Class 12 Physics

📘 Chapter 7 – Alternating Current

Notes By - The Conclusion Daily

7.1 Introduction

- In **DC (Direct Current)** circuits → current is constant with time.
- In **AC (Alternating Current)** → current changes **magnitude and direction** periodically.
- AC is widely used because it is easy to **generate, transmit, and transform**.

7.2 Representation of AC

Let instantaneous current be:

$$i = i_0 \sin(\omega t)$$

where

- i_0 = peak (maximum) current
- ω = angular frequency = $2\pi f$
- f = frequency (Hz)
- $T = \frac{1}{f}$ = time period

AC voltage:

$$v = v_0 \sin(\omega t)$$

Graph: Sinusoidal wave, positive half-cycle followed by negative half-cycle.

7.3 Peak and RMS Values

- **Peak (maximum) value:** i_0, v_0

- **Mean value (average over half cycle):**

$$i_{mean} = \frac{2}{\pi} i_0$$

- **Root Mean Square (RMS) value:**

$$i_{rms} = \frac{i_0}{\sqrt{2}}, \quad v_{rms} = \frac{v_0}{\sqrt{2}}$$

RMS value of AC = value of DC that produces the same heating effect.

7.4 AC through a Resistor

For resistor RRR,

$$i_0 = \frac{v_0}{R} \sin(\omega t)$$

- Current and voltage are **in phase**.
- Instantaneous power:

$$p = vi = \frac{v_0^2}{R} sin^2(\omega t)$$

- Average power over full cycle:

$$P_{avg} = \frac{v_0^2}{2R} = I^2_{rms} R$$

7.5 AC through a Pure Inductor

For inductor L:

$$v = L\frac{di}{dt}$$

$If\ v = v_0 \sin(\omega t):$

$$i = \frac{v_0}{\omega L} \sin(\omega t - \frac{\pi}{2})$$

- Current **lags** voltage by **90°**.
- **Inductive reactance:**

$$X_L = \omega L = 2\pi f L$$

- **Average power = 0** (as current lags by 90°).

7.6 AC through a Pure Capacitor

For capacitor C:

$$q = Cv \Rightarrow i = C\frac{dv}{dt}$$

$If\ v = v_0 \sin(\omega t):$

$$i = \omega C v_0 \sin(\omega t + \frac{\pi}{2})$$

- Current **leads** voltage by **90°**.
- **Capacitive reactance:**

$$X_C = \frac{1}{\omega C}$$

- **Average power = 0.**

7.7 AC through an LCR Series Circuit

A resistor (R), inductor (L), and capacitor (C) connected in series to AC source $v = v_0 \sin(\omega t)$

Net impedance:

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

Current amplitude:

$$i_0 = \frac{v_0}{Z}$$

Phase angle (φ):

$$tan\phi = \frac{X_L - X_C}{R}$$

- If $X_L > X_C$: current **lags** voltage.
- If $X_L < X_C$: current **leads** voltage.

Instantaneous current:

$$i = i_0 \sin(\omega t - \phi)$$

Average power:

$$P = V_{rms} I_{rms} \cos\phi$$

where $\cos\phi$ = **power factor**.

7.8 Resonance in LCR Circuit

Resonance occurs when inductive reactance = capacitive reactance:

$$X_L = X_C \Rightarrow \omega L = \frac{1}{\omega C}$$

$$\Rightarrow \omega_0 = \frac{1}{\sqrt{LC}}$$

At resonance:

- Impedance $Z = R$(minimum)
- Current is maximum: $I_0 = \frac{v_0}{R}$
- Voltage and current are in phase.

7.9 Power in AC Circuit

Instantaneous power:

$$p = vi = v_0 i_0 \sin(\omega t) \sin(\omega t - \phi)$$

Average over full cycle:

$$P = V_{rms} I_{rms} \cos\phi$$

$cos\ \phi$ = **Power factor**

- ϕ = phase difference between voltage & current.

Special cases:

Circuit	Phase (φ)	Power factor ($\cos\varphi$)	Average Power
Pure R	0°	1	Maximum
Pure L	90°	0	Zero
Pure C	90°	0	Zero

7.10 LC Oscillations

When a charged capacitor is connected to an inductor, energy oscillates between electric & magnetic forms.

At any instant:

$$\frac{q^2}{2C} + \frac{1}{2}Li^2 = constant$$

Natural frequency:

$$\omega = \frac{1}{\sqrt{LC}},\ f = \frac{1}{2\pi\sqrt{LC}}$$

Energy exchange:

- At t = 0 → all energy electric (capacitor charged).
- At t = T/4 → all energy magnetic (inductor current max).

7.11 Transformers

Principle:
Based on **mutual induction** — varying current in primary coil induces emf in secondary coil.

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = k$$

where
V_s , V_p = secondary and primary voltages

N_s , N_p = number of turns
k = turn ratio

Power (ideal transformer):

$$V_p I_p = V_s I_s$$

Types:

- Step-up: $N_s > N_p$ (voltage increases)
- Step-down: $N_s < N_p$ (voltage decreases)

Losses:
Eddy currents, hysteresis, flux leakage, resistance of windings.

7.12 Key Formula Summary

Concept	Formula	Description
Instantaneous current	$i = i_o \sin(\omega t)$	Varies sinusoidally
RMS value	$I_{rms} = \frac{I_0}{\sqrt{2}}$	Heating equivalent
Mean current	$I_{mean} = \frac{2I_0}{\pi}$	Over half cycle
Inductive reactance	$X_L = \omega L$	Opposition by inductor
Capacitive reactance	$X_C = \frac{1}{\omega C}$	Opposition by capacitor
Impedance	$Z = \sqrt{R^2 + (X_L - X_C)^2}$	Total opposition
Phase angle	$\tan\phi = \frac{(X_L - X_L)}{R}$	Lag/lead measure
Resonant frequency	$\omega_0 = \frac{1}{\sqrt{LC}}$	Maximum current condition
Average power	$P = V_{rms} I_{rms} \cos\phi$	True power
Transformer ratio	$\frac{V_s}{V_p} = \frac{N_s}{N_p}$	Step-up/down relation

LC frequency	$f = \frac{1}{2\pi\sqrt{LC}}$	Natural oscillation

7.13 Quick Recap

- **AC = Alternating current** changing with time.
- **R, L, C** show resistance, reactance, and phase difference.
- **Resonance:** $X_L = X_C$, current maximum.
- **Power factor (cosϕ):** efficiency indicator.
- **Transformer:** changes AC voltage using mutual induction.
- **LC circuit:** oscillates naturally with frequency $\frac{1}{2\pi\sqrt{LC}}$.