PHYSICS

CLASS NOTES FOR CBSE

Chapter 22. Electromagnetic Induction

01. Magnetic Flux

Proportional to the number of magnetic field lines passing through a surface. Denoted by ϕ_B.

$$\phi_B = \vec{B}.\vec{A} = BAcos\theta \qquad ...(i)$$

Where ϕ_B is the magnetic flux through a plane surface of area A placed in a uniform magnetic field B. θ is the angle between $\vec{B}$ and $\vec{A}$. Equation (i) can be extended to curved surfaced and non-uniform fields.

If the magnetic field has different magnitudes and directions at various parts of a surface the magnetic flux through the surface.

$$\phi_B = \vec{B_1}.\vec{dA_1} + \vec{B_2}.\vec{dA_2} + ... = \sum_{ALL} \vec{B_i}.\vec{dA_i}$$

02. Faraday's Law of Induction

The magnitude of the induced emf in a circuit is equal to the time rate of change of magnetic flux through the circuit.

$$e_{(t)} = -\frac{d}{dt}\phi_{(t)}$$

The average induced emf $\bar{e} = -\frac{\Delta\phi}{\Delta t} = -\left[\frac{\phi_2 - \phi_1}{t_2 - t_1}\right]$

In case of a closely wound coil of N turns, change of flux.

induced emf $\qquad e_{(t)} = -N\frac{d}{dt}\phi_{(t)}$

Lenz's Law :

The direction of induced emf (i.e., polarity of induced emf) and hence the direction of induced current in a closed circuit is to oppose the case due to which they are produced. For example, if the flux is increasing, induced emf (and hence induced current) will try to decrease the flux and vice-versa.

To Change the Magnetic Flux :

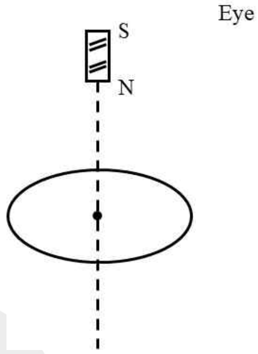
(i) Change the magnitude B of the magnetic field within the coil.

(ii) Change either the total area of the coil or the portion of that area that lies within the magnetic field.

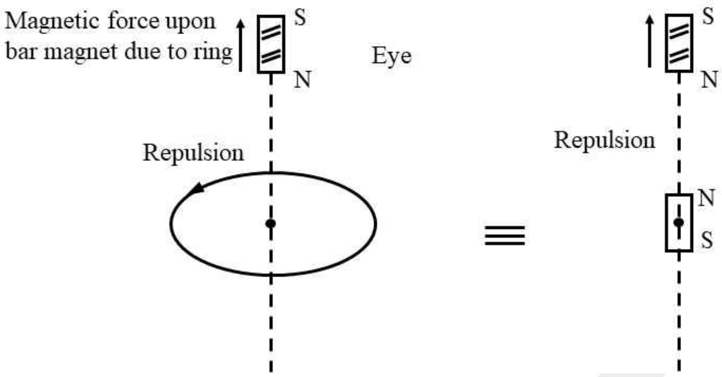
(iii) Change the angle between the direction of the magnetic field B and the plane of coil.

Lenz's law is in accordance with law of conservation of energy. As the induced emf opposes the change in flux, work has to be done against the opposition offered by induced emf/current in changing the flux. The work done appears as electrical energy in the circuit.

Example 1 A bar magnet is dropped through a horizontal aluminium ring along the axis of the ring. What will be direction of induced current in the loop for the observer shown? What will be the direction of magnetic fore experienced by the bar magnet?

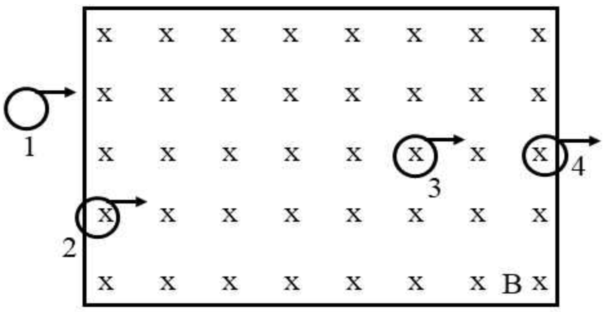


Solution 1 As per Lenz's law, induced current in the loop will be such that it will oppose the cause of change in flux (that is motion of the bar magnet towards itself). Thus current flows in the loop so that it is equivalent to a bar magnet with its North facing the approaching North pole of the magnet thereby repelling it. Thus current for the observer will be anticlockwise.



Thus, acceleration of the bar magnet a < g.

Example 2 A conducting loop is moving from left to right through a region of uniform magnetic (B) field. Its four positions are shown below. Show the direction of induced current in all four positions.



Solution 2 In situation 1 and 3 flux is constant and not changing with time, so there will not be any current induced. In situation 2 the loop is gradually getting into the magnetic field so overlapped area is increasing, so flux is increasing & hence the induced current will have the tendency to create B field in opposite direction i.e. in outward direction. Hence, anticlockwise current will be induced in the loop in situation 2. In situation 4 the loop is gradually getting out of the field, flux is decreasing, so induced current will support the B field. Current induced will be clockwise.

03. Eddy Current

Even when bulk pieces of conductors are subjected to changing magnetic flux, induced currents are produced in them. However, their flow patterns resembles swirling eddies in water. These currents are called eddy currents.

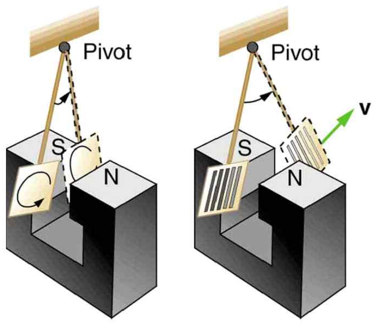


Fig. Eddy currents are generated in the copper plate, while entering and leaving the region of magnetic field.

Eddy currents are undesirable since they heat up the core and dissipate electrical energy in the form of heart. Eddy currents are minimised by using laminations of metal to make a metal core. The laminations are separated by an insulating material like lacquer. The plane of the laminations must be arranged parallel to the magnetic field, so that they cut across the eddy current paths. Eddy currents are used to take advantage in certain application

(i) Magnetic braking in trains
(ii) Electromagnetic damping
(iii) Induction furnace
(iv) Electric power meters

04. Self Inductances of Coil

Consider a long solenoid having number of turns per unit length n. Consider a section of this solenoid of length l. We have to find self inductances of this section. Magnetic flux linkage through the coil under consideration

$$\phi_B = \vec{B}.\vec{A} = (\mu_0 n I)(A n l) = \mu_0 n^2 A \times l I$$

$$L = \frac{\phi_B}{I} = \mu_0 n^2 . A \times l$$