Physics Notes for Class 12 chapter 6 ELECTROMAGNETIC I NDUCTION

Whenever the magnetic flux linked with an electric circuit changes, an emf is induced in the circuit. This phenomenon is called **electromagnetic induction**.

Faraday's Laws of Electromagnetic Induction

(i) Whenever the magnetic flux linked with a circuit changes, an induced emf is produced in it.

(ii) The induced emf lasts so long as the change in magnetic flux continues.

(iii) The magnitude of induced emf is directly proportional to the rate of change in magnetic flux, i.e.,

$E \propto d\varphi / dt \Rightarrow E = -d\varphi / dt$

where constant of proportionality is one and negative sign indicates Lenz's law.

Here, flux = NBA cos θ, SI unit of φ = weber,

CGS unit of φ = maxwell, 1 weber = 10^8 maxwell,

Dimensional formula of magnetic flux

$[\varphi] = [ML^2T^{-2}A^{-2}]$

Lenz's law

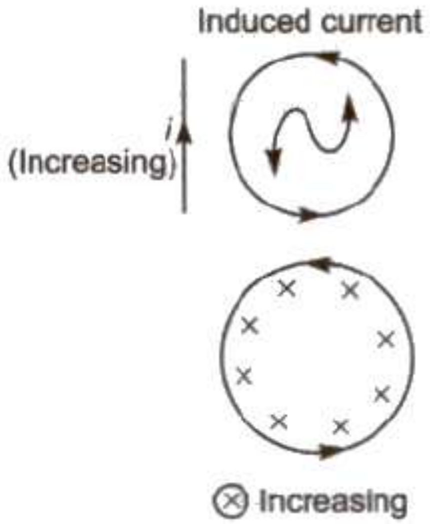
The direction of induced emf or induced current is always in such a way that it opposes the cause due to which it is produced.

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

Note To apply Lenz's law, you can remember RIN or ® In (when the loop lies on the plane of paper)

(i) RIN In RIN, R stands for right, I stands for increasing and N for north pole (anticlockwise). It means, if a loop is placed on the right side of a straight current carrying conductor and the current in the conductor is increasing, then induced current in the loop is anticlockwise

(ii) ®**IN** In ® IN suppose the magnetic field in the loop is perpendicular to paper inwards ® and this field is increasing, then induced current in the loop is anticlockwise 

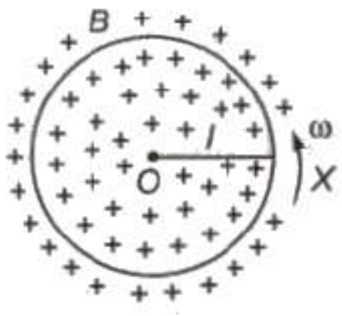


Motional Emf

If a rod of length 1 moves perpendicular to a magnetic field B, with a velocity v, then induced emf produced in it given by

E = B * v * I = bvl

If a metallic rod of length 1 rotates about one of its ends in a plane perpendicular to the magnetic field, then the induced emf produced across its ends is given by



$E = 1 / 2\ b\omega r^2 = BAf$

where, ω = angular velocity of rotation, f = frequency of rotation and $A = \pi r^2$ = area of disc.

The direction of induced current in any conductor can be obtained from Fleming’s right hand rule.

A rectangular coil moves linearly in a field when coil moves with constant velocity in a uniform magnetic field, flux and induced emf will be zero.

A rod moves at an angle θ with the direction of magnetic field, velocity $E = -Blv\sin\theta$.

An emf is induced

(i) When a magnet is moved with respect to a coil.

(ii) When a conductor falls freely in East-West direction.

(iii) When an aeroplane flies horizontally.

(iv) When strength of current flowing in a coil is increased or decreased, induced current is developed in the coil in same or opposite direction.

(v) When a train moves horizontally in any direction.

Fleming's Right Hand Rule

If we stretch the thumb, the forefinger and the central finger of right hand in such a way that all three are perpendicular to each other, th. if thumb represent the direction of motion, the forefinger represent tile direction of magnetic field, then centra} finger will represent the direction of induced current.

If R is the electrical resistance of the circuit, then induced current in the circuit is given by $I = E / R$

If induced current is produced in a coil rotated in uniform magnetic field, then

$I = NBA\,\omega \sin \omega t / R = I_o \sin \omega t$

where, $I_o = NBA\,\omega$ = peak value of induced current,

N = number of turns in the coil ,

B= magnetic induction,

ω = angular velocity of rotation and

A = area of cross-section of the coil.

Eddy Currents

If a piece of metal is placed in a varying magnetic field or rotated high speed in a uniform magnetic field, then induced current set up
the piece are like whire pool of air, called eddy currents.

The magnitude 0f eddy currents is given by $i = -e / R = d\varphi / dt / R$, where R is the resistance.

Eddy currents are also known as Facault's current.

Self-Induction

The phenomena of production of induced emf in a circuit due to change in current flowing in its own, is called self induction.

Coefficient of Self-Induction

The magnetic flux linked with a coil

$\varphi = LI$

where, L = = coefficient of self induction.

The induced emf in the coil

$E = -L\, dl / dt$

it unit of self induction is henry (H) and its dimensional formula is $[ML^2T^{-2}A^{-2}]$.

Self – inductance of a long solenoid is given by normal text

$L = \mu_o N^2 A / l = \mu_o n^2 Al$

where. N = total number of turns in the solenoid,

1 = length of the coil, n = number of turns in the coil and

A = area of cross-section of the coil.

If core of the solenoid is of any other magnetic material, then

$L = \mu_o \mu_r N^2 A / l$

Self – inductance of a toroid $L = \mu_o N^2 A / 2\pi r$

Where, r = radius of the toroid

Energy stored in an inductor $E = 1 / 2\ LI^2$

Mutual Induction

The phenomena of production of induced emf in a circuit due to the change in magnetic flux in its neighbouring circuit, is called mutual induction.

Coefficient of Mutual Induction

If two coils are coupled with each, other then magnetic flux linked with a Coil (secondary coil)

$\varphi = MI$

where M is coefficient of mutual induction and I is current flow in through primary coil.

The induced emf in the secondary coil

$E = – M\, dl / dt$

where dl / dt is the rate of change of current through primary coil.

The unit of coefficient of mutual induction is henry (H) and its dimension is $[ML^2T^{-2}A^{-2}]$.

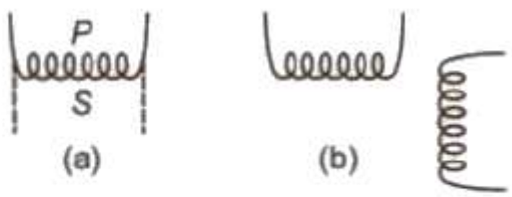
The coefficient of mutual induction depends on geometry of two coils, distance between them and orientation of the two coils.

Coefficient of Coupling

Two coils are said to be coupled if full a part of the fuse produced by one links with the other.

$K = \sqrt{}M / L_1$ L2, where L_1 and L_2 are coefficients of self-induction of the two coils and M is coefficient of mutual induction of the two coils.

Coefficient of coupling is maximum (K = 1) in case (a), when coils are coaxial and minimum in case (b), when coils are placed a right angles.



Mutual inductance of two long coaxial solenoids is given by

$M = \mu N_1 N_2 A / l$

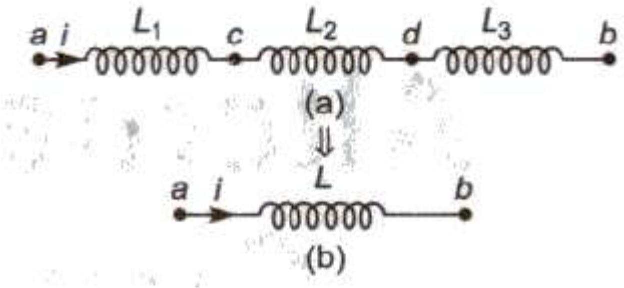
$= \mu n_1 n_2 Al$

where N_1 and N_2 are total number of turns in both coils, n_1 n_2 are number of turns per unit length in coils, A is area of cross-section of coils and 1 is length of the coils.

Grouping of Coils

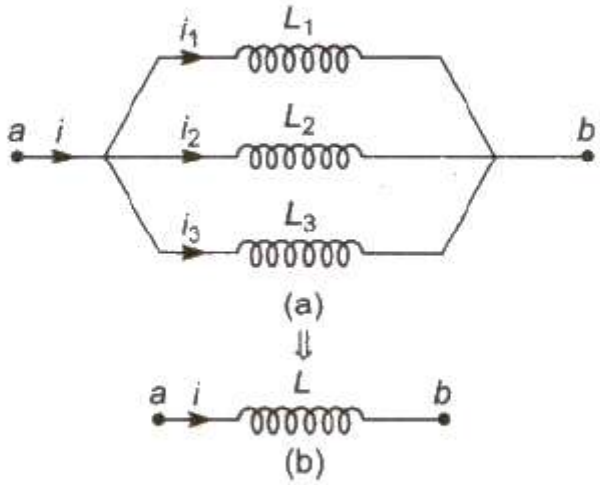
(a) When three coils of inductances L_1, L_2 and L_3 are connected in series and the coefficient of coupling K = 0, as in series, then

$L = L_1 + L_2 + L_3$



(b) When three coils of inductances L_1, L_2 and L_3 are connected in parallel and the coefficient of coupling K= 0 as in parallel, then

$L = 1 / L_1 + 1 / L_2 + 1 / L_3$



If coefficient of coupling K = 1, then

(i) **In series**

(a) If current in two coils are in the same direction, then

$L = L_1 + L_2 + 2M$

(b) If current in two coils are in opposite directions, then

$L = L_1 + L_2 – 2M$

(ii) **In parallel**

(a) If current in two coils are in same direction, then

$L = L_1 L_2 – M^2 / L_1 + L_2 + 2M$

(b) If current in two coils are in opposite directions, then

$L = L_1 L_2 – M^2 / L_1 + L_2 – 2M$