CBSE Class 12 physics

Important Questions

Chapter 7

Alternating Current

3 Mark Questions

1. A variable frequency 230V alternating voltage source is connected across a series combination of L = 5H, C = 80 μ F and R = 40 Ω . Calculate

(a) Angular frequency of the source which drives the circuit in resonance

(b) Impedance of the circuit

(c) Amplitude of current at resonance.

Ans. Power factor of circuit A

$$\cos\phi A = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + 9R^2}}$$

$$\cos\phi A = \frac{\cancel{R}}{\sqrt{10}\cancel{R}}$$

$$\cos\phi A = \frac{1}{\sqrt{10}} \text{ ----(1)}$$

Power factor of circuit B

$$\cos\phi B = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{R}{\sqrt{R^2 + (3R - R)^2}}$$

$$\cos\phi B = \frac{R}{\sqrt{R^2 + 4R^2}} = \frac{R}{\sqrt{5R^2}}$$

$$\cos\phi B = \frac{1}{\sqrt{5}} \text{ ----(2)}$$

$$\frac{\cos\phi B}{\cos\phi A} = \frac{\frac{1}{\sqrt{5}}}{\frac{1}{\sqrt{10}}}$$

$$\cos\phi B : \cos\phi A = \sqrt{2}$$

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2. Show that in the free oscillations of an LC circuit, the sum of the energies stored in the capacitor and the inductor is constant in time?

Ans. Energy stored in capacitor

$$= \frac{1}{2}\frac{q_2}{C} \; (\because q = q0\cos wt)$$

$$= \frac{1}{2} q0^2 \cos^2 wt \text{ ----(1)}$$

Energy stored in an inductor = $\frac{1}{2} LI^2$

$$\Rightarrow \text{E} = \frac{1}{2} L\left(\frac{dq}{dt}\right)^2 \left(I = Io\cos wt \because I = \frac{dq}{dt}\right)$$

$$E = \frac{1}{2} L\left[\frac{d}{dt}(q_o \cos wt)\right]^2$$

$$E = \frac{1}{2} Lq_0^2 w^2 \sin^2 wt$$

$$E = \frac{q_0^2}{2} \sin^2 wt \cancel{L}\left(\frac{1}{\cancel{L}C}\right)\left(\because w^2 = \frac{1}{LC}\right)$$

$$E = \frac{q_0^2}{2C} \sin^2 wt$$

Combining (1) & (2) to get total amount of energy

$$E = \frac{q_o^2}{2C}\left[\sin^2 wt + \cos^2 wt\right]$$

(Constant) $E = \frac{q_o^2}{2C}$

3. Define mutual inductance? What is its S.I. unit? Write the expression for the mutual inductance between a pair of circular coils of radius r and R (R > r).

Ans. It is defined as the phenomenon of inducing emf in a coil due to the rate of change of current in a nearby coil. Its S.I. unit is Henry (H).

Let two coaxial concentric

coils of radio r and R (R > r)

be placed in air. If current

I_2 flows through R, the magnetic flux gets linked up with secondary coil (coils of radius r) & is given by

$$\phi s = BA = \left(\frac{\mu_o I_2}{2R}\right)\left(\pi r^2\right)$$

$$\phi s = \frac{\mu_o \pi r^2 I_2}{2R} \text{ ----(1)}$$

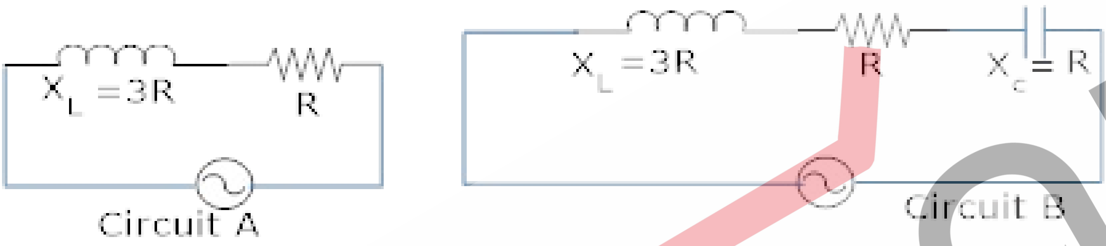
$$Also\ \phi s = MI_2 \text{ ----(2)}$$

Combining equation (1) & (2)

$$MI_2 = \frac{\mu_o \pi r^2 I_2}{2R}$$

$$M = \frac{\mu_o \pi r^2}{2R}$$

4. Figure shows two electric circuits A and B. calculate the ratio of power factor of the circuit B to the power factor of the circuit A?



Ans. Power factor of circuit A

$$\cos\phi A = \frac{R}{\sqrt{R^2 + X_L^2}} = \frac{R}{\sqrt{R^2 + 9R^2}}$$

$$\cos\phi A = \frac{\cancel{R}}{\sqrt{10}\cancel{R}}$$

$$\cos\phi A = \frac{1}{\sqrt{10}} \text{ ------(1)}$$

Power factor of circuit B

$$\cos\phi B = \frac{R}{\sqrt{R^2 + (X_L - X_C)^2}} = \frac{R}{\sqrt{R^2 + (3R - R)^2}}$$

$$\cos\phi B = \frac{R}{\sqrt{R^2 + 4R^2}} = \frac{R}{\sqrt{5R^2}}$$

$$\cos \phi B = \frac{1}{\sqrt{5}} \quad \text{----(2)}$$

$$\frac{\cos \phi B}{\cos \phi A} = \frac{\frac{1}{\sqrt{5}}}{\frac{1}{\sqrt{10}}}$$

$$\cos \phi B : \cos \phi A = \sqrt{2}$$

5. A horizontal straight wire l0 m long is extending along east and west and is falling with a speed of 5.0 m/s at right angles to the horizontal component of the earth's magnetic field of strength $0.30 \times 10^{-4} wb/m^2$.

(a) What is the instantaneous value of the emf induced in the wire?

(b) What is the direction of the emf?

(c) Which end of the wire is at the higher potential?

Ans. length of the wire, l =10m

υ = 5.0m/s.

$$B_H = 0.30 \times 10^{-4} wb/m^2$$

(a) Induced emf $E = B_H l \upsilon$

$$E = 0.30 \times 10^{-4} \times 10 \times 5$$

$$E = 1.5 \times 10^{-3} V$$

(b) Induced emf sets up from west to east.

(c) The potential will be more for eastern end.

6. A circular coil of N turns and radius r is kept normal to a magnetic field, given by B =

Bo cos wt. Deduce an expression for emf. Induced in the coil. State the rule which helps to detect the direction of induced current.

Ans. B = Bo cos wt (given)

$$E = \frac{-Nd\phi}{dt}$$

$$E = \frac{-NAd}{dt}(Bo\cos wt)$$

$$E = -NABo(-\sin wt)(wt)$$

$$E = NABo(-\sin wt)(w)$$

$$E = NABow\sin wt$$

$$(A = \pi R^2)$$

$$E = NBo\pi R^2 w\ sin\ wt$$

Lenz's law is used to fuid the direction of induced emf. It states the direction of induced emf is opposite to the cause producing the induced emf.

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7. **In Exercises 7.3 and 7.4, what is the net power absorbed by each circuit over a complete cycle. Explain your answer.**

Ans. In the inductive circuit,

Rms value of current, I = 15.92 A

Rms value of voltage, V = 220 V

Hence, the net power absorbed can be obtained by the relation,

$P = VI\cos\phi$

Where,

ϕ = Phase difference between *V* and *I*

For a pure inductive circuit, the phase difference between alternating voltage and current is $90°$ i.e., $\phi = 90°$.

Hence, *P* = 0 i.e., the net power is zero.

In the capacitive circuit,

Rms value of current, *I* = 2.49 A

Rms value of voltage, *V* = 110 V

Hence, the net power absorbed can ve obtained as:

P = *VI* Cos ϕ

For a pure capacitive circuit, the phase difference between alternating voltage and current is $90°$ i.e., $\phi = 90°$.

Hence, *P* = 0 i.e., the net power is zero.

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8. A series *LCR* circuit with *R* = 20 Ω, *L* = 1.5 H and *C* = 35 μF is connected to a variable-frequency 200 V ac supply. When the frequency of the supply equals the natural frequency of the circuit, what is the average power transferred to the circuit in one complete cycle?

Ans. At resonance, the frequency of the supply power equals the natural frequency of the given *LCR* circuit.

Resistance, *R* = 20 Ω

Inductance, *L* = 1.5 H

Capacitance, *C* = 35 $\mu F = 30 \times 10^{-6}\ F$

AC supply voltage to the *LCR* circuit, *V* = 200 V

Impedance of the circuit is given by the relation,

$$Z = \sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}$$

At resonance, $\omega L = \dfrac{1}{\omega C}$ s

$\therefore Z = R = 20\Omega$

Current in the circuit can be calculated as:

$$I = \frac{V}{Z}$$

$$= \frac{200}{20} = 10A$$

Hence, the average power transferred to the circuit in one complete cycle= *VI*

= 200 × 10 = 2000 W.

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9. A radio can tune over the frequency range of a portion of MW broadcast band: (800 kHz to 1200 kHz). If its *LC* circuit has an effective inductance of 200 μH , what must be the range of its variable capacitor?

[*Hint:* For tuning, the natural frequency i.e., the frequency of free oscillations of the *LC* circuit should be equal to the frequency of the radio wave.]

Ans. The range of frequency (ν) of a radio is 800 kHz to 1200 kHz.

Lower tuning frequency, ν_1 = 800 kHz = $800 \times 10^3\ Hz$

Upper tuning frequency, ν_2 = 1200 kHz = 1200×10^3 Hz

Effective inductance of circuit *L* = 200 $\nu = 200 \times 10^{2} H$

Capacitance of variable capacitor for ν_1 is given as:

$$C1 = \frac{1}{(\omega)_1^{\,2} L}$$

Where,

ω_1 = *Angular frequency for capacitor C1*

$$= 2\pi V_1 = 2\pi \times 800 \times 10^3\, radS^{-1}$$

$$\therefore C_1 = \frac{1}{(2\pi \times 800 \times 10^3)^2 \times 200 \times 10^{-6}}$$

$$= 1.9809 \times 10^{-10}\, F = 198.1\, pF$$

Capacitance of variable capacitor for v_2 ,

$$C2 = \frac{1}{(\omega)^2_{\,2} L}$$

Where,

ω_2 = *Angular frequency for capacitor* C_2

$$= 2\pi v_2 = 2\pi \times 1200 \times 10^3\, rad\, S^{-1}$$

$$\therefore C_2 = \frac{1}{(2\pi \times 1200 \times 10^3)^2 \times 200 \times 10^{-6}}$$

$$= 88.04\, pF\text{ s}$$

Hence, the range of the variable capacitor is from 88.04 pF to 198.1 pF.

10. Obtain the resonant frequency and Q-factor of a series LCR circuit with L = 3.0 H, C = 27 μF ***, and R = 7.4*** Ω ***. It is desired to improve the sharpness of the resonance of the circuit by reducing its 'full width at half maximum' by a factor of 2. Suggest a suitable way.***

Ans. *Inductance, L = 3.0 H*

Capacitance, C = 27 $\mu F = 27 \times 10^{-6}\ F$

Resistance, R = 7.4 Ω

At resonance, angular frequency of the source for the given LCR series circuit is given as:

$$(i)_r = \frac{1}{\sqrt{LC}}$$

$$= \frac{1}{\sqrt{3 \times 27 \times 10^{-6}}} = \frac{10^3}{9} = 111.11 rad\ S^{-1}$$

Q-factor of the series:

$$= \frac{111.11 \times 3}{7.4} = 45.0446$$

To improve the sharpness of the resonance by reducing its full width at half maximum' by a factor of 2 without changing ω_r *, we need to reduce R to half i.e.,*

Resistance $= \frac{R}{2} = \frac{7.4}{2} = 3.7\Omega$