REVISION of EMI and AC

Magnetic Flux

Magnetic flux through a plane of area **d*A*** placed in a uniform magnetic field **B,** $\phi = \int B.dA$,

If the surface is closed, then, $\phi = \oint \vec{B}.d\vec{A} = 0$

This is because magnetic lines of force are closed lines and free magnetic, poles do not exist.

Electromagnetic Induction: Faraday's Law

a). First Law: whenever there is a change in the magnetic flux linked with a circuit with time, an induced emf is produced in the circuit which lasts as long as the change in magnetic flux continues.

b). Second Law: Induced emf, $E \propto \left(\frac{d\phi}{dt}\right)$

Lenz's Law

The direction of the induced emf or current in the circuit is such that it opposes the cause due to which it is produced, so that, $E = -N\left(\frac{d\phi}{dt}\right)$, N is No. of turns in coil

Lenz's law is based on energy conservation.

EMF Current and Charge Induced in the Circuit

a). Induced emf $E = -N\left(\frac{d\phi}{dt}\right) = -\frac{N(\phi_2 - \phi_1)}{t}$

b). Induced current $I = \frac{E}{R} = -\frac{N}{R}\left(\frac{d\phi}{dt}\right) = -\frac{N}{R}\left(\frac{\phi_2 - \phi_1}{t}\right)$

Charge depends only on net change in flux does not depends on time.

Emf Induced Due to Linear Motion of a Conducting Rod in a Uniform Magnetic Field

$E = -\mathbf{L}.(\mathbf{v} \times \mathbf{B})$, If L, v and B are perpendicular to each other E = BvL

Induced EMF Due to Rotation of a Conducting Rod in a Uniform Magnetic Field

$$E = \frac{1}{2}B\omega L^2 = B\pi\nu L^2 = BA\nu$$

Where ν is the frequency of rotation of the conducting rod Induced EMF Due to Rotation of a Metallic Disc in a Uniform Magnetic Field

$$E = \frac{1}{2}B\omega L^2 = B\pi\nu L^2 = BA\nu$$

Induced EMF, Current and Energy Conservation in a Rectangular Loop Moving in a Non – Uniform Magnetic Field with a Constant Velocity

i) Net increase in flux crossing through the coil in time Δt; $\Delta\phi = (B_2 - B_1)Lv.(\Delta t)$

ii) Emf induced in the coil, $E = (B_1 - B_2)Lv$

iii) If the resistance of the coil is R, then the current induced in the coil $I = \frac{E}{R} = \frac{(B_1 - B_2)}{R}Lv$

iv) Resultant force acting on the coil, $F = IL(B_1 - B_2)$ towards left

FOR JEE ONLY

v) The work done against the resultant force $W = (B_1 - B_2)^2 \frac{L^2v^2}{R}.\Delta t$

Energy supplied in this process appears in the form of heat energy in the circuit.

vi) Energy supplied due to flow of current I in time Δt

$H = I^2R\,\Delta t$ Or $H = (B_1 - B_2)^2 \frac{L^2v^2}{R}.\Delta t$; Or H = W

Rotation of Rectangular Coil in a Uniform Magnetic Field

a) Magnetic flux linked with coil

$\phi = BAN\cos\theta = BAN\cos\omega t$

b) Emf induced in the coil $E = \frac{d\phi}{dt} = BAN\omega\sin\omega t = E_0\sin\omega t$

c) Current induced in the coil $I = \frac{E}{R} = \frac{BAN\omega}{R}\sin\omega t = \frac{E_0}{R}\sin\omega t$

d) Both Emf and current induced in the coil are alternating

Self Induction and Self Inductance (L) On changing the current in a coil, an induced e.m.f. is produced in the coil then the phenomenon is called self in induction

i) $\phi \propto I \Rightarrow \phi = LI \Rightarrow L = \frac{\phi}{I}$

ii) $E = -L\frac{dI}{dt}$; where L is constant, called coefficient of self induction $L = -\frac{E}{dI/dt}$

iii) Self Induction of circular coil, $L = \frac{\mu_0 N^2 \pi R}{2} = \frac{\mu_0 N^2 A}{2R}$

iv) Self Induction of a solenoid $L = \frac{\mu_0 N^2 A}{l} = \mu_0 n^2 Al$

FOR JEE ONLY

v) Without coupling,

In series $L = L_1 + L_2$ (placed far apart),

In Parallel $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \ldots$

Mutual Induction

i) On changing the current in a coil, if the flux linked with a second coil changes and induced emf is produced in that coil, then this phenomenon is called Mutual Induction

ii) $\phi_2 \propto I_1 \Rightarrow \phi_2 = MI_1 \Rightarrow M = \frac{\phi_2}{I_1}$

iii) $E_2 = -\frac{d\phi_2}{dt} = -M\frac{dI_1}{dt} \Rightarrow M = -\frac{E_2}{-(dI_1/dt)}$

iv) $M_{12} = M_{21} = M$

v) Mutual inductance of two coaxial solenoids $M = \frac{\mu_0 N_1 N_2 A}{l} = \mu_0 n_1 n_2 A.l$

FOR JEE ADVANCE ONLY

vi) Two coils of self inductance L_1 and L_2 are wound over each other, the mutual inductance is given $M = K\sqrt{L_1 L_2}$, where K is coupling constant

vii) For two coils wound in same direction and connected in series $L = L_1 + L_2 + 2M$

viii) For two coils wound in opposite direction and connected in series $L = L_1 + L_2 - 2M$

ix) For two coils in parallel $l = \frac{L_1 L_2 - M^2}{L_1 + L_2 \pm 2M}$

x) Energy in inductor $U = \frac{1}{2}LI^2 \Rightarrow u_B = \frac{B^2}{2\mu_0}$, where U is energy and u_B = Magnetic energy density

Eddy Currents

When a SOLID conductor is moved in a magnetic field, induced currents are generated in whole volume of conductor, these are strong and localized currents called as Eddy Currents

Transformer

Working on the principle of Mutual Induction,

Device, that changes the magnitude of alternating voltage or current. The voltage or current is fed into primary coil and taken from secondary coil.

If it increases the voltage, it is termed as STEP UP transformer, but consequently it will reduce the current.

Ratio of coils is termed as transformation or transfer ratio

$$\frac{E_S}{E_P} = \frac{N_S}{N_P} = K = \frac{I_P}{I_S}$$

For ideal transformer $P_{input} = P_{output}$; $E_P I_P = E_S I_S$

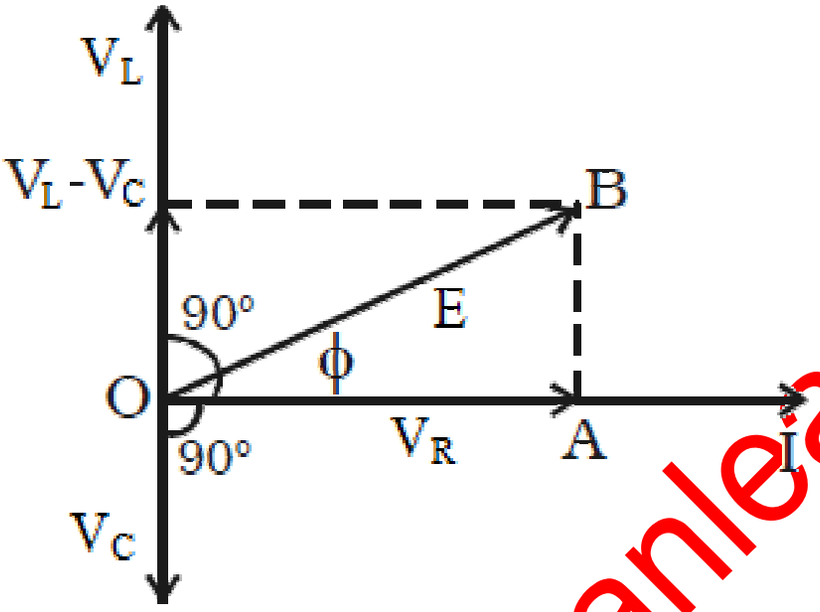
For STEPUP $N_S > N_P$

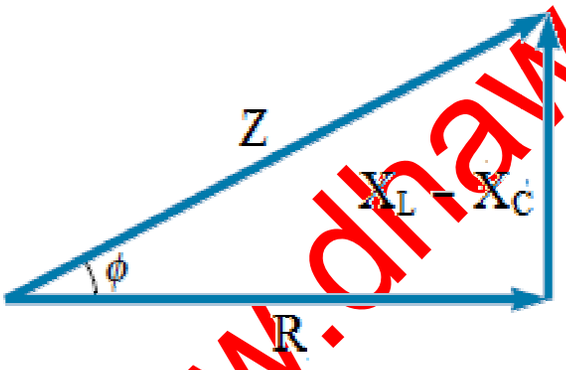
Efficiency = $\frac{P_{OUT}}{P_{IN}} = \frac{E_S I_S}{E_P I_P}$

GENERATOR converts Any energy (Mechanical/Hydo/Nuclear/Thermal etc) to convert to electrical energy

Values of Alternating Current and Voltage

a) Instantaneous value: It is the value of alternating current and voltage at an instant t.
b) Peak value: Maximum values of voltage E0 and current I0 in a cycle, are called peak values.
c) Mean value: For complete cycle is ZERO, For HALF CYCLE $E_{MEAN} = 0.636\ E_0$
d) Root – mean- square (rms) value: $E_{RMS} = 0.707\ E_0$





Phase difference Between the EMF (Voltage) and the Current in an AC Circuit
a) For pure resistance: The voltage and the current are in same phase i.e. phase difference $\phi = 0$
b) For pure inductance: The voltage is ahead of current by 90 OR $\pi/2$ i.e. phase difference $\phi = \pi/2$.
c) For pure capacitance: The voltage lags behind the current by 90 OR $\pi/2$ i.e. phase difference $\phi = -\pi/2$.

ROLE of CURRENT ELEMENTS, Resistance, Inductor and Capacitance in AC currents

RESISTANCE has SAME role in AC as well as DC to stop/ create obstruction in flow of current. The obstruction offered does not depend on the frequency of AC

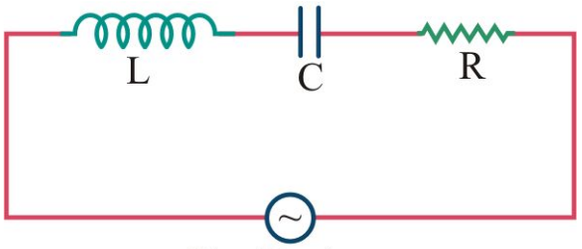
INDUCTOR has ZERO Resistance to flow of current in DC but offers obstruction in AC, and obstruction depends on frequency of AC as well. The resistance offered by it is NOT termed as resistance but REACTANCE (Differ in AC and DC), The reactance is given as $X_L = \omega L$.

Unit of X_L is OHM only. For all practical purposes of your syllabus, it is just as resistance but only DIFFERENCE that it depends on FREQUENCY, For DC circuit as ω is ZERO i.e. $X_L = 0$

CAPACITOR has INFINITE Resistance to flow of current in DC but offers obstruction in AC, and obstruction depends on frequency of AC as well. The resistance offered by it is NOT termed as resistance but REACTANCE (Differ in AC and DC), The reactance is given as $X_C = 1/\omega C$.

Unit of X_C is OHM only. For all practical purposes of your syllabus, it is just as resistance but only DIFFERENCE that it depends on FREQUENCY, For DC circuit as ω is ZERO i.e. X_C is INFINITE

SERIES LCR CIRCUIT



$V = V_0 \sin\omega t$

IMPEDANCE is defined as the net OBSTRUCTION to flow of current in AC

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

RESONANCE is a very special phenomenon in AC CIRCUIT

At resonance
$V_L = V_C$
$Z = R$
$X_L = X_C$
$\phi = 0$
Z is MINIMUM
I is MAXIMUM

These all CONDITIONS are interdependent.

POWER IN AN AC CIRCUIT

Now as the Formula for power is P = VI = EI, Also E and I are both Sine/Cosine functions. Every cycle they touch zero at least TWICE, and value keeps on changing regularly for instantaneous value.

The product P = VI also varies continuously.

So we don't define instantaneous Power in circuit, and we define and calculate the AVERAGE POWER for a cycle.

$P_{AVG} = E_v I_v \cos\phi$ $P_{AVG} = \dfrac{\int_0^T E_0 I_0 .dt}{\int_0^T dt} = E_{RMS}.I_{RMS}.\cos\phi$

Where this ϕ is same PHASE ANGLE.

For PURE inductor and Capacitor, POWER consumed is ZERO.

RESISTANCE CONSUMES MAXIMUM POWER

Wattless Current

The component of current differing in phase by π/2 relative to the voltage, is called wattles current. CONCEPT of WATTLESS current is used in decreasing Voltage without loss of ENERGY in AC only.

QUALITY FACTOR

It is defined as the ratio of voltage across Capacitor or Inductor at RESONANCE) (BOTH are same) to that across Resistance

$$Q = \frac{1}{R}\sqrt{\frac{L}{C}}$$