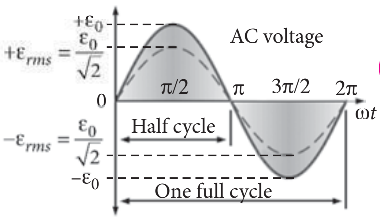
ALTERNATING CURRENT
ELECTROMAGNETIC WAVES

BRAIN MAP
CLASS XII



Alternating Current
Current which changes continuously in magnitude and periodically in direction.

Transformer
- Transformer ratios
  $$\frac{\varepsilon_S}{\varepsilon_P} = \frac{I_P}{I_S} = \frac{N_S}{N_P} = k$$
- Efficiency of a transformer,
  $$\eta = \frac{\text{output power}}{\text{input power}} = \frac{\varepsilon_S I_S}{\varepsilon_P I_P}.$$

Step-up transformer,
$\varepsilon_S > \varepsilon_P, I_S < I_P$ and $N_S > N_P$.

Step-down transformer,
$\varepsilon_S < \varepsilon_P, I_S > I_P$ and $N_S < N_P$.

Alternating voltage
$\varepsilon = \varepsilon_0 \sin \omega t$

Applied across capacitor

Applied across resistor

Applied across inductor

Purely capacitive circuit
Current leads the voltage by a phase angle of $\pi/2$.
$I = I_0 \sin(\omega t + \pi/2)$; $I_0 = \dfrac{\varepsilon_0}{X_C} = \omega C \varepsilon_0$
where $X_C = 1/\omega C$

Purely resistive circuit
Alternating voltage is in phase with current.
$I = \varepsilon/R = I_0 \sin\omega t$

Purely inductive circuit
Current lags behind the voltage by a phase angle of $\pi/2$.
$I = I_0 \sin(\omega t - \pi/2)$; $I_0 = \varepsilon_0/X_L = \varepsilon_0/\omega L$
where $X_L = \omega L$

Combining LCR in series

Series *LCR* circuit
- $\varepsilon = \varepsilon_0 \sin\omega t$, $I = I_0 \sin(\omega t - \phi)$
  Impedance of the circuit: $Z = \sqrt{R^2 + (X_L - X_C)^2}$
- Phase difference between current and voltage is ϕ
  $$\tan\phi = \frac{X_L - X_C}{R}$$
- For $X_L > X_C$, ϕ is +ve. (Predominantly inductive)
- For $X_L < X_C$, ϕ is −ve. (Predominantly capacitive)

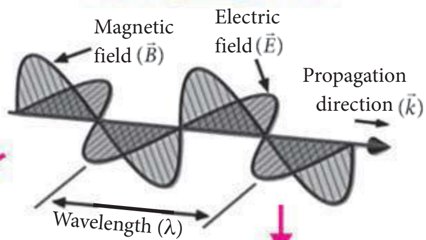
Power in ac circuit
Average power (P_{av})
$$P_{av} = \varepsilon_{rms} I_{rms} \cos\phi = \frac{\varepsilon_0 I_0}{2}\cos\phi$$

Power factor
- **Power factor:** $\cos\phi = \dfrac{R}{Z}$
- In pure resistive circuit,
  $\phi = 0°$; $\cos\phi = 1$
- In purely inductive or capacitive circuit
  $\phi = \pm\dfrac{\pi}{2}$; $\cos\phi = 0$
- In series *LCR* circuit,
  At resonance, $X_L = X_C$
  $\therefore$ $Z = R$ and $\phi = 0°, \cos\phi = 1$

Resonant series *LCR* circuit
When $X_L = X_C$, $Z = R$, current becomes maximum.
Resonant frequency $\omega_r = \dfrac{1}{\sqrt{LC}}$

Quality factor
It is a measure of sharpness of resonance.
$\therefore$ $Q = \dfrac{1}{R}\sqrt{\dfrac{L}{C}}$

Electromagnetic Waves
Waves having sinusoidal variation of electric and magnetic field at right angles to each other and perpendicular to direction of waves propagation.



Displacement current
Displacement current arises wherever the electric flux is changing with time.
$I_D = \varepsilon_0 d\phi_E/dt$

Maxwell's equations
$\oint \vec{E}\cdot d\vec{S} = \dfrac{q}{\varepsilon_0}$ (Gauss's law for electrostatics)

$\oint \vec{B}\cdot d\vec{S} = 0$ (Gauss's law for magnetism)

$\oint \vec{E}\cdot d\vec{l} = -\dfrac{d\phi_B}{dt}$ (Faraday's law of electro-magnetic induction)

$\oint \vec{B}\cdot d\vec{l} = \mu_0\left(I + \varepsilon_0 \dfrac{d\phi_E}{dt}\right)$ (Maxwell-Ampere's circuital law)

Energy density of electromagnetic waves
Average energy density
$$\langle u \rangle = \frac{1}{2}\varepsilon_0 E_0^2 = \frac{1}{2}\frac{B_0^2}{\mu_0}$$
Intensity of electromagnetic wave $= \dfrac{1}{2}\varepsilon_0 E_0^2 c$

Production of electromagnetic waves
- Through accelerating charge
- By harmonically oscillating electric charges.
- Through oscillating electric dipoles.