

# Chapter 7: Alternating Current

Detailed NCERT Revision Notes

## 1. Alternating Current

### 1.1 Introduction

**Definition:** An Alternating Current (AC) is an electric current whose magnitude changes continuously with time, and whose direction reverses periodically.

- Unlike Direct Current (DC) (like standard batteries) which flows strictly in a single, unyielding direction.
- AC repeatedly builds up from zero to a positive peak, falls back to zero, builds to an identical negative peak, and returns to zero over and over again.

Represented by sinusoidal mathematical functions. Instantaneous value at time  $t$  is:

$$i = I_0 \sin(\omega t) \quad \text{or} \quad i = I_0 \cos(\omega t)$$

Where:

- $i$  = Instantaneous current at time  $t$ .
- $I_0$  = Peak current (absolute maximum amplitude).
- $\omega = 2\pi f$  = Angular frequency (rad/s).
- $f$  = Conventional frequency (cycles per second).
- $t$  = Instantaneous time (seconds).

### Important Parameters of AC

1. **Time Period (T):** Time taken to complete one full sinusoidal cycle.

$$T = 1 / f$$

#### Exam Tip!

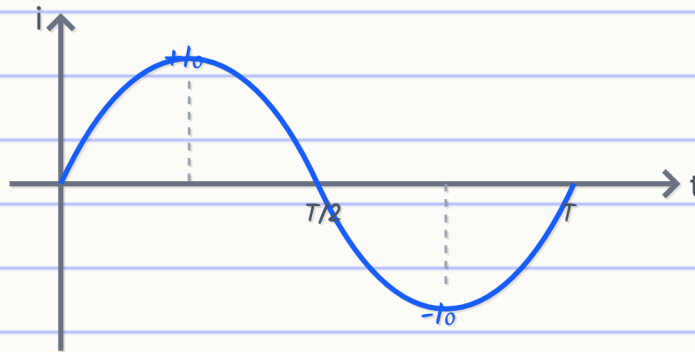
Standard domestic AC supply in India is **50 Hz**.  
(Direction reverses 100 times/sec!)

2. **Frequency (f)**: Number of complete cycles in one second. SI unit: Hertz (Hz).

3. **Angular Frequency ( $\omega$ )**: Rate at which phase angle changes.

$$\omega = 2\pi f = 2\pi / T$$

## 1.2 Graph of Alternating Current



### Observations:

- Current is maximum at  $\omega t = \pi/2$  (Positive peak)
- Current is zero at  $\omega t = 0, \pi, 2\pi$
- Direction reverses after every half cycle

## 1.3 AC vs DC Comparison

<b>Alternating Current (AC)</b>	<b>Direct Current (DC)</b>
Changes direction periodically. Magnitude varies with time.	Flows in one direction only. Magnitude constant.
Sinusoidal waveform.	Straight line waveform.
Produced by AC generator. Can be stepped up/down using transformer.	Produced by cell or battery. Cannot be transformed directly.

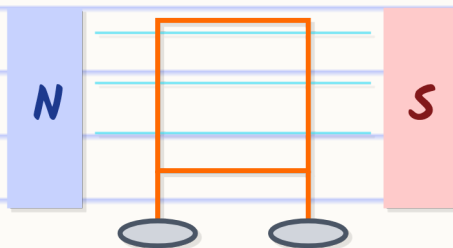
## 1.4 & 1.5 Generation & Construction

Generated using an AC Generator working on the principle of electromagnetic induction.

- Faraday's law:  $\Phi = BA \cos(\omega t)$
- $E = -N (d\Phi/dt) \Rightarrow E = NBA\omega \sin(\omega t)$

### Main Components:

- Armature (rotating coil)
- Field magnet (N & S poles)
- Slip rings
- Carbon brushes



### 1.6 Working

When coil rotates, angle between magnetic field & area vector changes. Flux changes sinusoidally, inducing alternating EMF.

- Maximum emf:  $E_0 = NBA\omega$
- Instantaneous emf:  $E = E_0 \sin(\omega t)$

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### ↻ 2. Instantaneous Value of Alternating Current ↻

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Value of current/voltage at any particular instant of time.

Current:  $i = I_0 \sin(\omega t)$

Voltage:  $v = V_0 \sin(\omega t)$

(In a purely resistive circuit,  $v$  &  $i$  are in phase!)

### 3. Important AC Quantities

#### 3.1 Time Period (T):

$$T = 1 / f \text{ (Seconds)}$$

#### 3.2 Frequency (f):

$$f = 1 / T \text{ (Hertz)}$$

India:  $f = 50 \text{ Hz}$

#### 3.3 Angular Freq ( $\omega$ ):

$$\omega = 2\pi f \text{ (rad/s)}$$

#### 3.4 Peak Value ( $I_0, V_0$ ):

Maximum value attained.

At  $\omega t = \pi/2, i = I_0$

#### 3.5 Average Value

Average over one complete cycle is ZERO. Therefore taken over half cycle.

$$I_{\text{avg}} = 2I_0 / \pi$$

(Numerically:  $I_{\text{avg}} = 0.637 I_0$ )

#### 3.6 RMS Value (Root Mean Square)

$$I_{\text{rms}} = I_0 / \sqrt{2}$$

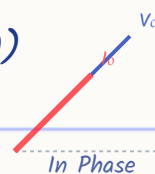
(Numerically:  $I_{\text{rms}} = 0.707 I_0$ )

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## 4 & 5. AC Circuits

### Resistor Only (Pure Resistive)

- Voltage & Current are **IN PHASE** (Phase angle  $\phi = 0$ )
- Power Factor =  $\cos(0) = 1$
- Average Power:  $P = V_{\text{rms}} \times I_{\text{rms}} = I_{\text{rms}}^2 R$
- Entire power is dissipated as heat!



## 5. Inductor Only (Pure Inductive)

Inductor opposes change in current. This opposition is **Inductive Reactance ( $X_L$ )**.

$$X_L = \omega L = 2\pi fL \quad (\text{Unit: } \Omega)$$

Increases with frequency!

### Phase Relationship:

Current **LAGS** voltage by  $90^\circ$  ( $\pi/2$ ).

(Or Voltage leads current by  $90^\circ$ )

**Average Power:** Since they are  $90^\circ$  out of phase...

$$P_{\text{avg}} = V_{\text{rms}} \times I_{\text{rms}} \times \cos(90^\circ) = 0$$

**ZERO POWER!** Energy is stored in magnetic field during one half cycle and returned in the next.



## 6. Capacitor Only (Pure Capacitive)

**6.1 Capacitive Reactance:** In a purely capacitive circuit, the capacitor opposes the change in voltage. This opposition is **Capacitive Reactance ( $X_C$ )**.

$$X_C = 1 / (\omega C) = 1 / (2\pi fC) \quad (\text{Unit: } \Omega)$$

Decreases with frequency! (Blocks DC, passes AC)

### Phase Relationship:

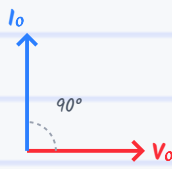
Current **LEADS** voltage by  $90^\circ$  ( $\pi/2$ ).

(Or Voltage lags current by  $90^\circ$ )

**Average Power:** Just like the pure inductor...

$$P_{\text{avg}} = V_{\text{rms}} \times I_{\text{rms}} \times \cos(90^\circ) = 0$$

**ZERO POWER!** Energy oscillates between the AC source and the electric field of the capacitor.



## 7. Series LCR Circuit

When an Inductor ( $L$ ), Capacitor ( $C$ ), and Resistor ( $R$ ) are connected in series across an AC source.



### Impedance ( $Z$ )

Total effective opposition offered by the LCR circuit:

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

### Phase Angle ( $\phi$ ):

Voltage and current have a phase difference  $\phi$  given by:

$$\tan(\phi) = (X_L - X_C) / R$$

- If  $X_L > X_C$ : Circuit is inductive ( $V$  leads  $i$ ).
- If  $X_C > X_L$ : Circuit is capacitive ( $i$  leads  $V$ ).

Impedance Triangle



## 8. Resonance in LCR Circuit

**💡 Exam Trick!**  
At resonance, the circuit acts like a **Pure Resistor!**

$$\text{Condition: } X_L = X_C \Rightarrow \omega L = 1 / \omega C$$

- Impedance becomes minimum:  $Z_{\min} = R$
- Current becomes MAXIMUM:  $I_{\max} = V_0 / R$
- Voltage and Current are exactly IN PHASE.

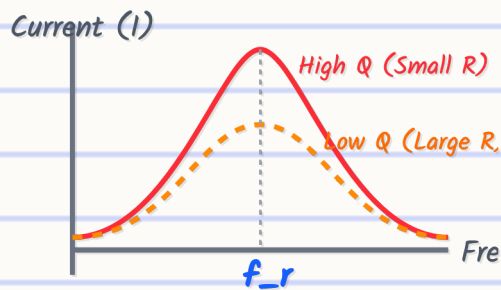
**Resonant Frequency ( $f_r$ ):**

$$f_r = 1 / (2\pi\sqrt{LC})$$

**Quality Factor (Q-factor):**

Measures the "sharpness" of resonance.

$$Q = (1 / R) \times \sqrt{L / C}$$



## 9. Power in AC Circuits & Power Factor

The average power dissipated in an AC circuit is given by:

$$P_{\text{avg}} = V_{\text{rms}} \times I_{\text{rms}} \times \cos(\phi)$$

- **Power Factor ( $\cos \phi$ ):**

Ratio of true power to apparent power.

$$\cos(\phi) = R / Z$$

- **Wattless Current:**

The component of current ( $I_{\text{rms}} \sin \phi$ ) that does **NOT** consume

any power! (Occurs in purely inductive or capacitive circuits where  $\phi = 90^\circ$ ).

## 10. Transformers

A device used to step-up (increase) or step-down (decrease) AC voltage. Works on the principle of **Mutual Induction**.

### Transformation Ratio (K):

$$V_s / V_p = N_s / N_p = I_p / I_s = K$$

- **Step-Up:**  $N_s > N_p$  (Voltage increases, Current decreases)
- **Step-Down:**  $N_s < N_p$  (Voltage decreases, Current increases)

### ⚡ Energy Losses in Transformer

1. **Copper Loss:** Heat loss in coil windings ( $I^2R$ ).
2. **Iron/Eddy Current Loss:** Currents induced in iron core. (Minimized by using laminated cores).
3. **Hysteresis Loss:** Magnetization & demagnetization of core.
4. **Flux Leakage:** All flux from primary doesn't link to secondary.

