# JEE Main Physics

## Short Notes

# Alternating Current

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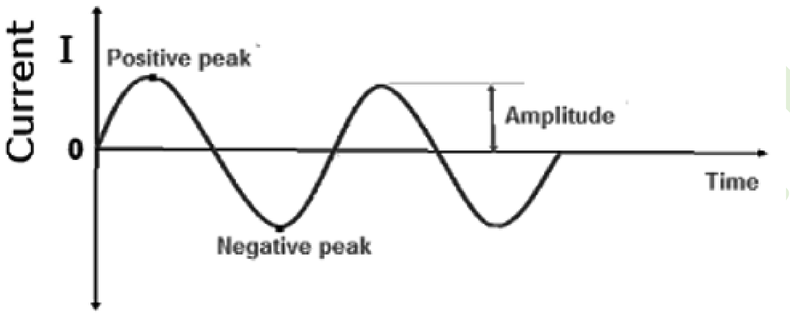
**Alternating Current** is an important topic from JEE Main / JEE Advanced Exam Point of view. Every year there are 1-2 questions asked from this topic. This short notes on Alternating Current will help you in revising the topic before the JEE Main & IIT JEE Advanced Exam.

## Alternating Current

# Alternating Current

Alternating current is a current which keeps changing in magnitude continuously. Alternating current also changes its direction periodically. The following formula gives the alternating current.




$I = I_0 \sin \omega t$

$I = I_0 \sin (2\pi/T)\, t$

where $I_0$ is the peak value of Alternating Current (AC), Angular frequency, $\omega = 2\pi n$ (n is the frequency of AC)

So, $I = I_0 \sin 2\pi nt$

Since Alternating Current is always fluctuating, we consider its mean, average or root mean squared value for calculations.

**Mean Value of AC**

Mean value is that value of a steady current which sends the same amount of charge through a circuit as an alternating current in does in one half of the cycle. Thus, peak value multiplied with $2/\pi = (0.637)$ gives the mean value of alternating current.

Half cycle $(I_{av}) = (2/\pi)I_0$

Half cycle $(V_{av}) = (2/\pi)\, V_0$

**Average value of AC**

In one complete cycle of AC, the magnitude of the current remains the same at the start and the end point. Hence the average of alternating current is, $I_{av} = 0$

**RMS Value of AC**

Root Mean Square value of the steady current is that value which produces a certain amount of heat produced in a resistance in a given time as much produced by the alternating current itself in the same time.

The peak value when multiplied with $1/\sqrt{2}$ (0.707) gives the RMS value.

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

$V_{rms} = V_0/\sqrt{2}$

**Inductive reactance-** Inductive reactance is the opposition that is offered to the current flow in an AC circuit. It is the electrical resistance of the inductor coil and is measured in ohms. Its formula is

$\mathbf{X_L = \omega L}$

where $\omega = 2\pi n$ (n is the frequency of AC), L = coefficient of self-inductance of the coil.

**capacitive reactance-** capitative reactance is the resistance in the flow of current, offered by a capacitor in an AC circuit. It is given by

$\mathbf{X_c = 1/\omega C}$

where C is the capacity of the capacitor

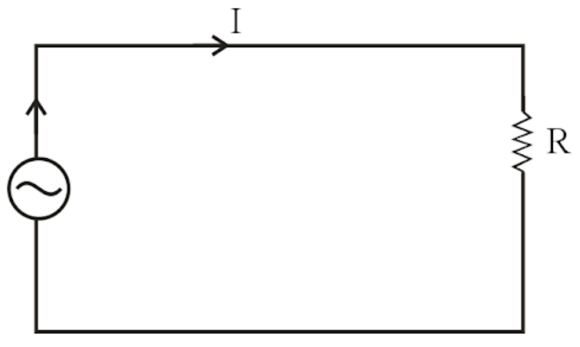
**Form Factor-** The form factor is a ratio of the RMS value of the alternating voltage with that of the average voltage.

Form Factor = RMS value of voltage/Average value of voltage

Form Factor = $\dfrac{\left(\dfrac{V_o}{\sqrt{2}}\right)}{\left(\dfrac{2V_o}{\pi}\right)} = \dfrac{\pi}{2\sqrt{2}}$

# AC Voltage Applied to a Resistor

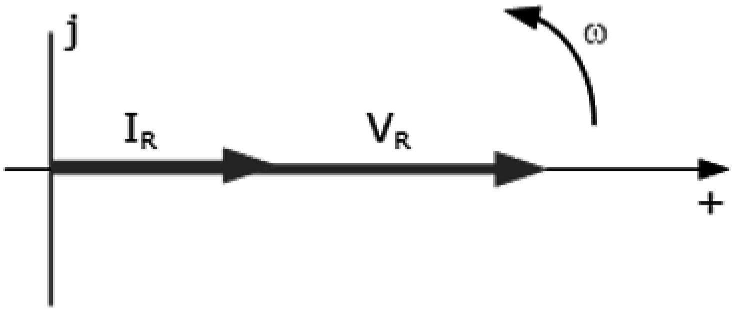
Let a resistance (R) is connected to a supplied alternating current source as shown in the figure.




Current flowing through the circuit is, $I = I_0 \sin(\omega t)$

Power dissipated in the resistance is, $P = I^2R = I^2_0 \sin^2(\omega t)$

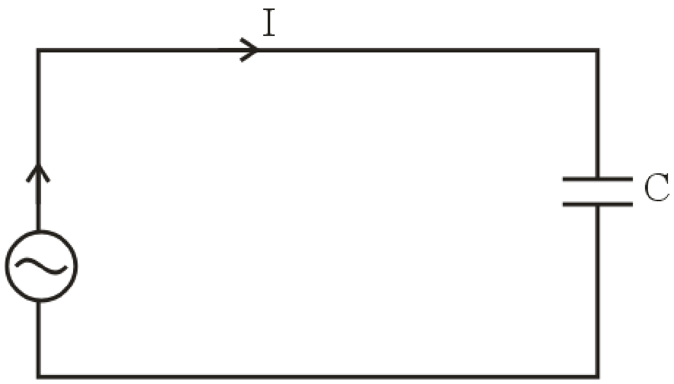
**Phasor diagram for a pure resistance circuit**




For a pure resistance circuit $V_R$ (Voltage across resistance) and $I_R$ are in the same phase.

# AC Voltage applied to a Capacitor

Let a capacitor (C) is connected to a supplied alternating current source as shown in the figure. The plates of the capacitor are alternatively charged with each half cycle.



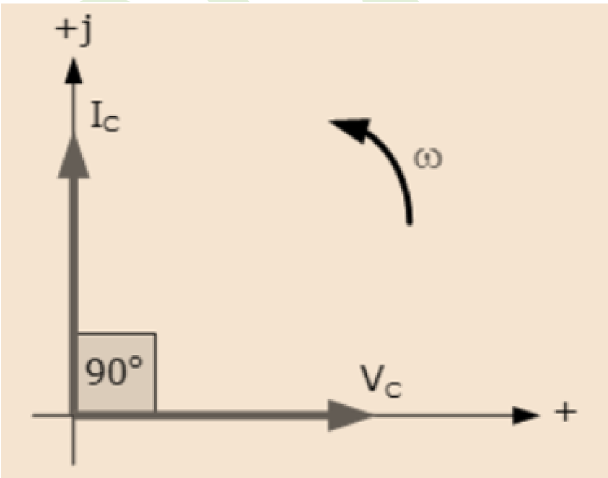

The charge q on the capacitor at a given time (t) is, $q = CV_0 \sin\omega t$

where $V_0 = I_0/\omega C$

Current flowing in the circuit, $I = I_0 \sin(\omega t + \pi/2)$

The impedance of the capacitor is, $X_c = 1/\omega C$

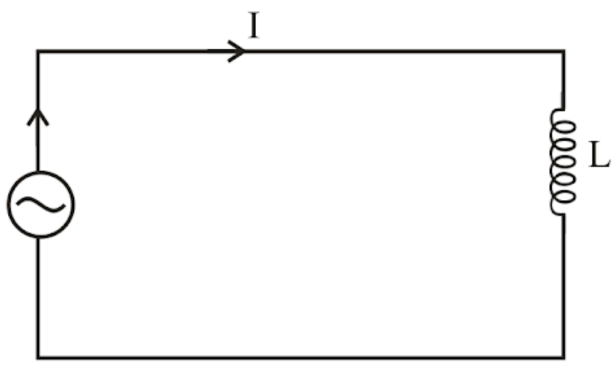
**Phasor diagram for a capacitive circuit**




For a pure capacitor, $V_C$ (Voltage across the capacitor) lags $I_C$ by 90°

## AC Voltage applied to an Inductor

Let an inductor (L) is connected to a supplied alternating current source as shown in the figure. An inductor in an AC circuit offers inductive reactance and limits the flow of current, similar to what a purely resistive circuit does.



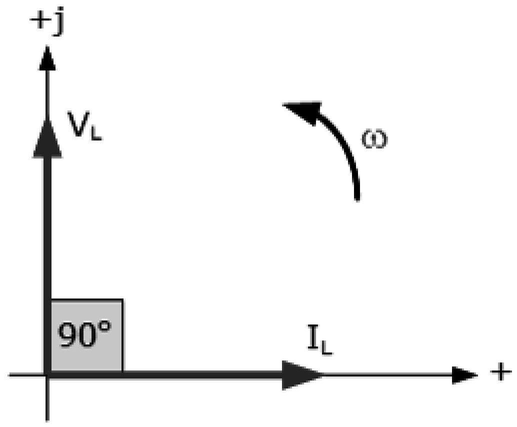

Impdeance of the inductor is, $X_L = \omega L$

Voltage across the inductor is, $V_L = L(dI/dt) = LI_0\omega \cos\omega t$

Current flowing through the circuit is, $I = (V_0/\ \omega L) \sin\omega t$

And the maximum current in the circuit is, $I_0 = V_0/X_L$

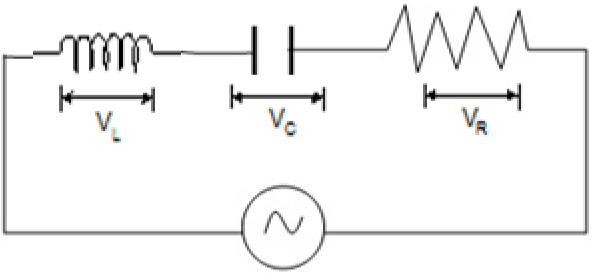
**Phasor diagram for an inductive circuit**




For a pure inductor circuit, $V_L$ (Voltage across the inductor) lags $I_L$ by $90^o$

# AC Voltage applied to an LCR circuit

In an LCR circuit, Resistor, Capacitor, and an Inductor are connected in series with an AC voltage supply.




According to Ohm's law supplied voltage is, V = IZ

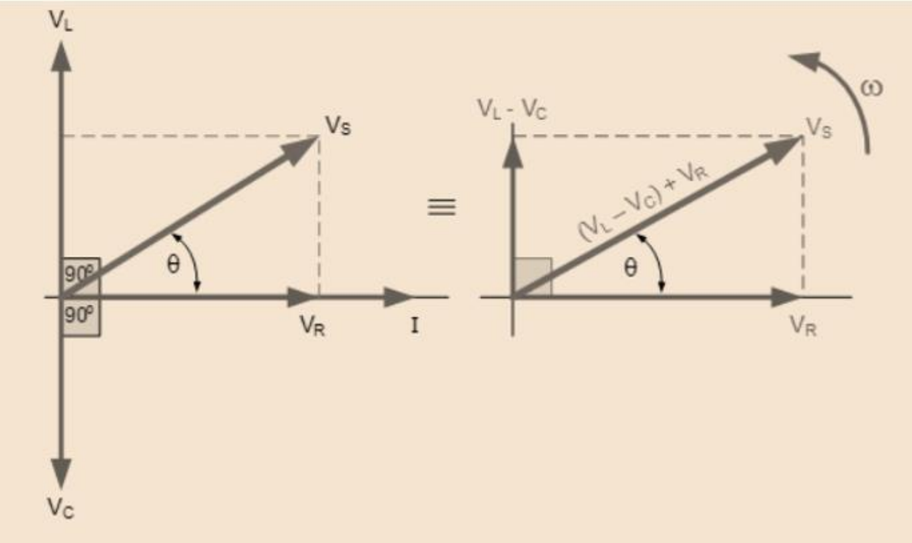
Where Z is the impedance of the circuit and I is the current flowing through the circuit.

The impedance of the circuit is, $|Z| = \sqrt{[R^2+(\omega L-1/\omega C)^2]}$

If $X_c > X_L$, the circuit is considered to be dominantly capacitive.

If $X_c < X_L$, the circuit is considered to be dominantly inductive.

**Phaser diagram of LCR circuit**




The potential difference lags the current by an angle θ, $\theta = \tan^{-1}[(\omega L - 1/\omega C)/R]$

The phasor diagram of an RLC circuit also represents the impedance diagram.

**Resonance in an RLC circuit**

The condition of resonance occurs when the capacitive reactance and the inductive reactance are equal in magnitude but are 180 degrees apart in phase, which is why they cancel out each other. This frequency of the system is called its natural frequency.

Resonance frequency is, $f_r = 1/2\pi\sqrt{LC}$

In the resonance condition,

$X_L = X_C$, $\phi = 0$, $Z = R$(minimum), $\cos\phi = 1$, $\sin\phi = 0$ and the current is maximum ($= E_0/R$)

## Power in AC circuit

Power in purely resistive circuits is, $P_{av} = (E_0/\sqrt{2})\times(I_0/\sqrt{2})$

where $E_v$ and $I_v$ are considered to be the virtual values of e.m.f and the current respectively.

Power in an LCR circuit is given, $P_{av} = (E_0/\sqrt{2})\times(I_0/\sqrt{2})\cos\phi = (E_v\times I_v)\cos\phi$

where $\cos\phi$ is the Power Factor

Power factor, $\cos\phi$ = Real power/Virtual power = $P_{av}/E_{rms}I_{rms}$

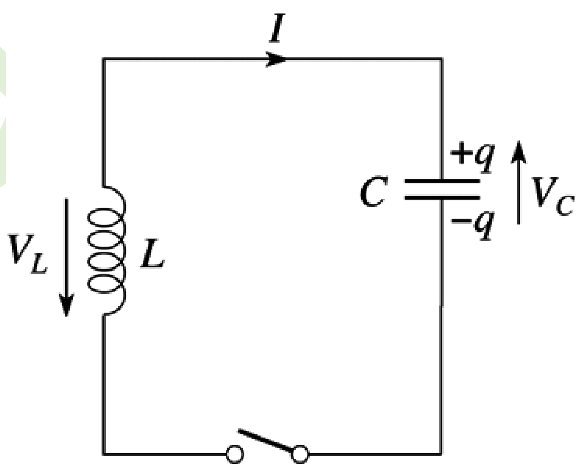
For a purely resistive circuit, $P_{av} = E_vI_v$

For a purely inductive circuit, $P_{av} = 0$

For a purely capacitive circuit, $P_{av} = 0$

## LC Oscillations

In an LC circuit, when the capacitor has charged and is allowed to discharge through a non-resistance, then electrical oscillations of a constant frequency and amplitude are produced. This phenomenon is termed as LC oscillations.

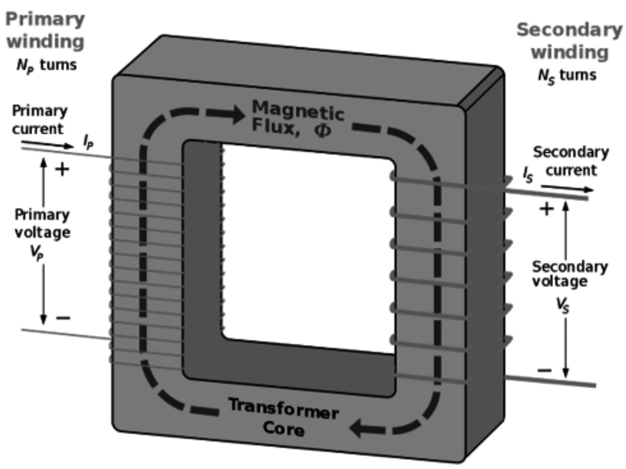


The frequency of oscillation, $\omega_0 = 1/\sqrt{LC}$

The total energy in LC circuit is, $U_E = \frac{1}{2}\frac{q_m^2}{C}$

# Transformers

Transformers are used to change the value of an alternating current from a higher value to a lower one or lower value to higher value. It has primary and secondary windings that help step up or step down voltage.




Where $N_p$ is the number of primary windings and $N_s$ is the number of secondary windings.

Induced emf in a primary coil is, ep $= N_p\ (d\phi/dt)$ .....(1)

Induced emf in secondary coil is, $e_s = N_s\ (d\phi/dt)$ ......(2)

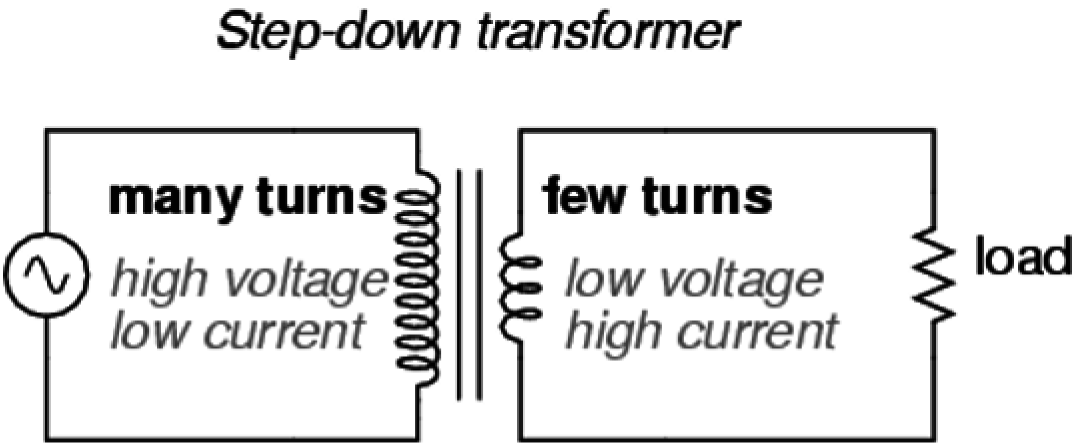
equation (1)/(2), $e_p / e_s = N_p/N_s$

Also, $e_p I_p = e_s I_s$ (where $I_s$ is the current flowing through secondary coil, $I_p$ is the current flowing through the primary coil)

Therefore $I_s/I_p = e_p/e_s = N_p/N_s$

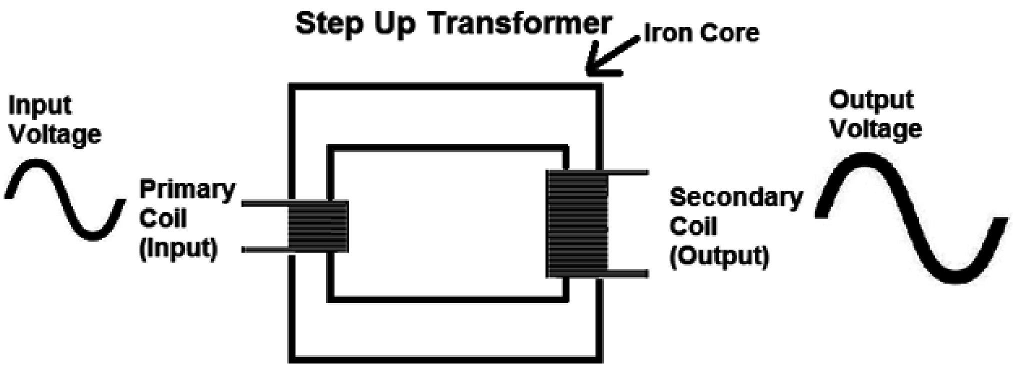
**Transformer are two types:-**

**Step down Transformer-** Step down transformer is one which converts high voltage at the primary coil to low voltage at the secondary coil. In step down transformer number of turns in the secondary coil is less than the number of turns in the primary coil ( $N_s < N_p$ ).




In step down transformer, $e_s < e_p$ and $I_s > I_p$

**Step up transformer-** Step up transformer is one which converts low voltage at the primary coil to high voltage at the secondary coil. In step up transformer number of turns in the primary coil is less than the number of turns in the secondary coil ($N_s > N_p$ ).




In step-up transformer, $e_s > e_p$, and $I_s < I_p$

The efficiency of the transformer is, $\eta = (e_s I_s)/(e_p I_p)$

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