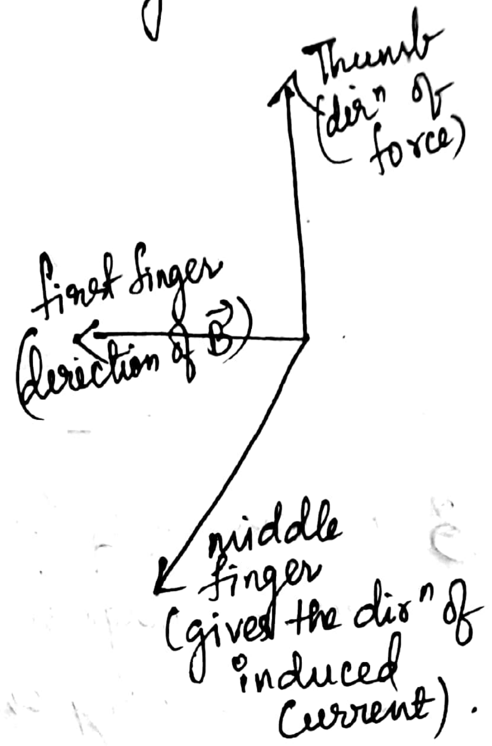
Difference between Fleming's Left Hand Rule and Fleming's Right Hand Rule:-

Fleming's Left Hand Rule.	Fleming's Right Hand Rule.
① The purpose of this rule is to find the direction of motion in an electric motor (direction of force).	① The purpose of this rule is to find the direction of induced current when a conductor moves in a magnetic field.
② According to this rule:- Stretch the first finger, middle finger and thumb of left hand in mutually perpendicular directions. If the first finger points towards magnetic field, middle finger points towards electric current, then the thumb gives the direction of force on the conductor.	② According to this rule:- Stretch the first finger, middle finger and thumb of right hand in mutually perpendicular directions. If the first finger points towards the direction of magnetic field, thumb points towards the direction of motion of the conductor, then middle finger gives the direction of induced current in the conductor.

③ It is used for electric motors.



③ It is used for electric generators.



Numericals:-

① A Small piece of metal wire is dragged across the gap between the pole pieces of a magnet in 0.5 Sec. The magnetic flux between the pole pieces is known to be 8×10^{-4} wb. Calculate the emf induced in the Wire.

Solⁿ:- Given ; $t = 0.5$ Sec , $\phi = 8 \times 10^{-4}$ wb

$$\therefore \mathcal{E} = \frac{\phi}{t} = \frac{8 \times 10^{-4}}{0.5} = \frac{8 \times 10}{5} \times 10^{-4}$$

$$= 16 \times 10^{-4} V$$

$$= 1.6 \times 10^{-3} V$$

② The magnetic flux through a coil perpendicular to the plane is varying according to the relation :-

$$\phi = (5t^3 + 4t^2 + 2t - 5)\ Wb$$

Calculate the induced current through the Coil at t = 2Sec, if the resistance of the Coil is 5Ω.

③ A current of 1A flows in a wire of length 0.1m in a magnetic field of 0.5T. Calculate the force acting on the wire when the wire makes an angle of (a) 90° (b) 0°, with respect to the magnetic field.