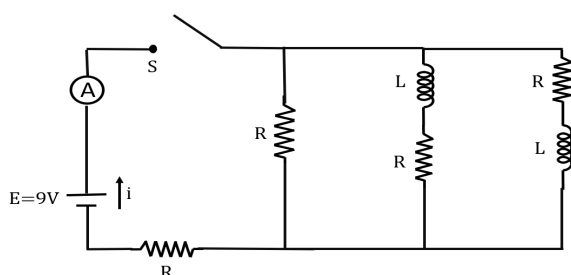


Topic : EMI, AC and EM Waves

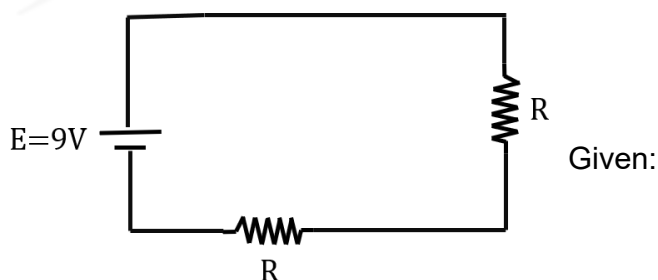
1. The figure shows a circuit that contains four identical resistors with resistance  $R = 2.0 \Omega$ . Two identical inductors with inductance  $L = 2.0 \text{ mH}$  and an ideal battery with emf  $E = 9 \text{ V}$ . The current ( $i$ ) just after the switch ' $s$ ' is closed will be:



- ☐ A. 9 A
- ☐ B. 3 A
- ☒ C. 2.25 A
- ☐ D. 3.37 A

Just when switch ' $s$ ' is closed, inductor will behave like an infinite resistance.

Hence, the circuit will be like



$$E = V = 9 \text{ V}$$

$$R_{\text{eq}} = 2 + 2 = 4 \Omega$$

From  $V = IR$ ,

$$I = \frac{V}{R} = \frac{9}{4} = 2.25 \text{ A}$$

2. Match List I with List II.

List I	List II
<i>a.</i> Source of microwave frequency	<i>i.</i> Radioactive decay of nucleus
<i>b.</i> Source of infrared frequency	<i>ii.</i> Magnetron
<i>c.</i> Source of Gamma Rays	<i>iii.</i> Inner shell electrons
<i>d.</i> Source of X-rays	<i>iv.</i> Vibration of atoms and molecules
	<i>v.</i> LASER
	<i>vi.</i> RC circuit

Choose the correct answer from the option given below:

- ☒ **A.** (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)
- ☐ **B.** (a)-(vi), (b)-(iv), (c)-(i), (d)-(v)
- ☐ **C.** (a)-(ii), (b)-(iv), (c)-(vi), (d)-(iii)
- ☐ **D.** (a)-(vi), (b)-(v), (c)-(i), (d)-(iv)

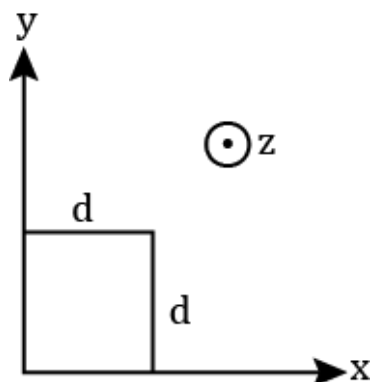
(a) Source of microwave frequency-(*ii*) Magnetron

(b) Source of infrared frequency-(*iv*) Vibrations of atoms and molecules

(c) Source of Gamma Ray-(*i*) Radioactive decay of nucleus

(d) Source of X-ray-(*iii*) Inner shell electron

3. The magnetic field in a region is given by  $\vec{B} = B_0 \left( \frac{x}{a} \right) \hat{k}$ . A square loop of side  $d$  is placed with its edges along the  $x$  and  $y$  axes. The loop is moved with a constant velocity  $\vec{v} = v_0 \hat{i}$ . The emf induced in the loop is:

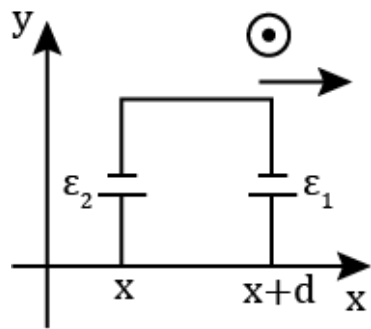


☐ A.  $\frac{B_0 v_0 d^2}{2a}$

☒ B.  $\frac{B_0 v_0 d^2}{a}$

☐ C.  $\frac{B_0 v_0 d}{2a}$

☐ D.  $\frac{B_0 v_0^2 d}{2a}$



Emf in the moving conductor is given as:

$$\varepsilon = \vec{v} \times \vec{B} \cdot \vec{l}$$

Since  $\vec{v} \times \vec{B}$  is along the length of the conductor of the loop for two arms, emf induced in these arms will be,  $\varepsilon = vBl$ .

For other two arms it is perpendicular to the length, so emf in those arms will be zero.

Let assume after some time, loop has moved a distance of  $x$ .

$$\varepsilon_1 = v_0 \frac{B_0(x+d)}{a} d$$

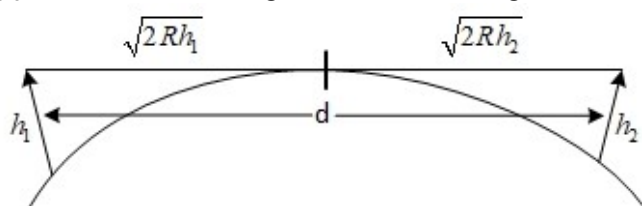
$$\varepsilon_2 = v_0 \frac{B_0 x}{a} d$$

$$\varepsilon_{net} = \varepsilon_1 - \varepsilon_2 = \frac{B_0 v_0 d^2}{a}$$

4. Two identical antennas mounted on identical towers are separated from each other by a distance of 45 km. What should nearly be the minimum height of receiving antenna to receive the signals in line of sight? (Assume radius of earth is 6400 km)

- ☐ A. 19.77 m
- ☐ B. 79.1 m
- ☐ C. 158.2 m
- ☒ D. 39.55 m

Suppose minimum height of the receiving antenna is  $h_2$ .



Given, Range,  $d = 45$  km and  $h_1 = h_2 = h$

Now, Range =  $\sqrt{2Rh} + \sqrt{2Rh}$

$$\Rightarrow d = 2\sqrt{2Rh}$$

$$\Rightarrow h = \frac{d^2}{8R} = \frac{45^2}{8 \times 6400} \text{ km}$$

$$\therefore h = 39.55 \text{ m}$$

5. What happens to the inductive reactance and the current in a purely inductive circuit if the frequency is halved?

- ☐ A. Both, inductive reactance and current will be doubled
- ☐ B. Both, inductive reactance and current will be halved
- ☐ C. Inductive reactance will be halved and current will be doubled
- ☒ D. Inductive reactance will be doubled and current will be halved

Inductive reactance,  $X_L = \omega L$

If frequency is halved,  $X'_L = \left(\frac{X_L}{2}\right)$

[inductive reactance is halved]

$$\therefore I = \frac{V}{X_L}$$

$$\text{So, } I' = \frac{2V}{X_L} = 2I \text{ [current will be doubled]}$$

6. The time taken for the magnetic energy to reach 25% of its maximum value, when a solenoid of resistance  $R$  and inductance  $L$  is connected to a battery, is -

- ☒ A.  $\frac{L}{R} \ln 2$
- ☐ B.  $\frac{L}{R} \ln 10$
- ☐ C. Infinite
- ☐ D.  $\frac{L}{R} \ln 5$

We know that, magnetic energy,

$$U = \frac{1}{2} Li^2,$$

When circuit has maximum current:

Maximum value of magnetic energy,

$$U_o = \frac{1}{2} Li_o^2$$

Given,

$$U = 25\% \text{ of } U_o$$

$$\Rightarrow \frac{1}{2} Li^2 = \frac{1}{4} \times \frac{1}{2} Li_o^2$$

$$\Rightarrow i^2 = \frac{i_o^2}{4}$$

$$\Rightarrow i = \frac{i_o}{2}$$

We know that, current in the circuit at any time  $t$  is given by :

$$i = i_o(1 - e^{-Rt/L})$$

$$\Rightarrow \frac{i_o}{2} = i_o(1 - e^{-Rt/L})$$

$$\Rightarrow \frac{1}{2} = e^{-Rt/L}$$

$$\Rightarrow e^{Rt/L} = 2$$

$$\Rightarrow \frac{Rt}{L} = \ln 2$$

$$\Rightarrow t = \frac{L}{R} \ln 2$$

7. A planer loop of wire rotates in a uniform magnetic field. Initially, at  $t = 0$ , the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane, then the magnitude of induced emf will be maximum and minimum, respectively at:

☐ A. 2.5 s and 7.5 s

☒ B. 2.5 s and 5.0 s

☐ C. 5.0 s and 7.5 s

☐ D. 5.0 s and 10.0 s

Given that, the time period,  $T = 10$  s

$$\therefore \text{Angular velocity, } \omega = \frac{2\pi}{10} = \frac{\pi}{5}$$

$$\text{Magnetic flux, } \phi(t) = BA \cos \omega t$$

Emf induced,

$$\mathcal{E} = \frac{-d\phi}{dt} = BA\omega \sin \omega t$$

$$\text{Induced emf, } |\mathcal{E}| \text{ is maximum when } \sin \omega t = 1 \rightarrow \omega t = \frac{\pi}{2}$$

$$\Rightarrow t = \frac{\left(\frac{\pi}{2}\right)}{\left(\frac{\pi}{5}\right)} = 2.5 \text{ s}$$

$\therefore$  Induced emf is maximum at  $t = 2.5$  s

For induced emf to be minimum i.e. zero

$$\omega t = \pi \Rightarrow t = \frac{\pi}{\left(\frac{\pi}{5}\right)} = 5 \text{ s}$$

$\therefore$  Induced emf is minimum at  $t = 5$  s

Hence, option (B) is correct.

8. An inductor coil stores 64 J of magnetic field energy and dissipates energy at the rate of 640 W when a current of 8 A is passed through it. If this coil is joined across an ideal battery, find the time constant of the circuit, in seconds.

- ☒ A. 0.2  
☐ B. 0.4  
☐ C. 0.8  
☐ D. 0.80

The energy stored in an inductor is,  $U = \frac{1}{2}LI_0^2$

$$64 = \frac{1}{2} \times L \times (8)^2$$

$$\therefore L = 2 \text{ H}$$

Power utilized in an  $R - L$  circuit, in steady state, is,

$$P = I_0^2 R$$

$$\Rightarrow 640 = (8)^2 \times R$$

$$\therefore R = 10 \Omega$$

The time constant of an  $R - L$  circuit is,

$$\tau = \frac{L}{R} = \frac{2}{10} = 0.2 \text{ sec}$$

Hence, (A) is the correct answer.

9. A light beam is described by  $E = 800 \sin \omega \left( t - \frac{x}{c} \right)$ . An electron is allowed to move normal to the propagation of light beam with a speed of  $3 \times 10^7 \text{ ms}^{-1}$ . What is the maximum magnetic force exerted on the electron ?

- ☐ A.  $1.28 \times 10^{-18} \text{ N}$   
☐ B.  $12.8 \times 10^{-18} \text{ N}$   
☒ C.  $12.8 \times 10^{-17} \text{ N}$   
☐ D.  $1.28 \times 10^{-21} \text{ N}$

Given:  $E_0 = 800 \text{ Vm}^{-1}$ ,  $c = 3 \times 10^7 \text{ ms}^{-1}$

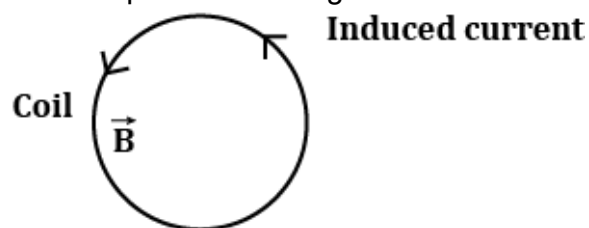
$$\text{Using } B_0 = \frac{E_0}{c} = \frac{800}{3 \times 10^7} = 266.7 \times 10^{-7}$$

The force on the particle is,

$$F = qvB_0 = 1.6 \times 10^{-19} \times 3 \times 10^7 \times 266.7 \times 10^{-7} = 1280.2 \times 10^{-19} = 12.8 \times 10^{-17} \text{ N}$$



10. A coil is placed in a magnetic field  $\vec{B}$  as shown below:



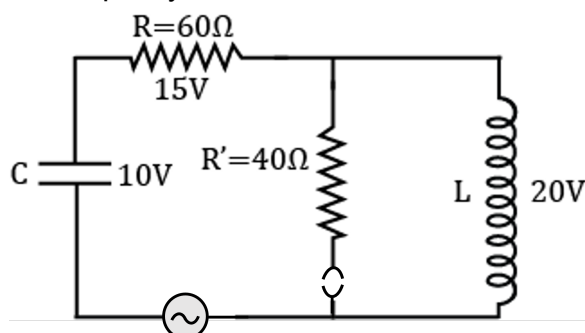
A current is induced in the coil because  $\vec{B}$  is

- ☒ A. outward and increasing with time
- ☒ B. outward and decreasing with time
- ☒ C. parallel to the plane of coil and increasing with time
- ☒ D. parallel to the plane of coil and decreasing with time

$\vec{B}$  must not be parallel to the plane of coil for non zero flux.

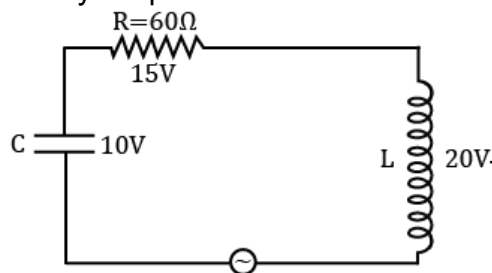
According to lenz law, if  $\vec{B}$  is outward it should be decreasing with time for anticlockwise current to be induced.

11. The angular frequency of alternating current in a  $LCR$  circuit is  $100 \text{ rad/s}$ . The components connected are shown in the figure. Find the value of inductance of the coil and capacity of condenser.



- ☒ A.  $0.8 \text{ H}$  and  $250 \mu\text{F}$
- ☐ B.  $0.8 \text{ H}$  and  $150 \mu\text{F}$
- ☐ C.  $1.33 \text{ H}$  and  $250 \mu\text{F}$
- ☐ D.  $1.33 \text{ H}$  and  $150 \mu\text{F}$

As key is open. The redrawn circuit is shown in the figure.



The shown circuit is series  $LCR$  circuit.

$$\therefore V_R = i_{\text{rms}} R$$

$$\Rightarrow 15 = i_{\text{rms}} \times 60$$

$$\Rightarrow i_{\text{rms}} = 0.25 \text{ A}$$

So,  

$$V_L = i_{\text{rms}} X_L$$

$$\Rightarrow V_L = i_{\text{rms}} \times \omega L$$

$$\Rightarrow 20 = 0.25 \times 100 \times L$$

$$\Rightarrow L = 0.8 \text{ H}$$

Further,

$$V_C = i_{\text{rms}} X_C$$

$$\Rightarrow V_C = i_{\text{rms}} \times \frac{1}{\omega C}$$

$$\Rightarrow 10 = 0.25 \times \frac{1}{100 \times C}$$

$$\Rightarrow C = 2.5 \times 10^{-4} \text{ F} = 250 \mu\text{F}$$

12. An alternating current is given by the equation,  $i = i_1 \sin \omega t + i_2 \cos \omega t$ . The RMS value of current will be :

- ☒ A.  $\frac{1}{2}(i_1^2 + i_2^2)^{\frac{1}{2}}$
- ☒ B.  $\frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{\frac{1}{2}}$
- ☐ C.  $\frac{1}{\sqrt{2}}(i_1 + i_2)^2$
- ☐ D.  $\frac{1}{\sqrt{2}}(i_1 + i_2)$

Given:

$$i = i_1 \sin \omega t + i_2 \cos \omega t$$

$$\Rightarrow i = i_1 \sin \omega t + i_2 \sin(90^\circ + \omega t)$$

So, net current,

$$I_o = \sqrt{i_1^2 + i_2^2 + 2i_1 i_2 \cos \theta}$$

$$\Rightarrow I_o = \sqrt{i_1^2 + i_2^2 + 2i_1 i_2 \cos 90^\circ}$$

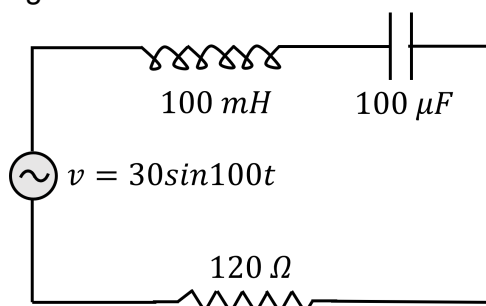
$$\Rightarrow I_o = \sqrt{i_1^2 + i_2^2}$$

We know that,

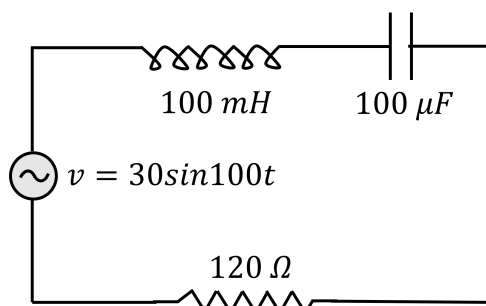
$$I_{RMS} = \frac{I_o}{\sqrt{2}}$$

$$\Rightarrow I_{RMS} = \frac{\sqrt{i_1^2 + i_2^2}}{\sqrt{2}} = \frac{1}{\sqrt{2}}(i_1^2 + i_2^2)^{\frac{1}{2}}$$

13. Find the peak current and the resonant frequency of the following circuit as shown in the figure.



- ☐ A. 0.2 A and 100 Hz
- ☐ B. 2 A and 50 Hz
- ☐ C. 2 A and 100 Hz
- ☒ D. 0.2 A and 50 Hz



Peak current in the series LCR circuit,

$$i = \frac{v_o}{Z}$$

$$\Rightarrow i = \frac{v_o}{\sqrt{(X_L - X_C)^2 + R^2}}$$

$$\Rightarrow i = \frac{30}{\sqrt{\left(100 \times 100 \times 10^{-3} - \frac{1}{100 \times 100 \times 10^{-6}}\right)^2 + 120^2}}$$

$$[X_L = \omega L \text{ and } X_C = \frac{1}{\omega C}]$$

$$\Rightarrow i = 0.2 \text{ A}$$

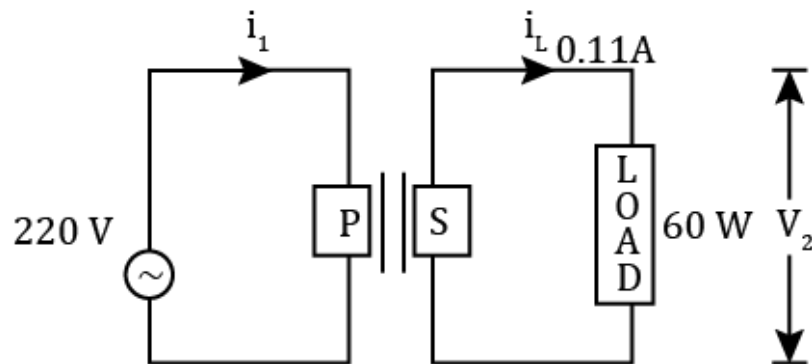
Now, resonance frequency,

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

$$\Rightarrow \omega = \frac{1}{\sqrt{100 \times 10^{-3} \times 100 \times 10^{-6}}} \approx 316 \text{ rad/s}$$

$$\text{So, } f = \frac{\omega}{2\pi} = \frac{316}{2 \times 3.14} \approx 50 \text{ Hz}$$

14. For the given circuit, comment on the type of transformer used.



- ☒ A. Step down transformer
- ☒ B. Auxilliary transformer
- ☒ C. Step up transformer
- ☒ D. Auto transformer

Given, Primary voltage,  $V_p = 220$  volt

For secondary coil:

$$P_s = V_s \times I_s$$

$$60 = V_s \times 0.11$$

$$\text{Secondary voltage, } V_s = \frac{60}{0.11} = 545.45 \text{ volts,}$$

$\therefore V_s > V_p$ , so it is a step up transformer.

15. In a series  $LCR$  resonance circuit, if we change the resistance only, from a lower to higher value:

- ☐ A. The resonance frequency will increase.
- ☐ B. The quality factor will increase.
- ☐ C. The quality factor and the resonance frequency will remain constant.
- ☒ D. The bandwidth of resonance circuit will increase.

The resonance frequency for a series  $LCR$  circuit is given by,

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

Here the value of  $L$  and  $C$  is constant, hence the resonance frequency will not change.

The quality factor is,

$$Q = \frac{\omega L}{R}$$

Hence if  $R \uparrow$  the  $Q \downarrow$

Now the band width of resonance circuit;

$$\Delta\omega = \frac{R}{L}$$

$\Delta\omega \propto R$ , since the value of  $L$  is constant

Thus if  $R \uparrow$  the  $\Delta\omega \uparrow$

Hence bandwidth of the resonance circuit will increase.



16. An AC source rated 220 V, 50 Hz is connected to a resistor. The time taken by the current to change from its maximum to the rms value is:

- ☒ A. 0.25 ms
- ☒ B. 25 ms
- ☒ C. 2.5 ms
- ☒ D. 2.5 s

Given,  $V_{rms} = 200$  V and  $f = 50$  Hz

So,  $V_0 = 220\sqrt{2}$  V and  $\omega = 2\pi f = 100\pi$

$$\Rightarrow V = V_0 \sin \omega t = 220\sqrt{2} \sin(100\pi t)$$

Current in the resistor,  $I = I_0 \sin 100\pi t$  where  $I_0 = \frac{220\sqrt{2}}{R}$

Let current is maximum for first time at time  $t_1$ :

$$I_0 = I_0 \sin(100\pi t_1)$$

$$1 = \sin(100\pi t_1)$$

$$\frac{\pi}{2} = 100\pi t_1$$

$$t_1 = \frac{1}{200}$$

Suppose that current is at its RMS value for first time at time  $t_2$ :

$$\frac{I_0}{\sqrt{2}} = I_0 \sin(100\pi t_2)$$

$$\frac{1}{\sqrt{2}} = \sin(100\pi t_2)$$

$$\frac{\pi}{4} = 100\pi t_2$$

$$t_2 = \frac{1}{400}$$

$$\Delta t = t_1 - t_2 = \frac{1}{200} - \frac{1}{400}$$

$$\Delta t = \frac{1}{400} \text{ s} = 2.5 \text{ ms}$$

17. Match List I with list II

List-I	List- II
(a) Phase difference between current and voltage in a purely resistive AC circuit	(i) $\pi/2$ ; current leads voltage
(b) Phase difference between current and voltage in a pure inductive AC circuit	(ii) zero
(c) Phase difference between current and voltage in a pure capacitive AC circuit	(iii) $\pi/2$ ; current lags voltage
(d) Phase difference between current and voltage in an LCR series circuit	(iv) $\tan^{-1} \left( \frac{X_C - X_L}{R} \right)$

- ☒ A. (a) – (ii), (b) – (iii), (c) – (iv), (d) – (i)  
☒ B. (a) – (i), (b) – (iii), (c) – (iv), (d) – (ii)  
☒ C. (a) – (ii), (b) – (iv), (c) – (iii), (d) – (i)  
☒ D. (a) – (ii), (b) – (iii), (c) – (i), (d) – (iv)

(a) phase difference betweenw current & voltage in a purely resistive AC circuit is zero.

(b) phase difference between current & voltage in a pure inductive AC circuit is  $\frac{\pi}{2}$  and current lags voltage.

(c) phase difference between current & voltage in a pure capacitive AC circuit is  $\frac{\pi}{2}$  and current lead voltage.

(d) phase difference b/w current & voltage in an LCR series circuit is  $= \tan^{-1} \left( \frac{X_C - X_L}{R} \right)$

18. In a series  $LCR$  circuit, the inductive reactance ( $X_L$ ) is  $10\ \Omega$  and the capacitive reactance ( $X_C$ ) is  $4\ \Omega$ . The resistance ( $R$ ) in the circuit is  $6\ \Omega$ . Find the power factor of the circuit.

- ☒ A.  $\frac{1}{\sqrt{2}}$
- ☐ B.  $\frac{\sqrt{3}}{2}$
- ☐ C.  $\frac{1}{2}$
- ☐ D.  $\frac{1}{2\sqrt{2}}$

Given:

$$X_L = 10\ \Omega$$

$$X_C = 4\ \Omega$$

$$R = 6\ \Omega$$

We know that power factor,

$$= \cos \phi = \frac{R}{Z}$$

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

$$= \frac{6}{\sqrt{6^2 + (10 - 4)^2}}$$

$$= \frac{6}{6\sqrt{2}}$$

$$= \frac{1}{\sqrt{2}}$$

Hence, (A) is the correct answer.

19. For a series  $LCR$  circuit with  $R = 100 \Omega$ ,  $L = 0.5 \text{ mH}$  and  $C = 0.1 \text{ pF}$  connected across  $220 \text{ V} - 50 \text{ Hz}$  AC supply, the phase angle between current and supplied voltage and the nature of the circuit is :

- ☐ A.  $0^\circ$ , resistive circuit
- ☐ B.  $\approx 90^\circ$ , predominantly inductive circuit
- ☐ C.  $0^\circ$ , resonance circuit
- ☒ D.  $\approx 90^\circ$ , predominantly capacitive circuit

Given:

$$R = 100 \Omega; L = 0.5 \text{ mH}; C = 0.1 \text{ pF}$$

$$V = 220 \text{ V}; f = 50 \text{ Hz}$$

Inductive reactance,

$$X_L = \omega L = 2\pi fL = 50\pi \times 10^{-3} \Omega$$

Capacitive reactance,

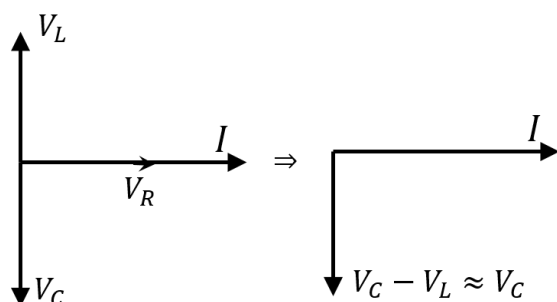
$$X_C = \frac{1}{\omega C} = \frac{1}{2\pi fC} = \frac{10^{11}}{100\pi} = \frac{10^9}{\pi} \Omega$$

From the given calculation, we get,

$$|X_C - X_L| \gg R \text{ \& } X_C \gg X_L$$

$$\Rightarrow X_C \gg R$$

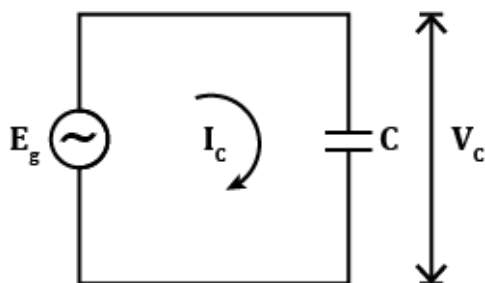
So, this is a capacitive dominant circuit, and phasor diagram of this circuit is,



So, angle between voltage and current is  $\approx 90^\circ$ .

Hence, option (D) is correct.

20. In a circuit consisting of a capacitance and a generator with alternating emf  $E_g = E_g \sin \omega t$ , where  $V_C$  and  $I_C$  are the voltage and current. Correct phasor diagram for such circuit is :



- ⊗ A. Phasor diagram A shows the voltage  $V_c$  as the reference phasor along the positive x-axis. The current  $I_c$  is shown leading  $V_c$  by an angle  $\omega t$ .
- ⊗ B. Phasor diagram B shows the current  $I_c$  as the reference phasor along the positive x-axis. The voltage  $V_c$  is shown leading  $I_c$  by an angle  $\omega t$ .
- ✓ C. Phasor diagram C shows the current  $I_c$  as the reference phasor along the positive x-axis. The voltage  $V_c$  is shown leading  $I_c$  by  $90^\circ$  (indicated by a right-angle symbol).
- ⊗ D. Phasor diagram D shows the voltage  $V_c$  as the reference phasor along the positive x-axis. The current  $I_c$  is shown leading  $V_c$  by  $90^\circ$ .

In a purely capacitive circuit, the current leads the voltage by  $\frac{\pi}{2}$  because first, the current flows through the two plates of the capacitor, where the charge is stored, after that the charge accumulates at the plates of the capacitor and causes an establishment of a voltage difference.

Hence, (C) is the correct answer.

21. In amplitude modulation, the message signal  $V_m(t) = 1 \sin(2\pi \times 10^5 t)$  volts and carrier signal  $V_C(t) = 20 \sin(2\pi \times 10^7 t)$  volts. The modulated signal now contains the message signal with lower side band and upper side band frequency. Therefore the bandwidth of modulated signal is  $\alpha$  kHz. The value of  $\alpha$  is :

- ☒ A. 200 kHz
- ☐ B. 50 kHz
- ☐ C. 100 kHz
- ☐ D. 0 kHz

In amplitude modulation, band width,

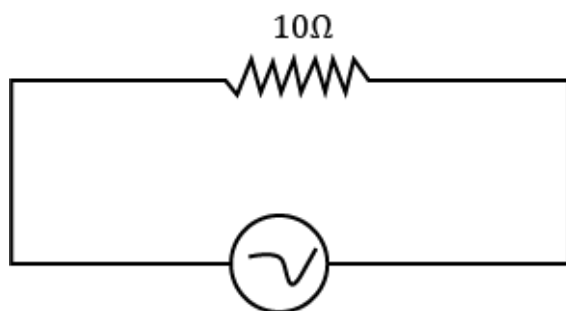
$$= 2 \times f_m = 2 \times \frac{\omega_m}{2\pi}$$

$$= 2 \times 10^5 \text{ Hz} = 200 \text{ kHz}$$

Hence, (A) is the correct answer.

22. A  $10\ \Omega$  resistance is connected across  $220\text{ V}$ – $50\text{ Hz}$   $AC$  supply. The time taken by the current to change from its maximum value to the  $RMS$  value is

- ☒ A.  $2.5\text{ ms}$
- ☐ B.  $1.5\text{ ms}$
- ☐ C.  $3.0\text{ ms}$
- ☐ D.  $4.5\text{ ms}$



As the given AC circuit is a pure  $R$  circuit,

$$V = 220 \text{ V/50 Hz}$$

$$\Rightarrow i = i_0 \sin \omega t$$

Let  $t_1$  be the time taken by the current from zero to maximum value,

When  $i = i_0$

$$\Rightarrow i_0 = i_0 \sin \omega t_1 \Rightarrow \omega t_1 = \frac{\pi}{2} \dots (1)$$

Let  $t_2$  be the time taken by the current from zero to  $RMS$  value,

$$\text{When } i = \frac{i_0}{\sqrt{2}}$$

$$\Rightarrow \frac{i_0}{\sqrt{2}} = i_0 \sin \omega t_2 \Rightarrow \omega t_2 = \frac{\pi}{4} \dots (2)$$

Time taken by current from maximum value to  $RMS$  value

$$\Rightarrow (t_1 - t_2) = \frac{\pi}{2\omega} - \frac{\pi}{4\omega} = \frac{\pi}{4\omega}$$

$$\Rightarrow (t_1 - t_2) = \frac{\pi}{4 \times 2\pi f}$$

$$\Rightarrow (t_1 - t_2) = \frac{1}{8 \times 50}$$

$$\Rightarrow (t_1 - t_2) = \frac{1}{400} \text{ s}$$

$$\Rightarrow (t_1 - t_2) = 2.5 \text{ ms}$$

Hence, option (A) is correct.



23. If a message signal of frequency  $f_m$  is amplitude modulated with a carrier signal of frequency  $f_c$  and radiated through an antenna, the wavelength of the corresponding signal in air is :

[ Given ,  $c$  = speed of electromagnetic wave in vacuum/air ]

☒ A.  $\frac{c}{f_c + f_m}$

☒ B.  $\frac{c}{f_c - f_m}$

☒ C.  $\frac{c}{f_m}$

☒ D.  $\frac{c}{f_c}$

The equation of an amplitude modulated wave is given by :

$$y = (A_c + A_m \sin \omega_m t) \sin \omega_c t$$

Here ,  $\omega_c$  = angular frequency of modulated signal

Thus , frequency of modulated signal =  $f_c$

Hence , wavelength ( $\lambda$ ) =  $\frac{v}{f} = \frac{c}{f_c}$

Option (d) is the correct answer .

24. A signal of 0.1 kW is transmitted in a cable. The attenuation of cable is  $-5$  dB per km and cable length is 20 km. The power received at receiver is  $10^{-x}$  W. The value of  $x$  is .  
 [Gain in  $dB = 10 \log_{10}(\frac{P_0}{P_i})$ ]

Accepted Answers

8      8.0      8.00

Solution:

Power of signal transmitted  $P_i = 0.1 \text{ kW} = 100 \text{ W}$

Rate of attenuation =  $-5 \text{ dB/Km}$

Total length of path = 20 km

Total loss suffered =  $5 \times 20 = -100 \text{ dB}$

Gain in  $dB = 10 \log_{10}(\frac{P_0}{P_i})$

$$\Rightarrow -100 = 10 \log_{10}(\frac{P_0}{P_i})$$

$$\Rightarrow \log_{10}(\frac{P_i}{P_0}) = 10$$

$$\Rightarrow \log_{10}(\frac{P_i}{P_0}) = \log_{10} 10^{10}$$

$$\Rightarrow \frac{100}{P_0} = 10^{10}$$

$$\Rightarrow P_0 = \frac{1}{10^8} = 10^{-8}$$

$$\Rightarrow x = 8$$

25. An audio signal  $v_m = 20 \sin 2\pi(1500t)$  amplitude modulates a carrier  $v_c = 80 \sin 2\pi(100,000t)$ . The value of percent modulation is

Accepted Answers

25    25.0    25.00

Solution:

We know that,

$$\text{Modulation index} = \frac{A_m}{A_c}$$

From given equations,  $A_m = 20$  and  $A_c = 80$

$$\text{Percentage modulation index} = \frac{A_m}{A_c} \times 100$$

$$= \frac{20}{80} \times 100 = 25\%$$

The value of percent modulation index is 25.

26. Given below are two statements :

Statement I : A speech signal of 2 kHz is used to modulate a carrier signal of 1 MHz. The bandwidth requirement for the signal is 4 kHz.

Statement II : The sideband frequencies are 1002 kHz and 998 kHz.

In the light of the above statements, choose the correct answer from the options given below.

- ☒ A. Both statement I and statement II are false.
- ☒ B. Statement I is false, but statement II is true.
- ☒ C. Statement I is true, but statement II is false.
- ☒ D. Both statement I and statement II are true.

$$\text{Sideband} = f_c - f_m \text{ to } f_c + f_m$$

$$= (1000 - 2) \text{ kHz to } (1000 + 2) \text{ kHz}$$

$$= 998 \text{ kHz to } 1002 \text{ kHz}$$

$$\text{Bandwidth} = 2f_m = 2 \times 2 = 4 \text{ kHz}$$

Hence, both statements are true.

27. The maximum and minimum amplitude of an amplitude modulated wave is 16 V and 8 V respectively. The modulation index for this amplitude modulated wave is  $x \times 10^{-2}$ . The value of  $x$  is \_\_\_\_\_. (up to two significant figures)

Accepted Answers

33    33.0    33.00

Solution:

$$A_m = \frac{A_{\max} - A_{\min}}{2} = \frac{16 - 8}{2} = 4 \text{ V}$$

$$A_c = \frac{A_{\max} + A_{\min}}{2} = \frac{16 + 8}{2} = 12 \text{ V}$$

So, Modulation Index,

$$MI = \frac{A_m}{A_c} = \frac{4}{12} = 0.333$$

$$\Rightarrow MI = 33.3 \times 10^{-2} \approx 33 \times 10^{-2}$$

28. If the highest frequency modulating a carrier is 5 kHz, then the number of AM broadcast stations accommodated in a 90 kHz bandwidth are \_\_\_\_\_.

Accepted Answers

9      9.0      9.00

Solution:

$$\text{Number of station, } n = \frac{\text{Bandwidth}}{2 \times \text{Highest Modulating Frequency}}$$

$$\Rightarrow n = \frac{90}{2 \times 5} = 9$$

29. A carrier signal  $C(t) = 25 \sin(2.512 \times 10^{10}t)$  is amplitude modulated by a message signal  $m(t) = 5 \sin(1.57 \times 10^8 t)$  and transmitted through an antenna. What will be bandwidth of the modulated signal?

- ☒ A. 1987.5 MHz
- ☒ B. 2.01 GHz
- ☒ C. 50 MHz
- ☒ D. 8 GHz

Bandwidth of modulated signal is given by,

$$\beta = 2f_{m(t)}$$

Where  $f_m$  is frequency of message signal.

Given,  $\omega_m = 1.57 \times 10^8 \text{ rad/s}$

$$\beta = 2 \times \frac{1.57 \times 10^8}{2\pi}$$

$$\beta = 50 \text{ MHz}$$

30. In a plane electromagnetic wave, the directions of electric field and magnetic field are represented by  $\hat{k}$  and  $2\hat{i} - 2\hat{j}$ , respectively. What is the unit vector along direction of propagation of the wave ?

- ☒ A.  $\frac{1}{\sqrt{2}}(\hat{i} + \hat{j})$
- ☐ B.  $\frac{1}{\sqrt{2}}(\hat{j} + \hat{k})$
- ☐ C.  $\frac{1}{\sqrt{5}}(\hat{i} + 2\hat{j})$
- ☐ D.  $\frac{1}{\sqrt{5}}(2\hat{i} + \hat{j})$

Electromagnetic wave will propagate perpendicular to the direction of Electric and Magnetic fields

$$\hat{C} = \hat{E} \times \hat{B}$$

Here unit vector  $\hat{C}$  is perpendicular to both  $\hat{E}$  and  $\hat{B}$

Given,  $\vec{E} = \hat{k}, \vec{B} = 2\hat{i} - 2\hat{j}$

$$\therefore \hat{C} = \hat{E} \times \hat{B} = \frac{1}{\sqrt{2}} \begin{vmatrix} \hat{i} & \hat{j} & \hat{k} \\ 0 & 0 & 1 \\ 1 & -1 & 0 \end{vmatrix} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$

$$\Rightarrow \hat{C} = \frac{\hat{i} + \hat{j}}{\sqrt{2}}$$