Collegedunia NCERT Formula Sheet

The Ultimate Formula Reference for Class 12 Physics

Chapter 7: Alternating Current

Constant / Unit	Value
Indian mains frequency	50 Hz
RMS / peak ratio	$1/\sqrt{2} \approx 0.707$
$\langle \sin^2 \omega t \rangle$, $\langle \cos^2 \omega t \rangle$	$1/2$ over a full cycle
Indian mains voltage	220 V (rms); peak ≈ 311 V

1 AC Quantities & RMS Values

AC current and voltage vary sinusoidally with time. Their root-mean-square (rms) values are the DC equivalents that produce the same power dissipation (NCERT 7.2–7.3).

Why RMS, not average?

The time-average of a sine wave over a full cycle is **zero**. But the time-average of its **square** is not. The rms value is the square root of the mean square — it correctly captures the heating effect of an AC current in a resistor.

AC voltage & current

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

$i(t) = i_m \sin(\omega t \pm \phi)$

where v_m, i_m = peak values; $\omega = 2\pi f$ = angular frequency.

ϕ is the **phase difference** between i and v. $\phi > 0$: current lags voltage. $\phi < 0$: current leads.

RMS values

$$I_{\text{rms}} = \frac{i_m}{\sqrt{2}}$$

$$V_{\text{rms}} = \frac{v_m}{\sqrt{2}}$$

An AC current of rms I dissipates the **same power** in a resistor as a DC current of value I. Indian mains: 220 V rms means peak is 311 V.

Average and mean values (half cycle)

Average over half cycle: $i_{\text{avg}} = \dfrac{2i_m}{\pi}$

Average over a **full** cycle is zero (positive and negative halves cancel). Half-cycle average is what matters for rectifiers.

2 AC through Pure R, L, C

Each circuit element responds differently to AC — resistors keep i in phase with v, inductors lag, capacitors lead (NCERT 7.4–7.6).

Pure resistor

$$i = \frac{v_m}{R}\sin\omega t$$

Phase: $\phi = 0$ (in phase).

Power: $P = V_{\text{rms}}I_{\text{rms}} = I_{\text{rms}}^2 R$.

Resistor responds instantaneously — voltage and current peak together.

Pure inductor

$$i = \frac{v_m}{X_L}\sin(\omega t - \pi/2)$$

Inductive reactance: $X_L = \omega L \quad (\Omega)$

Phase: **current lags voltage** by $\pi/2$.
Average power: $P = 0$.

Inductor opposes change in current. X_L rises with frequency: blocks high-frequency AC. No net energy dissipated — it stores and returns energy each cycle.

Pure capacitor

$$i = \omega C v_m \sin(\omega t + \pi/2)$$

Capacitive reactance: $X_C = \frac{1}{\omega C} \quad (\Omega)$

Phase: **current leads voltage** by $\pi/2$.
Average power: $P = 0$.

Capacitor blocks DC ($\omega = 0 \Rightarrow X_C = \infty$); passes high frequency. Like inductor, no net power dissipated.

ELI the ICE man

ELI: in inductors (L), **E**MF leads **I** (current).
ICE: in capacitors (C), **I** (current) leads **E**MF.
The single most useful AC mnemonic — it tells you the sign of ϕ on sight.

3 Series LCR Circuit

When R, L, C are in series, individual reactances combine via phasor addition into a single impedance (NCERT 7.7).

Impedance of series LCR

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

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

$$I_{\text{rms}} = \frac{V_{\text{rms}}}{Z}$$

$\phi > 0$: net inductive (current lags). $\phi < 0$: net capacitive (current leads). Z is the AC analogue of resistance.

Phasor diagram

V_R along $\vec{i}$; V_L at $+\pi/2$ (above); V_C at $-\pi/2$ (below).

Net voltage: $V = \sqrt{V_R^2 + (V_L - V_C)^2}$

Each voltage is a vector; the net is their phasor sum. The phase angle ϕ between V and I is the angle of this resultant.

4 Resonance & Quality Factor

At resonance, $X_L = X_C$ — the circuit looks purely resistive and current peaks (NCERT 7.7 cont.).

Resonance frequency

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

$$f_0 = \frac{1}{2\pi\sqrt{LC}}$$

At resonance: $Z_{\text{min}} = R$, $\phi = 0$, $I_{\text{max}} = V/R$.

Series LCR **maximises** current at resonance. Used in tuning circuits (radios). Sharper resonance gives finer selectivity.

Quality factor

$$Q = \frac{\omega_0 L}{R} = \frac{1}{\omega_0 RC} = \frac{1}{R}\sqrt{\frac{L}{C}}$$

Bandwidth: $\Delta\omega = R/L = \omega_0/Q$

Higher $Q \Rightarrow$ **sharper resonance peak**, narrower bandwidth, better frequency selectivity. Lower R raises Q.

5 Power in AC Circuits

In a circuit with reactance, only the in-phase component of current does net work — the rest oscillates without dissipating energy (NCERT 7.8).

Average power

$P_{avg} = V_{rms} I_{rms} \cos\phi$

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

Pure R: $\cos\phi = 1$ (max power). Pure L or C: $\cos\phi = 0$ (zero net power). Real circuits: between 0 and 1.

Apparent vs real power

Apparent power: $S = V_{rms} I_{rms}$ (V·A)

Real power: $P = S\cos\phi$ (W)

Wattless current: the component $I_{rms}\sin\phi$ that does no work but still loads the wires — utilities charge for it indirectly via power-factor correction.

Wattless current

The component of current $90°$ out of phase with voltage. Even though it dissipates **no energy** in the load, it still flows through the wires — so it adds to I^2R losses in transmission. Power-factor correction (adding capacitors to inductive industrial loads) cancels wattless current.

6 Transformer

Mutual induction between two coils on a common iron core changes voltage levels at constant power (NCERT 7.9).

How a transformer works

An AC current in the primary creates a changing flux that, via the iron core, links to the secondary. The induced EMF in each coil is proportional to its number of turns. **Energy is conserved** — power into primary equals power out of secondary (ideal case).

Transformer relations (ideal)

$$\frac{V_s}{V_p} = \frac{N_s}{N_p} = \frac{I_p}{I_s}$$

Power conservation: $V_p I_p = V_s I_s$

Step-up ($N_s > N_p$): voltage up, current down. Step-down: opposite. Used to transmit power efficiently at high voltage and step down for domestic use.

JEE/NEET Extension: Transformer losses

Real transformers lose energy via: (i) **copper loss** (I^2R in windings); (ii) **iron loss** (eddy currents, hysteresis in the core); (iii) **flux leakage**; (iv) **magnetostriction** (mechanical hum). Efficiency $\eta = P_{out}/P_{in}$ is typically 95–99%.

X_L vs X_C frequency response

$X_L = \omega L$ rises with ω; $X_C = 1/(\omega C)$ falls. Don't confuse them. At low frequency, capacitor blocks; at high frequency, inductor blocks. They are reciprocal in behaviour — at resonance they exactly cancel.

Quick Reference — Alternating Current

Quantity / Configuration	Expression	Notes
RMS current	$i_m/\sqrt{2}$	DC-equivalent value
Half-cycle avg	$2i_m/\pi$	Full cycle avg = 0
Inductive reactance	ωL	Rises with ω
Capacitive reactance	$1/(\omega C)$	Falls with ω
Pure L: phase	i lags v by $\pi/2$	ELI
Pure C: phase	i leads v by $\pi/2$	ICE
LCR impedance	$\sqrt{R^2 + (X_L - X_C)^2}$	Series
Phase angle	$\tan^{-1} \frac{X_L - X_C}{R}$	Inductive: > 0
Resonance frequency	$1/\sqrt{LC}$	$X_L = X_C$
Quality factor	$\frac{1}{R}\sqrt{L/C}$	Sharpness of resonance
Bandwidth	$R/L = \omega_0/Q$	Width of peak
Average power	$V_{\text{rms}} I_{\text{rms}} \cos\phi$	cos ϕ = power factor
Wattless current	$I_{\text{rms}} \sin\phi$	No power, still flows
Transformer (ideal)	$V_s/V_p = N_s/N_p$	$V_p I_p = V_s I_s$