UNIT - 3

ELECTROMAGNETIC INDUCTION

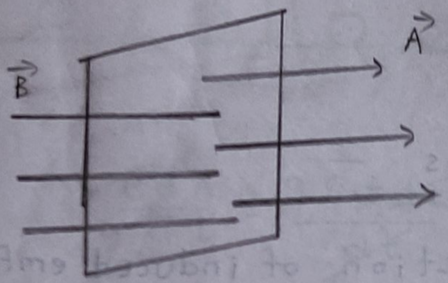
(Magnetic Induction & Circuits)

* When there is a relative motion between a magnet and a coil, an current (emf) is developed.

* No motion → No emf

Magnetic Flux (ϕ) ∝ No. of magnetic flux lines passing through the area

$$\boxed{\phi = \vec{B} \cdot \vec{A} = BA\cos\theta}$$



Angle between $\vec{A}$ & $\vec{B}$ = 0°

$\therefore \boxed{\theta = 0^\circ}$

$\phi = BA\cos 0^\circ = BA$ (max)

$$B = \frac{\phi}{A}$$

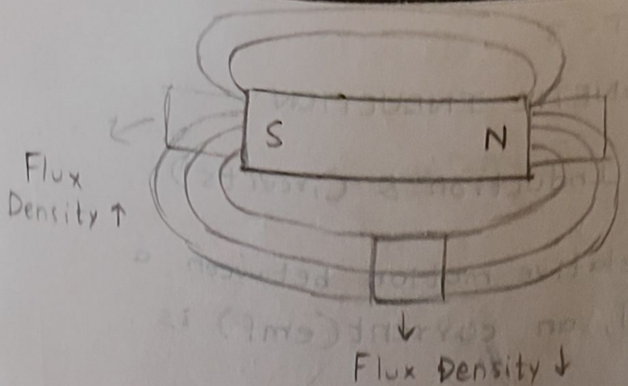
If $\theta = 90^\circ$; $\phi = 0$ (min)

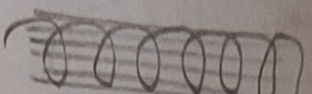
* Depending upon the angle (θ), the flux (ϕ) varies.

Unit of : $B \rightarrow Wb/m^2$ ($\because$ 1 Wb = 1 T.m

= T (SI-unit)

$\phi = Wb$





→ Flux Density is uniform inside the coil

Faraday's Law of Electromagnetic Induction:

i) First Law:

Magnitude of Induced EMF $\propto$ Rate at which the magnetic flux is changed

Lenz Law

$$E = -N \frac{d\phi_B}{dt}$$

where; $N \rightarrow$ no. of turns

Lenz's Law: The direction of induced emf will always oppose the motion of the magnetic field

Assignment: Lenz Law Applications

eg: $N = 5$ turns; $A = 0.002\ m^2$

$\frac{dB}{dt} = 0.4 T/s$ $\theta = 0$

$\phi_B = \int \vec{B} \cdot d\vec{A}$

$$E = -N \frac{d\phi_B}{dt} = -N \frac{d\int \vec{B} \cdot d\vec{A}}{dt}$$

BA

$$= -N \frac{d(BA)}{dt}$$

$$= -NA \frac{dB}{dt}$$

$$= -5 (0.002\ m^2)(0.4 \frac{T}{s})$$

$$= -0.004\ V$$

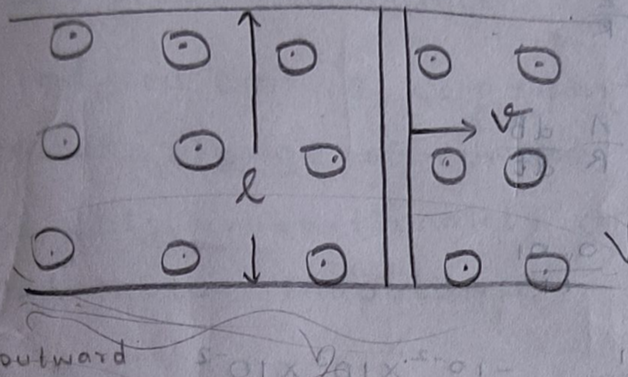
Q) An airplane travels 1000 km/h in a region where the Earth's magnetic field is about 5×10^{-5} T. What is the potential difference across the wing tip which is 70 m apart.

A) $|\mathcal{E}| = B l v$

$= (5 \times 10^{-5})(70)(280)$

$|\mathcal{E}| = 1$ V

EMF induced in a moving conductor:



$$\mathcal{E} = \frac{d\Phi_B}{dt} = \frac{B\,dA}{dt} = \frac{B l v \cancel{dt}}{\cancel{dt}} = B l v$$

This equation is valid as long as B, l and v are mutually perpendicular (If not, it is true for their perpendicular components).

Ex:) Blood contains charged ions, so blood flow can be measured by applying a magnetic field and measuring the induced emf. If a blood vessel is 2 mm in diameter and 0.08 T magnetic field causes an induced emf of 0.1 mV, what is the flow velocity.

A) $\mathcal{E} = B l v$

$v = \frac{\mathcal{E}}{B l} = \frac{0.1 \times 10^{-3}\ \text{V}}{(0.08\ \text{T}) \times (0.2 \times 10^{-3}\ \text{m})}$

$v = 0.63$ m/s

Q) A uniform magnetic field passes through a circular coil whose normal is parallel to the magnetic field. The coil's area is 10^{-2} m^2 and it has a resistance of $1\ m\Omega$.

B varies with time as show. Plot the current in the coil.

A) $$\mathcal{E} = -\frac{d\phi_B}{dt} = -\frac{d(BA)}{dt} = -A\frac{dB}{dt}$$

$$\mathcal{E} = IR \;; \quad I = \frac{\mathcal{E}}{R}$$

$$I = -\frac{A}{R}\frac{dB}{dt}$$

$$\frac{dB}{dt} = \frac{0.01-0}{11-0} = \frac{0.01}{11}$$

$$I = \frac{-10^{-2}}{10^{-3}} \times \frac{0.01}{11} = \frac{-10^{-2} \times 10^{3} \times 10^{-2}}{11}$$

$$= \frac{-10^{-2+3-2}}{11}$$

$$= \frac{-10^{-1}}{11} = -\frac{1}{11 \times 10} = -\frac{1}{110} = -9.09 \times 10^{-3}$$

Self induced emf & Self inductance :

The induced emf, e, in a coil is proportional to the rate of the change of the magnetic flux passing through it due to its own current. The emf is termed as "Self induced emf."