FARADAY'S LAW OF ELECTROMAGNETIC INDUCTION

Based on various experiments, Michael Faraday drew the following conclusions:

1. Whenever there's movement between a magnet (which creates a magnetic field) and a closed conducting loop, electric current is generated in the loop. This occurs due to the changing magnetic flux associated with the loop.
2. Because emf (electromotive force) induces current in a circuit, when the loop and magnet are set in relative motion, current flows in the loop. This means that an emf is established in the loop. This emf, known as induced emf, is directly proportional to the rate at which the magnetic flux through the loop changes over time.

   Now, let's delve into Faraday's law of electromagnetic induction. Mathematically, the induced electromotive force (emf) can be expressed by the following equation:

$$\varepsilon = -\frac{d\varphi_B}{dt}$$

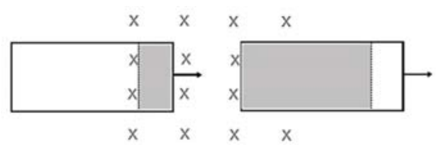
   Faraday's law alone provides the details about the size and direction of induced emf. However, Lenz's rule is often applied to figure out the direction of the induced current or the polarity of the induced emf.

Take note of the following information about Faraday's law:

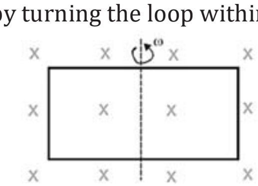
1. Just like we learned before, the induced emf occurs when there's a change in magnetic flux passing through a loop. The formula for the flux passing through the loop is $\phi = BA\cos\theta$. This means that the flux can be altered in various ways.

   The strength of $\vec{B}$, which represents the magnetic field, can vary over time. In situations where the magnetic field is provided as a function of time in a problem, it indicates that the magnetic field is changing, denoted as $B = B(t)$.

   The space inside the loop can change over time. You can make this happen by moving the loop into or out of a magnetic field. When you do this, the area within the loop (the shaded part) can be altered.



   The angle θ between $\vec{B}$ (magnetic field) and the perpendicular line to the loop can change over time. This change can be achieved by turning the loop within a magnetic field.



   Any combination of the above can occur.

2. If you make changes to the magnetic field passing through a loop, it creates an induced electric current in the circuit, thanks to the induced electromotive force (emf). If the circuit has a resistance represented by R, the induced current can be calculated using the following formula:

$$i = \frac{e}{R} = \frac{1}{R}\left(\frac{-d\phi_B}{dt}\right)$$

   Current starts flowing in the circuit, i.e., flow of charge takes place. Charge flown in the circuit in time dt will be given by

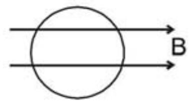
$$dq = i.dt = \frac{1}{R}(-d\phi_B)$$

   Thus, for a time interval Δt we can write

$$e = -\frac{\Delta\phi_B}{\Delta t}, i = \frac{1}{R}\left(\frac{-\Delta\phi_B}{dt}\right) \text{ and } \Delta q = i\Delta t = \frac{1}{R}(-\Delta\phi_B)$$

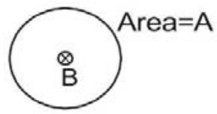
By looking at these equations, we can understand that e (induced emf) and i (induced current) are inversely related to Δt (time change), and Δq (charge change) is not influenced by Δt. It relies on the size of the flux change, not the time it takes.

Ex. A coil is placed in a constant magnetic field .The magnetic field is parallel to the plane of the coil as shown in figure. Find the emf induced in the coil.



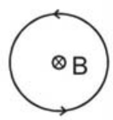
Sol. : $\phi = 0$ (always) since area is perpendicular to magnetic field.
$\therefore$ emf $= 0$

Ex. Find the emf induced in the coil shown in figure. The magnetic field is perpendicular to the plane of the coil and is constant.



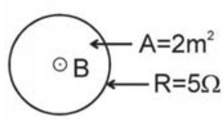
Sol. : $\phi = BA$ (always)
$= $ const.
$\therefore$ emf $= 0$

Ex. Find the direction of induced current in the coil shown in figure. Magnetic field is perpendicular to the plane of coil and it is increasing with time.



Sol. : Inward flux is increasing with time. To opposite it outward magnetic field should be induced. Hence current will flow anticlockwise

Ex. Figure shows a coil placed in decreasing magnetic field applied perpendicular to the plane of coil. The magnetic field is decreasing at a rate of 10T/s. Find out current in magnitude and direction



Sol. : $\phi = B.A$
emf $= A \cdot \frac{dB}{dt} = 2 \times 10 = 20$v
$\therefore$ i $= \frac{20}{5} = 4$ amp. From Lenz's law direction of current will be anticlockwise.