LCR series circuit, resonance,

CLASS-XII

SUBJECT : PHYSICS
CHAPTER NUMBER: 07
CHAPTER NAME : ALTERNATING CURRENT

CHANGING YOUR TOMORROW

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LEARNING OUTCOME

After this lesson, students will be able:

- Explain from where electricity comes and how we use it.
- Define electrical energy in terms of charge, voltage, current and resistance.
- Identify the types of engineering careers that work primarily with electrical energy.

Slide 2

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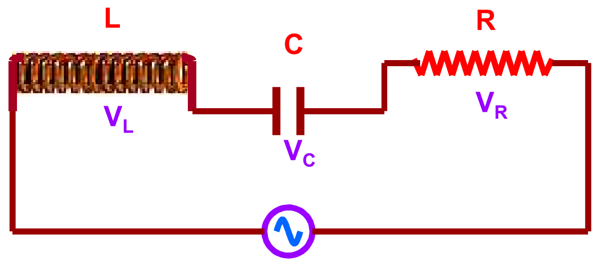
3 @Format for content and slide heading is missing? Just like you have mentioned in DOC., We need to specify, for each slide's heading and text content, what will be the font style +amanrouniyar@odmegroup.org
Assigned to you
-Swoyan Satyendu
, 6/17/2020

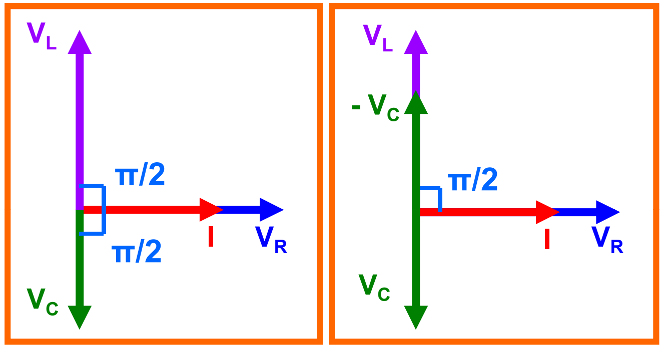
AC Circuit with L, C, R in Series Combination:

The applied emf appears as Voltage drops V_R, V_L and V_C across R, L and C respectively.

1) In R, current and voltage are in phase.
2) In L, current lags behind voltage by π/2
3) In C, current leads the voltage by π/2



$E = E_0 \sin \omega t$

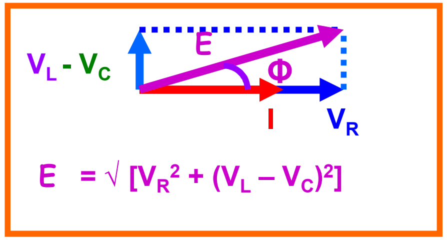


$$E = \sqrt{[V_R^2 + (V_L - V_C)^2]}$$

$$I = \frac{E}{\sqrt{[R^2 + (X_L - X_C)^2]}}$$

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

$$Z = \sqrt{[R^2 + (\omega L - 1/\omega C)^2]}$$



$$\tan \Phi = \frac{X_L - X_C}{R} \quad \text{or} \quad \tan \Phi = \frac{\omega L - 1/\omega C}{R}$$

$$\tan \Phi = \frac{X_L - X_C}{R}$$ or $$\tan \Phi = \frac{\omega L - 1/\omega C}{R}$$

Special Cases:

Case I: When $X_L > X_C$ i.e. $\omega L > 1/\omega C$,

$\tan \Phi = +ve$ or Φ is +ve

The current lags behind the emf by phase angle Φ and the LCR circuit is inductance - dominated circuit.

Case II: When $X_L < X_C$ i.e. $\omega L < 1/\omega C$,

$\tan \Phi = -ve$ or Φ is -ve

The current leads the emf by phase angle Φ and the LCR circuit is capacitance - dominated circuit.

Case III: When $X_L = X_C$ i.e. $\omega L = 1/\omega C$,

$\tan \Phi = 0$ or Φ is $0°$

The current and the emf are in same phase. The impedance does not depend on the frequency of the applied emf. LCR circuit behaves like a purely resistive circuit.

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Resonance in AC Circuit with L, C, R:

When $X_L = X_C$ i.e. $\omega L = 1/\omega C$, $\tan \Phi = 0$ or Φ is $0°$

$Z = \sqrt{[R^2 + (\omega L - 1/\omega C)^2]}$ becomes $Z_{min} = R$ and $I_{0max} = E / R$

i.e. The impedance offered by the circuit is minimum and the current is maximum. This condition is called resonant condition of LCR circuit and the frequency is called resonant frequency.

At resonant angular frequency ω_r,

$\omega_r L = 1/\omega_r C$ or $\omega_r = 1 / \sqrt{LC}$ or $f_r = 1 / (2\pi \sqrt{LC})$

Resonant Curve & Q - Factor:

Band width = $2 \Delta \omega$

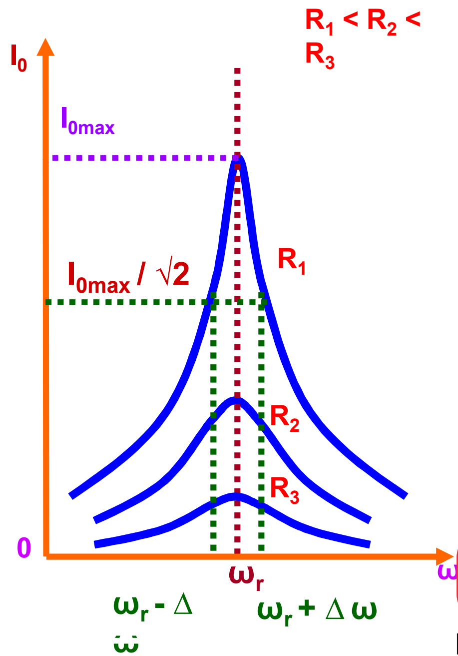
Quality factor (Q – factor) is defined as the ratio of resonant frequency to band width.

$$Q = \omega_r / 2 \Delta \omega$$

It can also be defined as the ratio of potential drop across either the inductance or the capacitance to the potential drop across the resistance.

$Q = V_L / V_R$ or $Q = V_C / V_R$

or $Q = \omega_r L / R$ or $Q = 1 / \omega_r CR$



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Power in AC Circuit with L, C, R:

$E = E_0 \sin \omega t$

$I = I_0 \sin (\omega t + \Phi)$ (where Φ is the phase angle between emf and current)

Instantaneous Power $= E\,I$

$= E_0 I_0 \sin \omega t \sin (\omega t + \Phi)$

$= E_0 I_0 [\sin^2 \omega t \cos\Phi + \sin \omega t \cos\omega t \ \cos\Phi]$

If the instantaneous power is assumed to be constant for an infinitesimally small time dt, then the work done is

$dW = E_0 I_0 [\sin^2 \omega t \cos\Phi + \sin \omega t \cos\omega t \ \cos\Phi]$

Work done over a complete cycle is

$$W = \int_0^T E_0 I_0 [\sin^2 \omega t \cos\Phi + \sin \omega t \cos\omega t \ \cos\Phi]\, dt$$

$W = E_0 I_0 \cos \Phi \times T / 2$

Average Power over a cycle is $P_{av} = W / T$

$P_{av} = (E_0 I_0 / 2) \cos \Phi$

$P_{av} = (E_0/\sqrt{2}) (I_0/\sqrt{2}) \cos \Phi$

$P_{av} = E_v I_v \cos \Phi$

(where $\cos \Phi = R / Z$

$= R / \sqrt{[R^2 + (\omega L - 1/\omega C)^2]}$ is called **Power Factor**)

$P_{av} = E_v I_v \cos \Phi$

Power in AC Circuit with R:

In R, current and emf are in phase.

$\Phi = 0°$

$P_{av} = E_v I_v \cos \Phi = E_v I_v \cos 0° = E_v I_v$

Power in AC Circuit with L:

In L, current lags behind emf by π/2.

$\Phi = - \pi/2$

$P_{av} = E_v I_v \cos (-\pi/2) = E_v I_v (0) = 0$

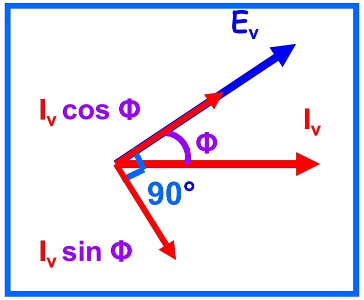
Power in AC Circuit with C:

In C, current leads emf by π/2.

$\Phi = + \pi/2$

$P_{av} = E_v I_v \cos (\pi/2) = E_v I_v (0) = 0$

Wattless Current or Idle Current:



The component $I_v \cos \Phi$ generates power with E_v.

However, the component $I_v \sin \Phi$ does not contribute to power along E_v and hence power generated is zero. This component of current is called wattless or idle current.

Note:

Power (Energy) is not dissipated in Inductor and Capacitor and hence they find a lot of practical applications and in devices using alternating current.

HOME ASSIGNMENT

1. Two bulbs are rated (P_1, V) $and(P_2, V)$. If they are connected (i) in series and (ii) in parallel across a supply V, find the power dissipated in the two combinations in terms of P_1 and P_2 .
2. Two electric bulbs P and Q have their resistances in the ratio of 1:2. They are connected in series across a battery. Find the ratio of the power dissipation in these bulbs.

3. A 25 W and a 100W bulb are joined in (i) series (ii) parallel and connected to the main. Which bulb glows brighter?

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