Physics Notes

BY

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Class:10+2
Unit: IV
Topic: Electromagnetic Induction & Alternating Currents

<u>*SYLLABUS*</u>: UNIT-IV-*A,B*

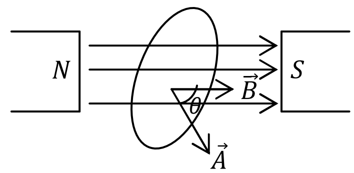
Electromagnetic induction; Faraday's law, induced emf and current; Lenz's Law; Eddy currents, Self and mutual inductance.
Need for displacement current.
Alternating current, peak and rms value of alternating current/voltage; reactance and impedance; LC oscillations (Qualitative treatment only), LCR series circuit, resonance; power in AC circuits, wattles current.
AC generator and transformer.

Q.1. What is magnetic flux? Scalar or Vector? Units? Dimensions?

Ans. **<u>Magnetic Flux</u>**:-

$$\Phi = \vec{B} \cdot \vec{A} = \text{B.A.} \cos\theta$$

Magnetic Flux is a <u>scalar quantity</u>.

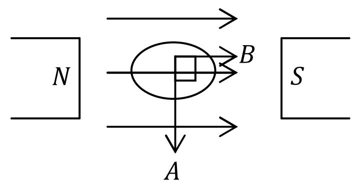


S.I. units → weber

1 weber = 1 tesla x $1m^2$

<u>Dimensional Formula</u>:-

$Case\ I\ \theta = 90^0, \phi\ is\ min.$



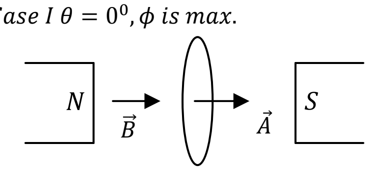
$$F = q\,V\,B$$

$$\frac{F}{qV} = B$$

$$\Phi = BA$$

$$= \frac{FA}{qV}$$

$Case\ I\ \theta = 0^0, \phi\ is\ max.$



$$= \frac{M^1L^1T^{-2} \cdot L^2}{A^1T^1T^{-1}}$$

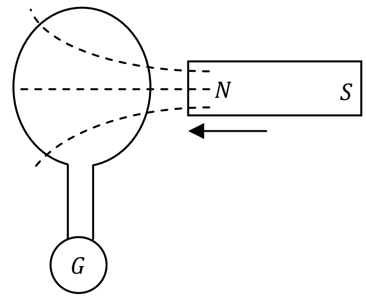
$$\boxed{[\Phi] = [M^1L^2T^{-2}\,A^{-1}]}$$

Problem: A ring of Area $2m^2$ is place in a magnetic filed of 0.4 tesla in following 2 position.

a) Ring axis parallel to magnetic field.
b) Ring axis perpendicular to magnetic field.

Solution:

Q2. **a) Discuss two experiments for production of EMI.**
b) Faraday's Law of EMI?

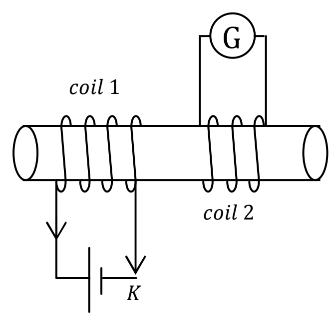


Ans.a) **<u>Faraday's Experiments</u>**:-

<u>Example 1</u>:- Current induced by a magnet

1. Whenever there is a relative motion between the coil and the magnet, the galvanometer shows a sudden deflection. This deflection indicate that current is induced in the coil.
2. The deflection is temporary. It lasts so long as relative motion between the coil and the magnet continues.
3. The deflection is more when the magnet is moved faster and less when the magnet is moved slowly.
4. The direction of deflection is reversed when same pole of magnet is moved in the opposite direction or opposite pole of magnet is moved in the same direction.

<u>Example 2</u>:-



When we press K, galvanometer G in coil 2 shows a sudden temporary deflection. This indicates current is induced in coil 2. This is because current in coil 1 increases from zero to a certain steady value increasing the magnetic field of coil 1 and hence the number of magnetic lines of force entering coil 2.

On releasing K, Galvanometer shows a sudden temporary deflection in the opposite direction.

b) **<u>Faraday Laws of Electromagnetic induction</u>**:-

<u>First Law</u>:

Whenever the amount of magnetic flux linked with a circuit changes, an *em.f.* is induced in the circuit. The induced *e.m.f.* lasts so long as the change in magnetic flux continues.

<u>Second Law</u>:

The magnitude of *e.m.f.* introduced in circuit is directly proportional to the rate of change of magnetic flux linked with the circuit.

Combining the two equations:-

$$e = \int E\,dl = \frac{-d\Phi}{dt}$$

$$|e| \ \alpha \ \left(\frac{d\Phi}{dt}\right)$$

$$|e| = \frac{d(BA\cos wt)}{dt}$$

Q3. a) Lenz's Law for direction of induced current?
b) Is Lenz's Law in accordance with Law of conservation of Energy?

Ans.a) **<u>Lenz's Law</u>**:-

Len's Law is used to find direction of induced *e.m.f.*

"Direction of induced e.m.f. is such that it tries to oppose the cause".

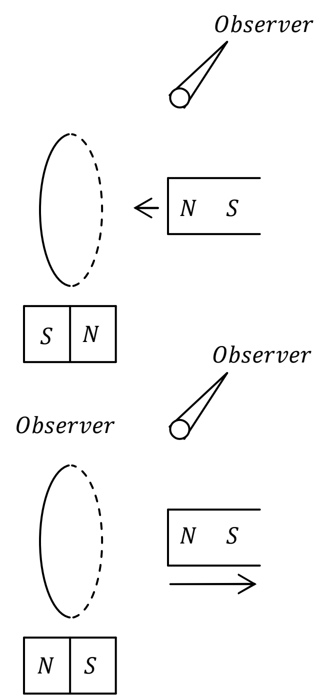
If we move *N* pole towards the ring, *e.m.f.* is such that it tries to oppose the cause.

Cause → "Moving N pole towards ring".

e.m.f. in the ring will oppose it.

Right face of the ring will become *N* pole observer will find current flowing in "*ACW*" direction.

If we move North pole away, observer will find current flowing in "*CW*" direction.



b) **<u>Lenz's Law and Energy conservation</u>**:-

Len's Law is in accordance with the law of conservation of energy.

<u>Example</u>:

In the experimental verification of Lenz's Law, when N pole of magnet is moved towards the coil, the upper face of the coil acquires North polarity, therefore, work has to be done against force of repulsion, in bringing the magnet closer to the coil.

It is the mechanical work done in moving the magnet *w.r.t* the coil that changes into electrical energy producing induced current. Thus energy is being transformed only.

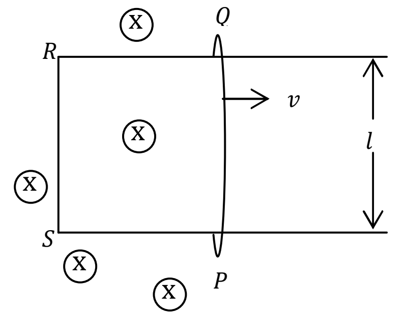
Conservation of Energy, therefore work has to be done against force of repulsion, mechanical work done in moving, electrical energy producing induced current, Energy is being transformed only.

Q4. **Discuss the following three methods of producing *emf***

a) **By changing Area**
b) **By changing Angle (Generator)**
c) **By changing *B* (changing *emf*) (Transformer)**

Ans.a) <u>**By changing Area**</u>:-

$Observer$



$$|e| = \frac{d\Phi}{dt}$$

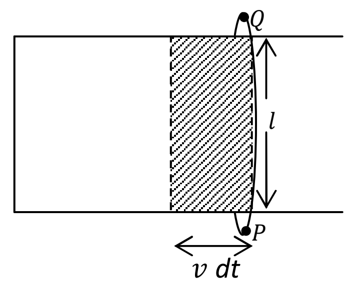
$$= \frac{d(BA\cos wt)}{dt}$$

$$= \text{B}\cos\theta\left(\frac{dA}{dt}\right)$$

$$= \text{B}\,(1)\left(\frac{dA}{dt}\right)$$

$$= \text{B}\,(1)\left(\frac{lvdt}{dt}\right)$$

$$\boxed{|e| = Blv}$$



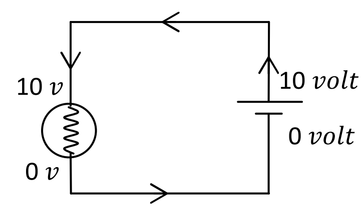
<u>Direction of current (in *PQ*)</u>

As per right hand rule, current flows *P* to *Q*

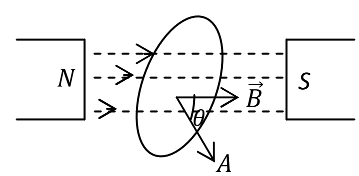
Which of the two (i.e. *P* or *Q*) is at high potential?

Ans:- *Q*

[**Hint**: In a resistance, current flows from high to low potential. In a cell current flows from low to high potential]



b) <u>**By changing Angle**</u>:-



$$\Phi = \text{BA}\cos\theta$$

$$|e| = \frac{d\Phi}{dt}$$

$$= \frac{BA\,d(\cos\theta)}{dt}$$

$$= \text{BA}\frac{d}{dt}(\cos\omega t)$$

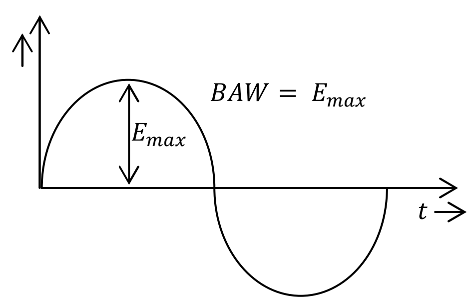
$$= \text{BA}\,(-\sin\omega t)\,\omega$$

$$|e| = (\text{BA}\,\omega) - \sin\omega t$$

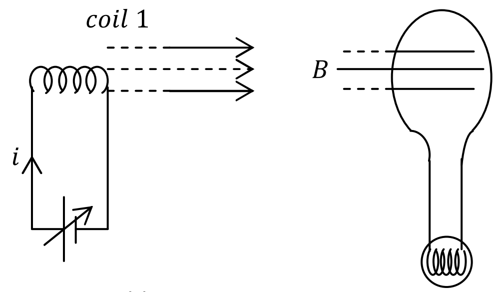
<u>**Shape of WAVE**</u>:-

ω, A, B → constant

$$|e| = (E_{max})\sin\omega t$$



c) **By changing *B*:-**



$$|e| = \frac{d\Phi}{dt}$$

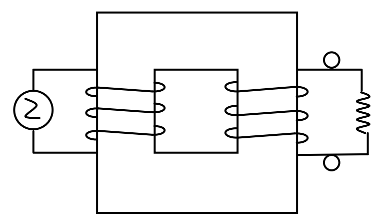
$$= \frac{d(BA\cos\theta)}{dt}$$

$$= A\cos\theta\,\frac{dB}{dt}$$

$$= A(1)\,\frac{dB}{dt}$$

$$|e| = A\,\frac{dB}{dt}$$

For domestic supply



$$B = B_0 \sin wt$$

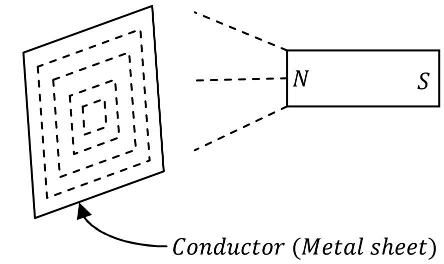
$$|e| = \frac{Ad(B_0 \sin wt)}{dt}$$

$$= A(1)\,B_0\,\omega\,\cos\,\omega t$$

$$= (B_0 A\,\omega)\cos\,\omega t$$

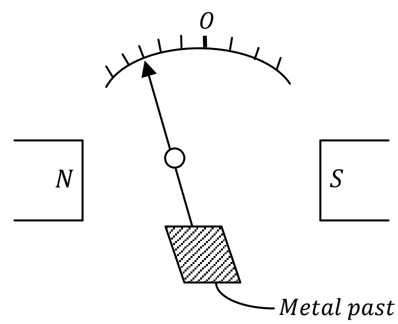
Q5. What are Eddy currents? Discuss few applications of Eddy currents?

Ans. Eddy currents are the currents induced in the body of a conductor when the amount of magnetic flux linked with the conductor changes. They are also called Foucault Currents.



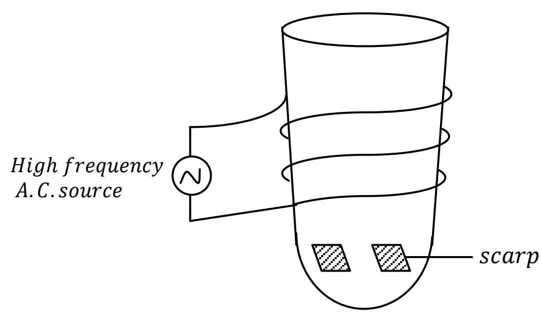
Applications of Eddy currents are:

1. Electro Magnetic damping

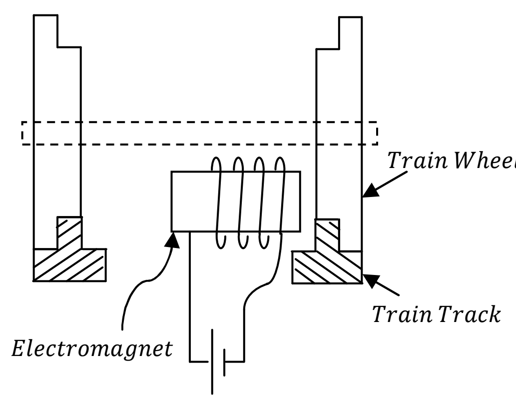


An ammeter without electromagnetic damping has high wait time. When a metal *M* is connected with pointer, an *emf* is induced in metal *M* which tries to oppose the cause i.e. relative motion this metal part will act as brakes and will provide the necessary electromagnetic damping.

2. Induction furnace



3. Electro Magnetic brakes



When wheels are in motion electromagnetic is applied and switched on due to which flux is induced and changes into magnet due to which *emf* is induced and opposes the cause.

Advantage: These are smooth causes.

4. Induction motor

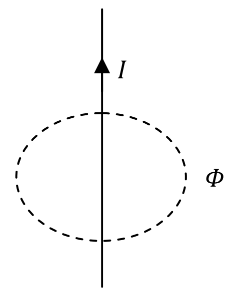
Rotating magnet filed is taken and cage is taken at the centre magnet rotates the cage.

5. In Speedometers of automobiles and energy meters

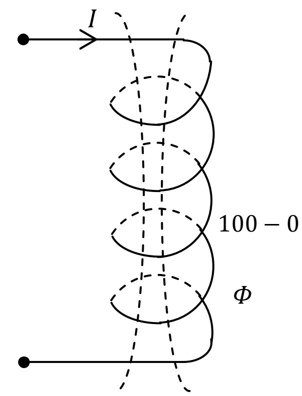
6. Eddy currents are also used in dia-thermy → in deep heat treatment of the human.

Q6. Define self induction? Self inductance coefficient? Units? Dimensions?

Ans. **Self Induction**:-



When current in a wire or in a coil increases, magnetic flux *Φ* also increases. As per *Faraday's Law* of *E.M.I.*, an *emf* is induced such that it tries to oppose the cause, In this case, cause is increase in current. So *emf* is induced so that it does not allow easy increase of current, Same is true for decrease in current.



Self induction is the property of a coil by virtue of which, the coil opposes any change in the strength of current flowing through it by inducing an *emf* in itself. For this reason, self induction is also called the inertia of electricity.

Self Inductance:-

Magnetic flux, $\Phi \;\; \alpha \;\; I$

$\Phi = (L)\, I$

(L) → Co-efficient of self inductance

$$\boxed{\frac{\Phi}{I} = L}$$

S.I. unit → Henry

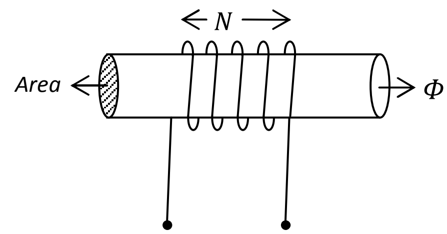
Dimensional Formula → $\frac{[\Phi]}{[I]} = \frac{[B][A]}{[I]} = M^1L^2A^{-2}T^{-2}$

Problem: A current of 2 amp in a wire produces a flux of 6 weber in surrounding space. Find self inductance of wire.

Solution:

Q7. **Prove self inductance of a solenoid is $\left(\frac{N^2}{reluctance}\right)$?**

Ans. **Self Inductance**:-



ψ = N. Φ is total flux likages

$$L = \frac{\psi}{I}$$

$$= \frac{N\Phi}{I}$$

$$= \frac{N.B.A}{I}$$

$$= \left(\frac{\mu_0 N\, I}{l}\right)\frac{AN}{I}$$

$$\left[\begin{aligned} B &= \mu_0.H \\ &= \mu_0.\frac{N.I}{l}\end{aligned}\right]$$

$$= \frac{N^2}{\frac{l}{\mu_0 A}}$$

$$\boxed{L = \frac{N^2}{R_e}}$$

$$\boxed{\left[Reluctance, R_e = \frac{l}{\mu_0.A}\right]}$$

$$e = \frac{-d(\Phi)}{dt}$$

$$= \frac{-d(LI)}{dt}$$

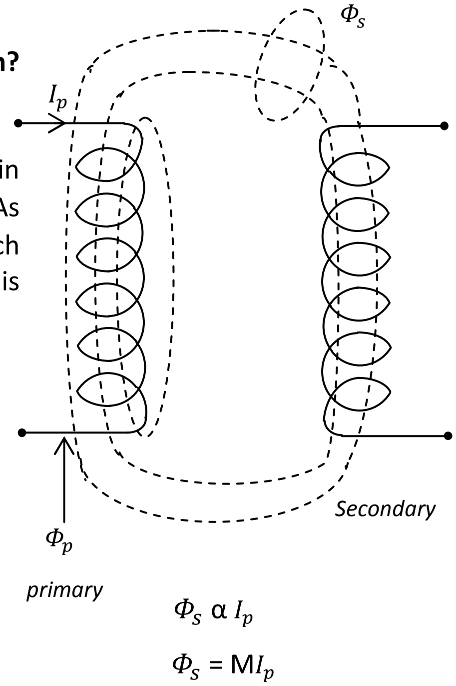
ψ = N. Φ is total flux likages

$$\boxed{e = \frac{-LdI}{dt}}$$

Problem: In an inductor of 3 *mH*, current of 5 *amp*. is reduced to *ZERO* in 3 seconds. Find *e.m.f* induced in inductor.

Solution:

Q8. What is Mutual Induction? Co-efficient of Mutual Induction? Units? Dimensions?



Ans. Current I_p in primary coil causes magnetic flux Φ_s in secondary coil, When current I_p increases Φ_s also increases. As per Faraday's Law of EMI, emf is induced in secondary coil such that it tries to oppose the cause, i.e. increase in I_p. This phenomenon is termed as phenomenon of mutual inductance.

Φ_s → Flux is secondary coil
I_p → Current in primary coil

$\Phi_s \;\alpha\; I_p$

$$\boxed{\Phi_s = M\, I_p}$$

M → Co-efficient of mutual inductance

SI units and dimensions of *M* are same as that of *L*.

Q9. Prove M = $\frac{N_1 N_2}{R_e}$?

Ans.

$$M = \frac{N_2 \Phi}{I_p}$$

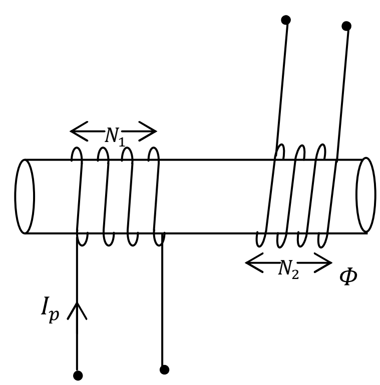
$$= \frac{N_2 (B_1 A_1)}{I_p}$$

$$= \frac{N_2\left[\left(\frac{\mu N_1\, I_p}{l}\right) A\right]}{I_p}$$

$$= \frac{N_1 N_2}{\left(\frac{l}{\mu A}\right)}$$

$$\boxed{M = \frac{N_1 N_2}{R_e}}$$

Here $Reluctance, R_e = \frac{l}{\mu . A}$



Where M = co-efficient of mutual inductance

N_1 = number of turns in coil 1

N_2 = number of turns in coil 2

R_e = reluctance