ELECTROMAGNETIC INTERFERENCE

Magnetic Flux:

(i) The magnetic flux through a small area $d\vec{A}$ placed in a magnetic field $\vec{B}$ is defined as:

$$d\phi = \vec{B}.d\vec{A} = B(dA)\cos\theta$$

(ii) The magnetic flux can be positive, negative or zero depending on the angle θ. For $\theta = 90^o$ and $\phi = 0$. Thus, whenever the angle between area vector, and magnetic field is 90°, the flux is zero, i.e., whenever the plane of the surface is parallel to $\vec{B}$, the flux is zero. The flux is positive for $0^o \le \theta \le 90^o$ and negative for $180^o \ge \theta \ge 90^o$.

(iii) The magnetic flux through a closed surface is always zero, i.e.,

$$\phi = \oint \vec{B}.d\vec{A} = 0 \;;$$ This equation suggests, there is no existance of monopoles.

Laws of electromagnetic induciton:

(i) First law: Whenever there occurs a change in the magnetic flux linked with a coil, there is produced an induced e.m.f. in the coil. The induced e.m.f. lasts so long as the change in flux is taking place. There is an induced current only when coil circuit is complete.

(ii) Second Law : The magnitude of induced e.m.f. is equal to the rate of change in the magnetic flux, i.e. $e \propto (d\phi/dt)$. For N turns, $e \propto N(d\phi/dt)$

Lenz's Law :

The direction of the induced current is such that it tends to oppose the cause of change in magnetic flux.

(a) Combining with Faradays law of EMI, we have $e = -N.\frac{d\phi}{dt}$ for N number of turns.

(b) Lenz's law is based on law of conservation of energy.

Some other important points:

(i) The induced e.m.f. in a circuit does not depend on the resistance of the circuit as $e = -\frac{d\phi}{dt}$. However, the induced current in the circuit does depend on the resistance.

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

(ii) The induced charge that flows in the circuit depends on the change of flux only and not on how fast or slow the flux changes.

$$\frac{dq}{dt} = -\frac{1}{R}\left(\frac{d\phi}{dt}\right) \quad \text{or} \quad dq = \frac{d\phi}{R}$$

On integrating, the total charge that flows in the circuit is found to be:

$$q = \frac{(\phi_1 - \phi_2)}{R}$$

Induced E.M.F. across a conducting rod:

(i) Conducting rod moving in a uniform magnetic field: When a conducting rod of length l moves with a velocity υ in a uniform magnetic field of induction B such that the plane containing $\vec{\upsilon}$ and l makes an angle θ with $\vec{B}$ thent he magnitude of the average induced e.m.f. |e| is given by : $|e| = \upsilon Bl\sin\theta$

(ii) Conducting rod rotating with angular velocity ω in a uniform magnetic field : When a rod of length l rotates with angular velocity ω in a uniform magnetic field B, then induced e.m.f. across the ends of the rotating rod is : $e = (1/2)B\omega l^2 = B\pi f l^2 = BAf$

where $A = \pi l^2$ = area swept by the rod in one rotation and f is the frequency of rotation.

Self-inductance :

(i) When a current I flows through a coil, it produces a magnetid flux ϕ through it. Then $\phi \propto I$ or $\phi = LI$, where L is constant, called the coefficient of self-in-duction or self-inductance of the coil.

(ii) Further, $e = -(d\phi/dt) = -\frac{d}{dt}(LI) = -L(dI/dt)$

(iii) Self-inductance L of a solenoid ofN turns, length l, area of cross-section A, with a core material of relative permeability μ_r is given by : $L = \mu_r\left(\frac{\mu_0}{4\pi}\right)\frac{4\pi N^2 A}{l}$

Mutual inductance :

(i) When a current I flowing in the primary coil produces a magnetic flux ϕ in the secondary coil, then $\phi \propto I$ or $\phi = MI$, where M is a constant, called the coefficient of mutual induction or mutual inductance.

(ii) $e = -\frac{d\phi}{dt} = -\frac{d}{dt}(MI) = -M\left(\frac{dI}{dt}\right)$

(iii) Mutual inductance M of two coaxial solenoid is given by : $M = \mu_r\left(\frac{\mu_0}{4\pi}\right)\frac{4\pi N_1 N_2 A}{l}$

where N_1 and N_2 represent the total number of turns in the primary coil and the secondary coil.

Series and parallel combination of inductances :

(i) Two inductors of self-inductances L_1 and L_2 are kept so far apart that their mutual inductance is zero. These are connected in series. Then the equivalent inductance is : $L = L_1 + L_2$

(ii) Two inductors of self-inductances L_1 and L_2 are connected in series and they have mutual inductance M. Then the equivalent inductance of the combination is : $L = L_1 + L_2 \pm 2M$

The plus sign occurs if windings in the two coils are in the same sense, while minus sign occurs if windings are in opposite sense.

(iii) Two inductors of self-inductances L_1 and L_2 are connected in parallel. The inductors are so far apart that their mutual inductance is negligible. Then their equivalent inductance is :

$$L = \frac{L_1 L_2}{L_1 + L_2} \quad \text{or} \quad \frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$$

(iv) If two coils of self-inductances L_1 and L_2 are wound over each other, the mutual inductance is given by: $M = K\sqrt{L_1 L_2}$ (where K is called coupling constant). It is equal to zero if there is no coupling. It is equal to zero if there is no coupling. It is equal to 1 for maximum coupling. The maximum coupling occurs when the two coils are wound over each other, over a ferromagnetic core.

Growth and decay of current in LR circuit :

(i) When a switch in an LR circuit is closed, the current does not become maximum immediately but it takes some time, i.e. there is a time lag.

(ii) If R be the resistance present in the circuit, then current I at any instant is given by : E – L (dI/dt) = IR

(a) At start, I = 0, so (dI/dt) is maximum and $(dI/dt)_{max.} = E/L$.

(b) Finally, (dI/dt) = 0, therefore I is maximum and $I_{max.} = E/R$ i.e. final current in the circuit is independent of inductance L.

(iv) The instantaneous current in the circuit during its growth is given by : $I = \frac{E}{R}(1 - e^{-\frac{R}{L}t})$

Here, (L/R) = time constant of LR circuit. The time constant is the time in which current rises to 0.6321 times the maximum current whichis equal to (E/R).

(v) When the switch in an LR circuit is opened, the instantaneous current I is given by $I = \left(\frac{E}{R}\right)e^{-\frac{R}{L}t}$

Hence, the time consant of an LR circuit may also be defined as the time in which the current falls to 0.3679 times of its initial current.

(vi) Decay or growth of current in LR circuit is fast when L/R is small and slow when (L/R) is large.

Transformer :

(i) The transformer was inverted by Henry. It works on the principle of mutual induction and is used in AC only. It suitably changes AC voltage.

(ii) A transformer consists of a (a) primary coil of turns N_p, (b) seconcdary coil of turns N_s and (c) a laminated soft iron core.

(iii) If V_p and V_s denote the voltage across the primary coil and the secondary coilrespectively. then $(V_s/V_p) = (N_s/N_p)$.

(iv) In an actual transformer,

Output power $\leq$ input power but in an ideal transformer

Output power = input power i.e. $V_sI_s = V_pI_p$

(I_p and I_s are the current in primary and secondary coils respectively).

$$\frac{V_s}{V_p} = \frac{I_p}{I_s} = \frac{N_s}{N_p}$$

(v) There are two types of transformers :

(a) Step-up trnasformer : Here, $N_s > N_p$, so $V_s > V_p$ and $I_s < I_p$.

(b) Step-down transfomer : Here, $N_s < N_p$, so $V_s < V_p$ and $I_s > I_p$.