

Chapter 7 · Alternating Current

CBSE Class 12 Physics (042) · Unit IV · Unit III + IV = 17 marks · LCR by phasors only · Ultimate Revision Sheet

60-SECOND RECALL

RMS values	$I_{\text{rms}} = I_0/\sqrt{2} = 0.707 I_0$ · same for V
Reactances	$X_L = \omega L$ · $X_C = 1/\omega C$
Impedance	$Z = \sqrt{R^2 + (X_L - X_C)^2}$
Phase angle	$\tan\phi = (X_L - X_C)/R$
Resonance	$X_L = X_C \rightarrow \omega_0 = 1/\sqrt{LC}$, Z = R minimum, I maximum
Power	$P = V_{\text{rms}} I_{\text{rms}} \cos\phi$ · power factor $\cos\phi = R/Z$
Transformer	$V_s/V_p = N_s/N_p = I_p/I_s$

1. RMS and Peak Values

DEFINITION The RMS (virtual) value of an alternating current is that *steady current* which produces the *same heating effect* in a given resistance in the same time.

FORMULAS

$$I = I_0 \sin\omega t \cdot I_{\text{rms}} = I_0/\sqrt{2} \cdot V_{\text{rms}} = V_0/\sqrt{2}$$

Average value over a full cycle = ZERO; over a half cycle = $2I_0/\pi$

Indian mains: 220 V is the RMS value, so the peak is $220\sqrt{2} \approx 311$ V. Frequency 50 Hz.

2. AC Through R, L and C Separately

THE THREE CASES — phase is the whole point

Element	Opposition	Phase	Power consumed
Resistor R	R	V and I in phase	Yes, $V_{\text{rms}} I_{\text{rms}}$
Inductor L	$X_L = \omega L = 2\pi fL$	Voltage LEADS current by $\pi/2$	Zero
Capacitor C	$X_C = 1/\omega C = 1/2\pi fC$	Current LEADS voltage by $\pi/2$	Zero

Memory hook: "ELI the ICE man." In an L, E (voltage) comes before I. In a C, I comes before E.

TRAP — frequency behaviour $X_L \propto f$ — an inductor *blocks high frequencies* and passes DC (at $f = 0$, $X_L = 0$).

$X_C \propto 1/f$ — a capacitor *blocks DC* (infinite reactance at $f = 0$) and passes high frequencies.

A pure L or pure C consumes **no power**, because $\phi = 90^\circ$ and $\cos 90^\circ = 0$. The current in that case is called **wattless current**.

3. Series LCR Circuit (phasors only)

FORMULAS

$$Z = \sqrt{R^2 + (X_L - X_C)^2} \cdot I_{\text{rms}} = V_{\text{rms}}/Z$$

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

$X_L > X_C \rightarrow$ circuit is *inductive*, voltage leads current.

$X_C > X_L \rightarrow$ circuit is *capacitive*, current leads voltage.

$X_L = X_C \rightarrow$ *resonance*, circuit behaves as *purely resistive*.

RESONANCE — the standard 3-marker

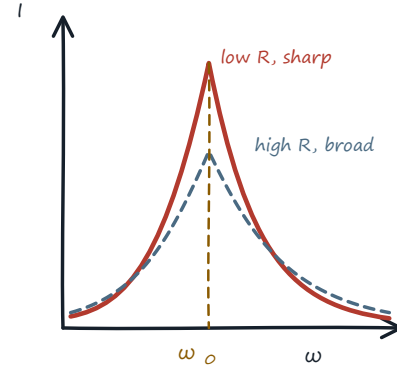
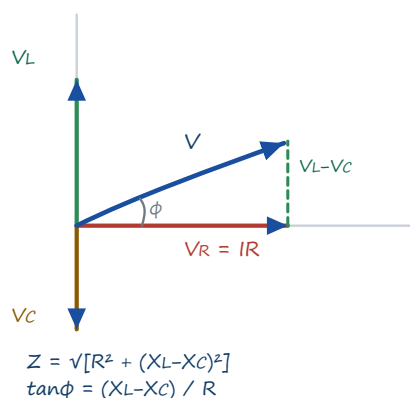
$$\omega_0 = 1/\sqrt{LC} \rightarrow f_0 = 1/2\pi\sqrt{LC}$$

At resonance: Z is minimum and equals R , current is maximum, $\phi = 0$ and the power factor is 1.

A series LCR circuit at resonance is called an *acceptor circuit* — it is used to *tune a radio* to one station.

Sharpness = quality factor $Q = \omega_0 L/R = (1/R)\sqrt{L/C}$. Smaller $R \rightarrow$ sharper resonance.

(a) Phasor diagram, series LCR (taking $V_L > V_C$) (b) Resonance curve



At resonance $X_L = X_C$, $Z = R$ (minimum), I is maximum and $\phi = 0$.

Resonance needs **both L and C** — an RL or RC circuit never resonates. Sharpness is measured by $Q = \omega_0 L/R$: smaller R , sharper peak.

4. Power in AC Circuits

FORMULAS

$$P_{\text{avg}} = V_{\text{rms}} I_{\text{rms}} \cos\phi \quad \cos\phi = R/Z \text{ is the power factor}$$

Pure resistive: $\cos\phi = 1$, full power. Pure L or C : $\cos\phi = 0$, zero power — wattless current.

At resonance: $\cos\phi = 1$, maximum power.

5. AC Generator and Transformer

AC GENERATOR

Works on *electromagnetic induction*: a coil rotating in a magnetic field changes the flux linked with it.

$$\epsilon = NBA\omega \sin\omega t \rightarrow \epsilon_0 = NBA\omega$$

Uses **slip rings** (a DC generator uses a split-ring commutator instead).

TRANSFORMER Works on **mutual induction**. Changes AC voltage; **cannot work on DC**, because DC produces no changing flux.

$$V_s/V_p = N_s/N_p = I_p/I_s \quad \text{ideal: } V_p I_p = V_s I_s$$

Step-up: $N_s > N_p$, voltage up, current down. **Step-down:** the reverse. Power is never stepped up.

THE FOUR ENERGY LOSSES — and how each is reduced 1. **Copper loss** (I^2R heating in windings) → use thick copper wire.

2. **Iron / eddy current loss** → use a laminated core.

3. **Hysteresis loss** → use a soft iron core with a narrow hysteresis loop.

4. **Flux leakage** → wind the coils **one over the other** on the same core.

WHY POWER IS TRANSMITTED AT HIGH VOLTAGE Power loss in the line is I^2R . Stepping the voltage **up** makes the current **small** for the same power, and since the loss goes as the **square** of the current, it falls dramatically. This is the standard 2-marker.

WORKED EXAMPLE A series LCR circuit has $R = 30 \Omega$, $X_L = 60 \Omega$, $X_C = 20 \Omega$, supply $V_{rms} = 200 \text{ V}$.

$$Z = \sqrt{30^2 + (60 - 20)^2} = \sqrt{900 + 1600} = \sqrt{2500} = 50 \Omega$$

$$I_{rms} = 200/50 = 4 \text{ A}$$

$$\text{Power factor } \cos\phi = R/Z = 30/50 = 0.6$$

$$P = V_{rms} I_{rms} \cos\phi = 200 \times 4 \times 0.6 = 480 \text{ W}$$

Since $X_L > X_C$, the circuit is **inductive** and voltage **leads** the current.

6. Question Triggers what the wording is really asking

If the question says...	The answer is...
"current is maximum / impedance minimum"	Resonance , $\omega_0 = 1/\sqrt{LC}$
"power consumed by a pure inductor"	Zero — wattless current
"device blocks DC but passes AC"	Capacitor
"device passes DC but blocks high frequency"	Inductor
"can a transformer work on DC?"	No — no changing flux
"why laminated core"	To reduce eddy current loss
"tuning a radio"	Series resonance (acceptor circuit)
"220 V mains, find peak voltage"	$V_0 = \sqrt{2} \times 220 \approx 311 \text{ V}$

MOST-ASKED BOARD QUESTIONS

1. [3M] Draw the **phasor diagram** for a series LCR circuit and obtain Z and $\tan\phi$.
2. [3M] Explain **resonance**, derive $\omega_0 = 1/\sqrt{LC}$, and sketch I against ω for two values of R .
3. [3M] Describe a **transformer**: principle, working, and the four energy losses with remedies.
4. [2M] Define **power factor** and **wattless current**.
5. [2M] Why is electric power transmitted at **high voltage**?
6. [2M] Numerical on Z , I , power factor and average power.
7. [1M] What is the average value of AC over one full cycle? → **Zero**

THE HABIT THAT SCORES — Draw the phasor triangle before any LCR numerical: R along the reference, X_L up, X_C down. Once the triangle is on paper, Z , ϕ and the power factor all read straight off it, and you cannot mix up which quantity leads.