19 Alternating Current And Electromagnetic Induction

Numerical

Q.1. A 20 cm long metallic rod is rotated with 210 rpm about an axis normal to the rod passing through its one end. The other end of the rod is in contact with a circular metallic ring. A constant and uniform magnetic field 0.2 T parallel to the axis exists everywhere. The emf developed between the centre and the ring is ___________ mV

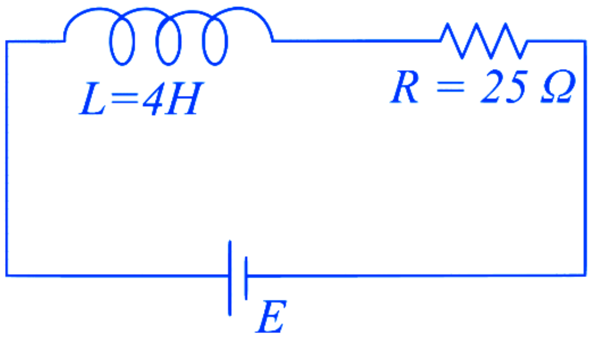
Take $\pi = \frac{22}{7}$

JEE Main 2023 (Online) 15th April Morning Shift

Q.2. An insulated copper wire of 100 turns is wrapped around a wooden cylindrical core of the cross-sectional area $24 \text{ cm}2$. The two ends of the wire are connected to a resistor. The total resistance in the circuit is $12 \ \Omega$. If an externally applied uniform magnetic field in the core along its axis changes from 1.5 T in one direction to 1.5 T in the opposite direction, the charge flowing through a point in the circuit during the change of magnetic field will be ___________ mC.

JEE Main 2023 (Online) 13th April Evening Shift

Q.3. In the given figure, an inductor and a resistor are connected in series with a battery of emf E volt. $\frac{E^a}{2b}\ \mathrm{J}/s$ represents the maximum rate at which the energy is stored in the magnetic field (inductor). The numerical value of a/b will be ________.



JEE Main 2023 (Online) 13th April Morning Shift

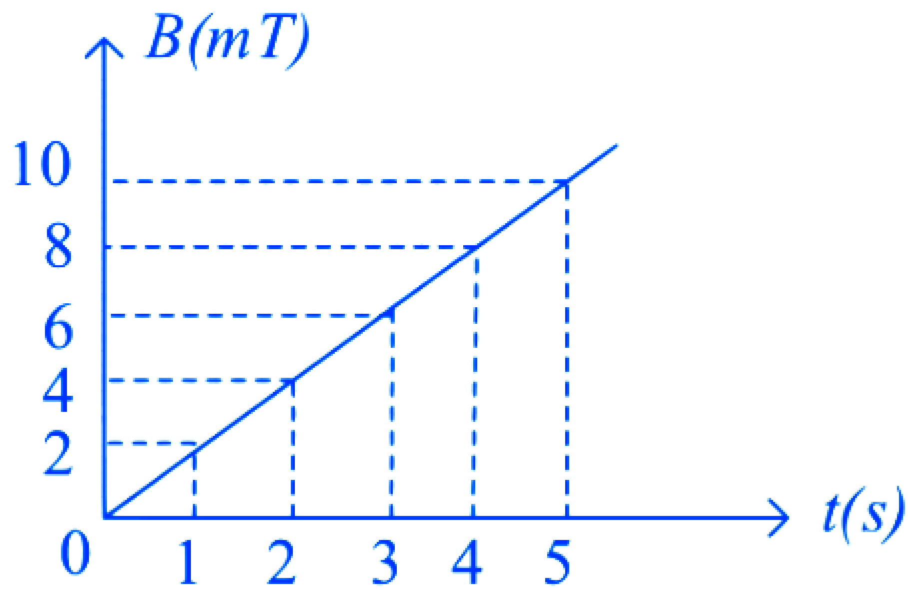
Q.4. A conducting circular loop is placed in a uniform magnetic field of 0.4 T with its plane perpendicular to the field. Somehow, the radius of the loop starts expanding at a constant rate of 1 mm/s. The magnitude of induced emf in the loop at an instant when the radius of the loop is 2 cm will be __________ μV.

JEE Main 2023 (Online) 12th April Morning Shift

Q.5. A coil has an inductance of 2H and resistance of 4 Ω. A 10 V is applied across the coil. The energy stored in the magnetic field after the current has built up to its equilibrium value will be __________ $\times 10^{-2}$ J.

JEE Main 2023 (Online) 11th April Evening Shift

Q.6. The magnetic field B crossing normally a square metallic plate of area 4 m^2 is changing with time as shown in figure. The magnitude of induced emf in the plate during t=2s to t=4s, is _________ mV.



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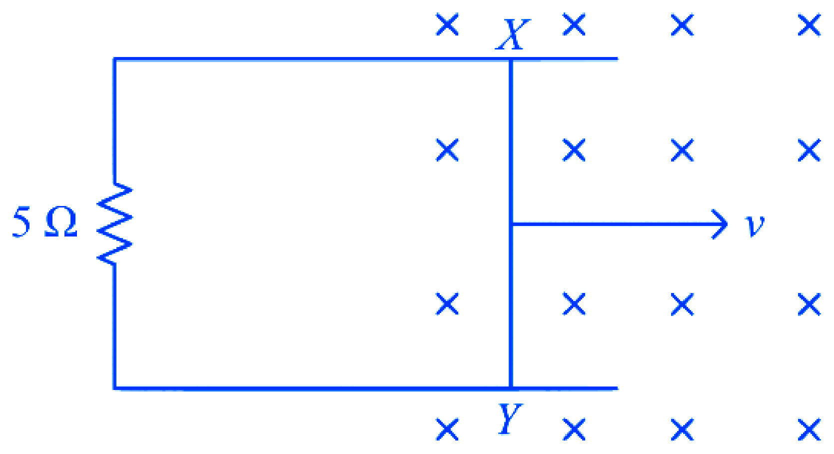
Q.7. A square loop of side 2.0 cm is placed inside a long solenoid that has 50 turns per centimetre and carries a sinusoidally varying current of amplitude 2.5 A and angular frequency 700 rad s^{-1}. The central axes of the loop and solenoid coincide. The amplitude of the emf induced in the loop is $x \times 10^{-4}$ V. The value of x is ________.

(Take, $\pi = \frac{22}{7}$)

JEE Main 2023 (Online) 10th April Morning Shift

Q.8. A 1 m long metal rod XY completes the circuit as shown in figure. The plane of the circuit is perpendicular to the magnetic field of flux density 0.15 T. If the resistance of the circuit is 5Ω, the force needed to move the rod in direction, as indicated, with a constant speed of 4 m/s will be __________ 10^{-3} N.



JEE Main 2023 (Online) 10th April Morning Shift

Q.9. A series combination of resistor of resistance $100\ \Omega$, inductor of inductance $1\ \mathrm{H}$ and capacitor of capacitance $6.25\ \mu\mathrm{F}$ is connected to an ac source. The quality factor of the circuit will be ________

JEE Main 2023 (Online) 8th April Evening Shift

Q.10. An oscillating LC circuit consists of a $75\ \mathrm{mH}$ inductor and a $1.2\ \mu\mathrm{F}$ capacitor. If the maximum charge to the capacitor is $2.7\ \mu\mathrm{C}$. The maximum current in the circuit will be

____

JEE Main 2023 (Online) 8th April Morning Shift

Q.11. Two concentric circular coils with radii $1\ \mathrm{cm}$ and $1000\ \mathrm{cm}$, and number of turns 10 and 200 respectively are placed coaxially with centers coinciding. The mutual inductance of this arrangement will be __________ $\times 10^{-8}\mathrm{H}$. (Take, $\pi^2 = 10$)

JEE Main 2023 (Online) 6th April Evening Shift

Q.12. An ideal transformer with purely resistive load operates at $12\ \mathrm{kV}$ on the primary side. It supplies electrical energy to a number of nearby houses at $120\ \mathrm{V}$. The average rate of energy consumption in the houses served by the transformer is 60 kW. The value of resistive load (R_s) required in the secondary circuit will be __________ mΩ.

JEE Main 2023 (Online) 6th April Morning Shift

Q.13. A square shaped coil of area 70 cm^2 having 600 turns rotates in a magnetic field of 0.4 wbm^{-2}, about an axis which is parallel to one of the side of the coil and perpendicular to the direction of field. If the coil completes 500 revolution in a minute, the instantaneous emf when the plane of the coil is inclined at 60° with the field, will be ___________ V. (Take $\pi = \frac{22}{7}$)

JEE Main 2023 (Online) 1st February Evening Shift

Q.14. A series LCR circuit is connected to an ac source of 220 V,50 Hz. The circuit contain a resistance R=100 Ω and an inductor of inductive reactance X_L=79.6 Ω. The capacitance of the capacitor needed to maximize the average rate at which energy is supplied will be ________ µF.

JEE Main 2023 (Online) 1st February Morning Shift

Q.15. A series LCR circuit consists of R=80Ω,X_L=100Ω, and X_C=40Ω. The input voltage is 2500 $\cos(100\pi t)V$. The amplitude of current, in the circuit, is ________ A.

JEE Main 2023 (Online) 31st January Evening Shift

Q.16. An inductor of 0.5 mH, a capacitor of 20 µF and resistance of 20 Ω are connected in series with a 220 V ac source. If the current is in phase with the emf, the amplitude of current of the circuit is $\sqrt{x}$ A. The value of x is __________.

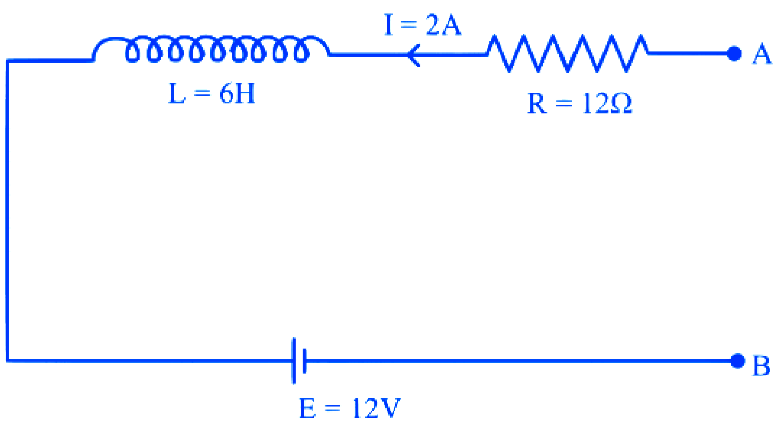
JEE Main 2023 (Online) 31st January Morning Shift

Q.17. In an ac generator, a rectangular coil of 100 turns each having area 14×10^{-2} m2 is rotated at 360 rev/min about an axis perpendicular to a uniform magnetic field of magnitude 3.0 T. The maximum value of the emf produced will be _______ V.

(Take $\pi = \frac{22}{7}$)

JEE Main 2023 (Online) 30th January Evening Shift

Q.18.



As per the given figure, if $\frac{dI}{dt} = -1\, A/s$ then the value of V_{AB} at this instant will be __________ V.

JEE Main 2023 (Online) 30th January Morning Shift

Q.19. An inductor of inductance 2 μH is connected in series with a resistance, a variable capacitor and an AC source of frequency 7 kHz. The value of capacitance for which maximum current is drawn into the circuit 1/xF, where the value of x is __________.

(Take $\pi = \frac{22}{7}$)

JEE Main 2023 (Online) 29th January Evening Shift

Q.20. A certain elastic conducting material is stretched into a circular loop. It is placed with its plane perpendicular to a uniform magnetic field B = 0.8 T. When released the radius of the loop starts shrinking at a constant rate of 2 cms^{-1}. The induced emf in the loop at an instant when the radius of the loop is 10 cm will be _________ mV.

JEE Main 2023 (Online) 29th January Morning Shift

Q.21. A series LCR circuit is connected to an AC source of 220 V, 50 Hz. The circuit contains a resistance R = 80Ω, an inductor of inductive reactance $X_L = 70\Omega$, and a capacitor of capacitive reactance $X_C = 130\Omega$. The power factor of circuit is $x/10$. The value of x is :

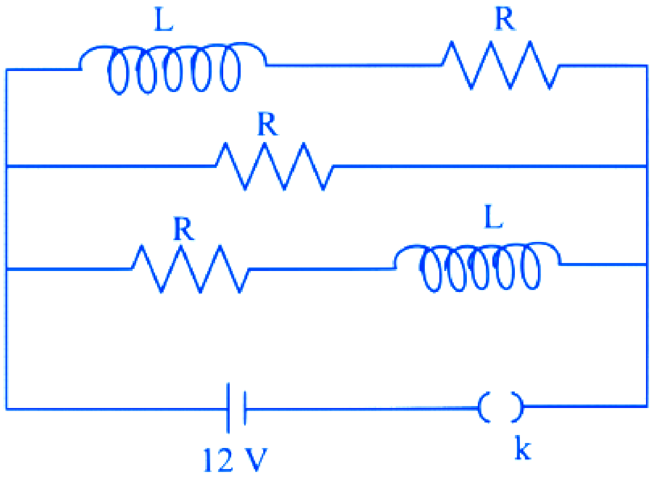
JEE Main 2023 (Online) 25th January Evening Shift

Q.22. An LCR series circuit of capacitance 62.5 nF and resistance of 50 Ω, is connected to an A.C. source of frequency 2.0 kHz. For maximum value of amplitude of current in circuit, the value of inductance is _________ mH.

(Take $\pi^2 = 10$)

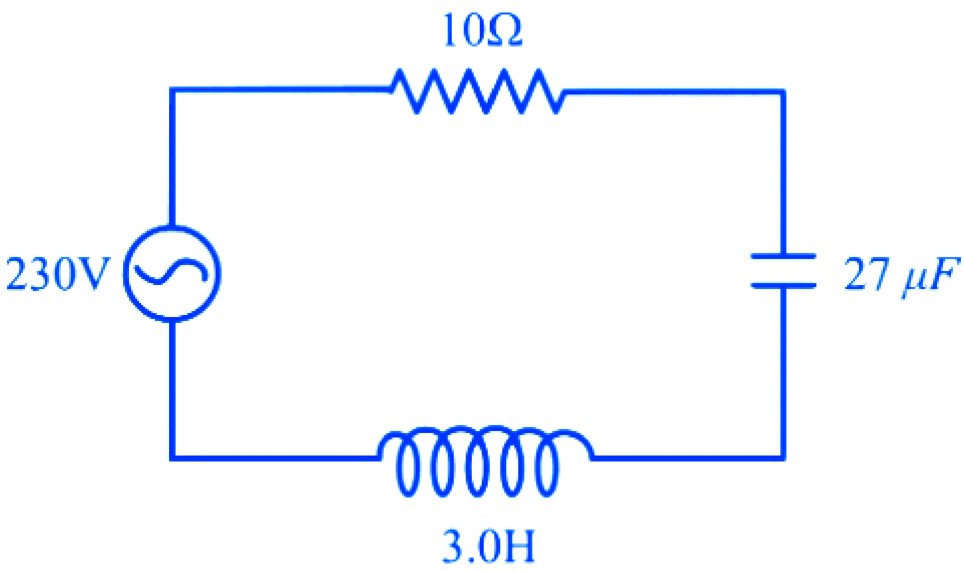
JEE Main 2023 (Online) 25th January Morning Shift

Q.23. Three identical resistors with resistance R = 12Ω and two identical inductors with self inductance L = 5 mH are connected to an ideal battery with emf of 12 V as shown in figure. The current through the battery long after the switch has been closed will be _____________ A.



JEE Main 2023 (Online) 24th January Evening Shift

Q.24. In the circuit shown in the figure, the ratio of the quality factor and the band width is __________ s.



JEE Main 2023 (Online) 24th January Morning Shift

Answer Key & Explanation

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1. Ans. Correct answer is 88

Explanation

Given that the rod is rotating at 210 rpm, we first convert this to radians per second:

$$\omega = 210 \cdot \frac{2\pi \mathrm{rad}}{60 \mathrm{s}} = 22 \mathrm{rad/s}$$

Now, we can find the linear velocity v of the tip of the rod:

$$v = \omega r$$

where r is the length of the rod (0.2 m).

$$v = 22 \mathrm{rad/s} \cdot 0.2 \mathrm{m} = 4.4 \mathrm{m/s}$$

Now, we can find the emf developed between the center and the ring using the formula:

$$\epsilon = \frac{1}{2} B \ell v$$

where B is the magnetic field (0.2 T), ℓ is the length of the rod (0.2 m), and v is the linear velocity (4.4 m/s).

$$\epsilon = \frac{1}{2} \cdot 0.2 \mathrm{T} \cdot 0.2 \mathrm{m} \cdot 4.4 \mathrm{m/s} = 0.088 \mathrm{V}$$

To express this value in mV, we can simply multiply it by 1000:

$$\epsilon = 0.088 \mathrm{V} \cdot 1000 = 88 \mathrm{mV}$$

So the emf developed between the center and the ring is 88 mV.

2. Ans. Correct answer is 60

Explanation

The induced emf in the circuit is given by Faraday's law of electromagnetic induction, which is $\mathcal{E} = -d\phi/dt$, where ϕ is the magnetic flux through the circuit.

The magnetic flux through the circuit is proportional to the magnetic field through the core, so we can write $\phi = NBA$, where N is the number of turns in the loop, B is the magnetic field through the core, and A is the cross-sectional area of the core.

As the magnetic field changes from $1.5\,\mathrm{T}$ in one direction to $-1.5\,\mathrm{T}$ in the opposite direction, the change in magnetic flux is $\Delta\phi = 2NBA$.

The induced emf drives a current I through the resistor in the circuit, and the current and the resistance are related by Ohm's law, which is $I = \mathcal{E}/R$. Substituting the expression for $\mathcal{E}$ into this equation, we get $I = -d\phi/dtR$.

The charge Q that flows through the circuit during the change in magnetic field is given by $Q = \int I dt$. Substituting the expression for I into this equation and integrating with respect to time, we get $Q = -\Delta\phi/R$, where $\Delta\phi$ is the change in magnetic flux and R is the resistance of the circuit.

Substituting the given values into this expression, we get:

$$Q = -\frac{2NBA}{R} = -\frac{2(100)(1.5)(24\times10^{-4})}{12} = -0.06\,\mathrm{C} = -60\,\mathrm{mC}$$

Therefore, the charge flowing through a point in the circuit during the change of magnetic field is $60\,\mathrm{mC}$, which is the same as the provided answer.

3. Ans. Correct answer is 25

Explanation

$E=\frac{1}{2} L I^2$

Rate of energy storing $=\frac{d E}{d t}=L I \frac{d I}{d t}$

Now we Know for $R-L$ circuit

$I=\frac{E}{R}\left(1-e^{-t \frac{R}{L}}\right)$

So $\frac{d I}{d t}=\frac{E}{L} e^{-\frac{t R}{L}}$

$\frac{d E}{d t}=\frac{E^2}{R}\left(1-e^{-\frac{t R}{L}}\right)\left(e^{-t \frac{R}{L}}\right)$

Time at which rate of power storing will be $\max$

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

So $\frac{d E}{d t}=\frac{E^2}{R}\left(1-\frac{1}{2}\right) \times \frac{1}{2}$

$\Rightarrow \frac{E^2}{4 R}=\frac{E^2}{100}=\frac{E^2}{2 \times 50}$

$a=2, b=50$

4. Ans. Correct answer is 50

Explanation

The problem involves a conducting circular loop placed in a uniform magnetic field with its plane perpendicular to the field. The radius of the loop is expanding at a constant rate, and we are asked to find the magnitude of the induced emf in the loop at an instant when the radius of the loop is $2\,\mathrm{cm}$.

The magnetic flux through a circular loop of radius r and area $A = \pi r^2$ placed in a uniform magnetic field B perpendicular to the plane of the loop is given by:

$$\Phi_B = BA = B\pi r^2$$

The induced emf in the loop is given by Faraday's law of electromagnetic induction:

$$\mathcal{E} = -\frac{d\Phi_B}{dt}$$

In this case, the radius of the loop is expanding at a constant rate of $10^{-3}\,\mathrm{m/s}$, which means that the rate of change of the area of the loop is:

$$\frac{dA}{dt} = \frac{d}{dt}(\pi r^2) = 2\pi r\frac{dr}{dt} = 2\pi(0.02\,\mathrm{m})(10^{-3}\,\mathrm{m/s}) = 4 \times 10^{-5}\,\mathrm{m^2/s}$$

The magnetic flux through the loop is changing at this rate, and the induced emf in the loop is given by:

$$\mathcal{E} = \left|\frac{d\Phi_B}{dt}\right| = \left|\frac{dB}{dt}\frac{dA}{dt}\right| = \left|B\frac{dA}{dt}\right| = \left|0.4\,\mathrm{T} \times 4 \times 10^{-5}\,\mathrm{m^2/s}\right| = 16\pi\mu\mathrm{V}$$

Therefore, the magnitude of the induced emf in the loop at an instant when the radius of the loop is $2\,\mathrm{cm}$ is $50.24 \simeq 50\ \mu\mathrm{V}$.

5. Ans. Correct answer is 625

Explanation

To find the energy stored in the magnetic field after the current has built up to its equilibrium value, we first need to find the steady-state current in the coil.

When the current reaches its equilibrium value, the coil behaves like a resistor because the back-emf induced by the changing magnetic field is zero. Ohm's law can be applied:

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

where

I is the current
V is the voltage across the coil (10 V)
R is the resistance of the coil (4 Ω)

Plugging in the values:

$I = \frac{10}{4}$ $I = 2.5\ \mathrm{A}$

Now that we have the steady-state current, we can find the energy stored in the magnetic field using the formula:

where

W is the energy stored in the magnetic field
L is the inductance of the coil (2 H)
I is the steady-state current (2.5 A)

Plugging in the values:

$W = \frac{1}{2}(2)(2.5)^2$

$W = 1(6.25)$

$W = 6.25\ \mathrm{J}$

To express this in terms of $10^{-2}\ \mathrm{J}$, divide by 10^{-2}:

$6.25 \div 10^{-2} = 625$

Therefore, the energy stored in the magnetic field after the current has built up to its equilibrium value is $625 \times 10^{-2}\ \mathrm{J}$.

6. Ans. Correct answer is 8

Explanation

$$\mathrm{m}=\tan\theta=\frac{10}{5}=2$$

$$\mathrm{B}=\mathrm{mt}$$

$$\mathrm{B}=2\mathrm{t}$$

$$\varepsilon=\left|\frac{\mathrm{d}\phi}{\mathrm{dt}}\right|=\frac{\mathrm{d(BA)}}{\mathrm{dt}}=\frac{\mathrm{AdB}}{\mathrm{dt}}$$

$$\varepsilon=\frac{4\,\mathrm{d(2t)}}{\mathrm{dt}}=4\times2=8\mathrm{mV}$$

7. Ans. Correct answer is 44

Explanation

In this problem, a square loop is inside a long solenoid, and there's a varying current flowing through the solenoid. Because the current is changing, it induces a changing magnetic field inside the solenoid.

According to Faraday's law of electromagnetic induction, a changing magnetic field will induce an electromotive force (emf) in a loop placed in that field. In this case, the loop is the square loop inside the solenoid.

The formula used here is based on Faraday's law, which states that the induced emf in a loop is equal to the rate of change of magnetic flux through the loop. This is given by:

$$\text{emf}=-\frac{d\Phi}{dt}$$

where Φ is the magnetic flux.

The magnetic field inside a solenoid is given by $B = \mu_0 n I$, where μ_0 is the permeability of free space, n is the number of turns per unit length in the solenoid, and I is the current through the solenoid.

The magnetic flux through the square loop is then given by $\Phi = B \cdot A = \mu_0 n I A$, where A is the area of the loop.

When the current is sinusoidal, i.e., $I(t) = I_0 \sin(\omega t)$, its derivative with respect to time is $dI/dt = I_0 \omega \cos(\omega t)$, where ω is the angular frequency.

Hence, the rate of change of flux becomes:

$$\frac{d\Phi}{dt} = \mu_0 n A \frac{dI}{dt} = \mu_0 n A I_0 \omega \cos(\omega t)$$

The emf, which is equal to the negative of the rate of change of flux, will have a maximum value (the amplitude) when $\cos(\omega t) = 1$, giving:

Emf amplitude $= \mu_0 n A I_0 \omega$

$$= 4\pi \times 10^{-7}\,\text{T m/A} \times \left(\frac{50}{10^{-2}}\right)\text{turns/m} \times (2 \times 10^{-2}\,\text{m})^2 \times 2.5\,\text{A} \times 700\,\text{rad/s}$$

which simplifies to:

Emf amplitude $= 44 \times 10^{-4}\,\text{V}$

So, the value of x in the question is 44

8. Ans. Correct answer is 18

9. Ans. Correct answer is 4

Explanation

The Q factor (quality factor) in a series RLC circuit can be given by the formula:

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

where (X_L) is the inductive reactance, (R) is the resistance, (L) is the inductance, and (ω) is the angular frequency.

In a series RLC circuit at resonance, the resonant frequency (f) is given by

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

or equivalently, the angular frequency (ω) at resonance is

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

Substituting (L = 1H) and ($C = 6.25\mu F = 6.25 \times 10^{-6}F$) into the equation for (\omega) gives

$$\omega = \frac{1}{\sqrt{1H \times 6.25 \times 10^{-6}F}}$$ = 400 rad/s

Substituting ($\omega = 400rad/s$), (L = 1H), and ($R = 100\Omega$) into the equation for the Q factor gives

$$Q = \frac{\omega L}{R} = \frac{400rad/s \times 1H}{100\Omega} = 4$$

So, the Q factor of the circuit is 4.

10. Ans. Correct answer is 9

Explanation

The maximum current in an LC circuit can be found using the following formula related to simple harmonic motion:

$$I_{\text{max}} = \omega Q_{\text{max}} \ ,$$

where:

I_{max} is the maximum current,
ω is the angular frequency, and
Q_{max} is the maximum charge on the capacitor.

The angular frequency ω for an LC circuit is given by:

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

where:

L is the inductance, and
C is the capacitance.

Given that $L = 75\,\text{mH} = 75 \times 10^{-3}\,\text{H}$, $C = 1.2\,\mu\text{F} = 1.2 \times 10^{-6}\,\text{F}$,

and $Q_{\text{max}} = 2.7\,\mu\text{C} = 2.7 \times 10^{-6}\,\text{C}$,

we can substitute these values into the formulas to find I_{max} :

$$\omega = \frac{1}{\sqrt{(75 \times 10^{-3})(1.2 \times 10^{-6})}} = 3333.33\,\text{rad/s},$$

$$I_{\text{max}} = \omega Q_{\text{max}} = 3333.33 \times 2.7 \times 10^{-6} = 0.009\,\text{A}.$$

Therefore, the maximum current in the circuit is 0.009 A, or equivalently, 9 mA.

11. Ans. Correct answer is 4

Explanation

The magnetic field B_2 due to the current I_2 in the larger coil with 200 turns is given by:

$$B_2 = \frac{N_2 \mu_0 I_2}{2 r_2} = \frac{200 \mu_0 I_2}{2 \times 10}$$

The magnetic flux $\phi_{1,2}$ through the smaller coil due to this magnetic field is given by:

$$\phi_{1,2} = N_1 \vec{B}_2 \cdot \vec{A}_1 = N_1 N_2 \frac{\mu_0 I_2}{2r_2} \cdot \pi r_1^2$$

Since $\phi_{1,2} = MI_2$, we can solve for the mutual inductance M:

$$M = \frac{N_1 N_2 \frac{\mu_0 I_2}{2r_2} \cdot \pi r_1^2}{I_2}$$

Substituting the given values for r_1, N_1, r_2, and N_2:

$$M = \frac{10 \times 200 \times 4\pi \times 10^{-7} \times \pi \times (0.01)^2}{2 \times 10}$$

Simplifying the expression, we get:

$$M = 4 \times 10^{-8} \mathrm{H}$$

So, the mutual inductance between the two concentric coils is $4 \times 10^{-8} \mathrm{H}$.

12. Ans. Correct answer is 240

Explanation

The power delivered to the houses is given as 60 kW. This power is supplied at a voltage of 120 V. The power consumed in a resistive load can be found using the formula $P = V^2/R$, where P is the power, V is the voltage, and R is the resistance.

We can rearrange this formula to solve for the resistance:

$$R = V^2/P$$

Substituting the given values gives:

$$R = (120\,\mathrm{V})^2/60,000\,\mathrm{W} = 0.24\,\Omega$$

Since we want the resistance in milliohms (mΩ), we can convert this to milliohms by multiplying by 1000:

$$R = 0.24\,\Omega \times 1000 = 240\,m\Omega$$

So, the value of resistive load required in the secondary circuit is 240 mΩ.

13. Ans. Correct answer is 44

Explanation

Area $(\mathrm{A}) = 70\,\mathrm{cm}^2 = 70 \times 10^{-4}\,\mathrm{m}^2$

$\mathrm{B} = 0.4\,\mathrm{T}$

$f = \frac{500 \text{ revolution}}{60 \text{ minute}} = \frac{500}{60}\,\frac{\text{rev.}}{\text{sec.}}$

Induced emf in rotating coil is given by

$e = N\omega BA \sin\theta$

$= 600 \times 2 \times \frac{22}{7} \times \frac{500}{60} \times 0.4 \times 70 \times 10^{-4} \sin 30^\circ$

$= 600 \times 2 \times \frac{22}{7} \times \frac{500}{6} \times 0.4 \times 70 \times 10^{-4} \times \frac{1}{2}$

$= 44$ Volt

14. Ans. Correct answer is 40

Explanation

To maximize the average rate at which energy supplied i.e. power will be maximum.

So in LCR circuit power will be maximum at the condition of resonance and in resonance condition

$\therefore X_L = X_C$

$$79.6=\frac{1}{2\pi(50)\times C}$$

$$C=\frac{1}{79.6\times 2\pi(50)}$$

$$\approx 40\mu\mathrm{F}$$

15. Ans. Correct answer is 25

Explanation

$$\omega=100\pi$$

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

$$=\sqrt{80^2+(100-40)^2}$$

$$=100\Omega$$

$$i_0=\frac{V_0}{Z}=\frac{2500}{100}\ \mathrm{A}=25\ \mathrm{A}$$

16. Ans. Correct answer is 242

Explanation

$$X_L=X_C$$

So, $\mathrm{Z}=\mathrm{R}=20\Omega$

$$\mathrm{i}_{\mathrm{rms}} = \frac{220}{20} = 11$$

$$\mathrm{i}_{\mathrm{max}} = 11\sqrt{2} = \sqrt{242}$$

17. Ans. Correct answer is 1584

Explanation

$$\phi = B.A$$

$$\phi = \mathrm{BNA}\cos\omega t$$

So, $Emf = \frac{-d\phi}{dt} = NBA\omega\sin\omega t$

So maximum value of emf is

$$E_{\mathrm{max}} = NBA\omega$$

$$= 100 \times 3 \times 14 \times 10^{-2} \times \frac{360\times2\pi}{60} = 1584$$

18. Ans. Correct answer is 30

Explanation

From the circuit :

$$V_A - iR - \frac{Ldi}{dt} - 12 = V_B$$

$\Rightarrow V_A - V_B = 2 \times 12 + 6(-1) + 12$ volts

$= 30$ volts

19. Ans. Correct answer is 3872

Explanation

Current drawn is maximum when circuit is in resonance.

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

$$2\pi(7000)=\frac{1}{\sqrt{2\times10^{-6}C}}$$

$$\Rightarrow C=\frac{1}{3872}F$$

20. Ans. Correct answer is 10

Explanation

$$EMF=\frac{d}{dt}\left(B\pi r^2\right)$$

$$=2\,\mathrm{B}\pi\mathrm{r}\frac{\mathrm{dr}}{\mathrm{dt}}=2\times\pi\times0.1\times0.8\times2\times10^{-2}$$

$=2\pi\times1.6=\mathbf{10.06}$ [rounding off $\mathbf{10.06}=\mathbf{10}$]

21. Ans. Correct answer is 8

Explanation

$$\cos\phi=\frac{\mathrm{R}}{\mathrm{Z}}=\frac{\mathrm{R}}{\sqrt{\mathrm{R}^2+\left(\mathrm{X_C}-\mathrm{X_L}\right)^2}}$$

$$\cos\phi=\frac{80}{\sqrt{(80)^2+(60)^2}}$$

$$\cos\phi=\frac{80}{100}\Rightarrow\frac{8}{10}$$

So, $x=8$

22. Ans. Correct answer is 100

Explanation

$\because$ For maximum amplitude of current, circuit should be at resonance.

$$\therefore X_L = X_C$$

$$\omega L = \frac{1}{\omega C}$$

$$L = \frac{1}{\omega^2 C}$$

$$= \frac{1}{\left(2\pi \times 2 \times 10^3\right)^2 \times 62.5 \times 10^{-9}}$$

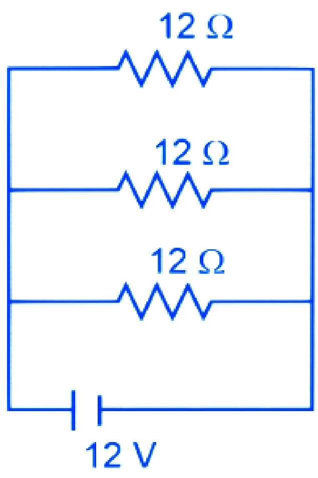
$$= 100\,\text{mH}$$

23. Ans. Correct answer is 3

Explanation

After long time, inductors are shorted.

Effective circuit becomes



Current through battery $= \frac{V}{\mathrm{R_{eq}}} = \frac{12\ \mathrm{V}}{4\Omega} = 3\ \mathrm{A}$

where $\mathrm{R_{eq}} = 3$ resistors in parallel.

24. Ans. Correct answer is 10

Explanation

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

Quality factor $Q = \frac{1}{R}\sqrt{\frac{L}{C}}$

So $\frac{Q}{\Delta\omega} = \frac{\frac{1}{R}\sqrt{\frac{L}{C}}}{\frac{R}{L}}$

$$= \frac{L^{\frac{3}{2}}}{R^2\sqrt{C}}$$

$$= \frac{3^{\frac{3}{2}}}{10^2\left(27 \times 10^{-6}\right)^{\frac{1}{2}}}$$

$$= \frac{3\sqrt{3}}{100\left(3\sqrt{3} \times 10^{-3}\right)}$$

$$= 10$$

MCQ (Single Correct Answer)

Q.1. Match **List I** with **List II** of Electromagnetic waves with corresponding wavelength range :

List I	List II
(A) Microwave	(I) 400 nm to 1 nm
(B) Ultraviolet	(II) 1 nm to 10^{-3} nm
(C) X-Ray	(III) 1 mm to 700 nm
(D) Infra-red	(IV) 0.1 m to 1 mm

Choose the correct answer from the options given below:

A (A)-(I), (B)-(IV), (C)-(II), (D)-(III)

B (A)-(IV), (B)-(I), (C)-(II), (D)-(III)

C (A)-(IV), (B)-(I), (C)-(III), (D) -(II)

D (A)-(IV), (B)-(II), (C)-(I), (D)-(III)

JEE Main 2023 (Online) 15th April Morning Shift

Q.2. 12 V battery connected to a coil of resistance 6Ω through a switch, drives a constant current in the circuit. The switch is opened in $1 \mathrm{~ms}$. The emf induced across the coil is $20 \mathrm{~V}$. The inductance of the coil is :

A $5 \mathrm{~mH}$

B $8 \mathrm{~mH}$

C $10 \mathrm{~mH}$

D $12 \mathrm{~mH}$

JEE Main 2023 (Online) 15th April Morning Shift

Q.3. Given below are two statements:

Statement I : An AC circuit undergoes electrical resonance if it contains either a capacitor or an inductor.

Statement II : An AC circuit containing a pure capacitor or a pure inductor consumes high power due to its non-zero power factor.

In the light of above statements, choose the correct answer form the options given below:

A Both Statement I and Statement II are false

B Statement I is true but statement II is false

C Statement I is false but statement II is true

D Both Statement I and Statement II are true

JEE Main 2023 (Online) 13th April Evening Shift

Q.4. Match List - I with List - II

	List - I (Layer of atmosphere)		**List - II (Approximate height over earth's surface)**
(A)	F1 - Layer	(I)	10 km
(B)	D - Layer	(II)	170 - 190 km
(C)	Troposphere	(III)	100 km
(D)	E - Layer	(IV)	65 - 75 km

Choose the correct answer from the options given below:

A A - II, B - IV, C - III, D - I

B A - II, B-I, C - IV, D - III

C A - II, B - IV, C - I, D - III

D A - III, B - IV, C - I, D - II

JEE Main 2023 (Online) 13th April Morning Shift

Q.5. Which of the following Maxwell's equation is valid for time varying conditions but not valid for static conditions :

A $\oint \overrightarrow{\mathrm{E}} \cdot \overrightarrow{dl} = 0$

B $\oint \vec{B} \cdot \overrightarrow{dl} = \mu_0 I$

C $\oint \vec{E} \cdot \overrightarrow{dl} = -\frac{\partial \phi_B}{\partial t}$

D $\oint \vec{D} \cdot \overrightarrow{dA} = Q$

JEE Main 2023 (Online) 13th April Morning Shift

Q.6. Given below are two statements:

Statement I : When the frequency of an a.c source in a series LCR circuit increases, the current in the circuit first increases, attains a maximum value and then decreases.

Statement II : In a series LCR circuit, the value of power factor at resonance is one.

In the light of given statements, choose the most appropriate answer from the options given below.

A Both Statement I and Statement II are False.

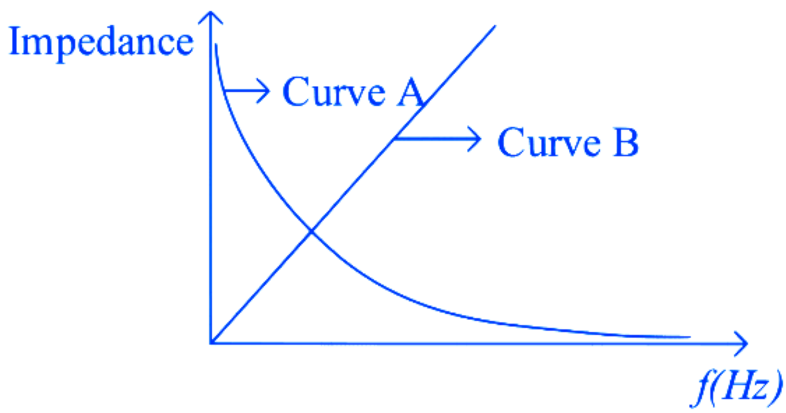
B Statement I is incorrect but Statement II is true.

C Both Statement I and Statement II are true.

D Statement I is correct but Statement II is false.

JEE Main 2023 (Online) 12th April Morning Shift

Q.7.



As per the given graph, choose the correct representation for curve A and curve B.

Where XC= reactance of pure capacitive circuit connected with A.C. source

XL= reactance of pure inductive circuit connected with A.C. source

R = impedance of pure resistive circuit connected with A.C. source.

Z= Impedance of the LCR series circuit

A $\mathrm{A}=\mathrm{X}_{\mathrm{L}}, \mathrm{B}=\mathrm{R}$

B $\mathrm{A}=\mathrm{X}_{L}, \mathrm{~B}=Z$

C $\mathrm{A}=\mathrm{X}_{\mathrm{C}}, \mathrm{B}=\mathrm{X}_{\mathrm{L}}$

D $\mathrm{A}=\mathrm{X}_{\mathrm{C}}, \mathrm{B}=\mathrm{R}$

JEE Main 2023 (Online) 11th April Morning Shift

Q.8. Given below are two statements:

Statement I : If the number of turns in the coil of a moving coil galvanometer is doubled then the current sensitivity becomes double.

Statement II : Increasing current sensitivity of a moving coil galvanometer by only increasing the number of turns in the coil will also increase its voltage sensitivity in the same ratio

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

A Statement I is true but Statement II is false

B Statement I is false but Statement II is true

C Both Statement I and Statement II are false

D Both Statement I and Statement II are true

JEE Main 2023 (Online) 10th April Morning Shift

Q.9. Given below are two statements:

Statement I : Maximum power is dissipated in a circuit containing an inductor, a capacitor and a resistor connected in series with an AC source, when resonance occurs

Statement II : Maximum power is dissipated in a circuit containing pure resistor due to zero phase difference between current and voltage.

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

A Statement I is false but Statement II is true

B Both Statement I and Statement II are false

C Statement I is true but Statement II is false

D Both Statement I and Statement II are true

JEE Main 2023 (Online) 10th April Morning Shift

Q.10. An emf of $0.08\ \mathrm{V}$ is induced in a metal rod of length $10\ \mathrm{cm}$ held normal to a uniform magnetic field of $0.4\ \mathrm{T}$, when moves with a velocity of:

(A) $20\ \mathrm{ms}^{-1}$

(B) $2\ \mathrm{ms}^{-1}$

(C) $3.2\ \mathrm{ms}^{-1}$

(D) $0.5\ \mathrm{ms}^{-1}$

JEE Main 2023 (Online) 8th April Evening Shift

Q.11. Certain galvanometers have a fixed core made of non magnetic metallic material. The function of this metallic material is

(A) to bring the coil to rest quickly

(B) to produce large deflecting torque on the coil

(C) to oscillate the coil in magnetic field for longer period of time

(D) to make the magnetic field radial

JEE Main 2023 (Online) 8th April Morning Shift

Q.12. capacitor of capacitance 150.0 μF is connected to an alternating source of emf given by $\mathrm{E} = 36 \sin(120\pi \mathrm{t})\mathrm{V}$. The maximum value of current in the circuit is approximately equal to :

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

B $2\sqrt{2} A$

C $\sqrt{2} A$

D $2 A$

JEE Main 2023 (Online) 6th April Evening Shift

Q.13. The induced emf can be produced in a coil by

A. moving the coil with uniform speed inside uniform magnetic field

B. moving the coil with non uniform speed inside uniform magnetic field

C. rotating the coil inside the uniform magnetic field

D. changing the area of the coil inside the uniform magnetic field

Choose the correct answer from the options given below:

A. A and C only

B. C and D only

C. B and D only

D. B and C only

JEE Main 2023 (Online) 6th April Morning Shift

Q.14. A coil is placed in magnetic field such that plane of coil is perpendicular to the direction of magnetic field. The magnetic flux through a coil can be changed :

A. By changing the magnitude of the magnetic field within the coil.

B. By changing the area of coil within the magnetic field.

C. By changing the angle between the direction of magnetic field and the plane of the coil.

D. By reversing the magnetic field direction abruptly without changing its magnitude.

Choose the most appropriate answer from the options given below :

A. A, B and D only

B. A, B and C only

C. A and B only

D. A and C only

JEE Main 2023 (Online) 1st February Evening Shift

Q.15. Match List - I with List - II :

	List I		List II
A.	AC generator	I.	Presence of both L and C
B.	Transformer	II.	Electromagnetic Induction
C.	Resonance phenomenon to occur	III.	Quality factor
D.	Sharpness of resonance	IV.	Mutual Induction

Choose the correct answer from the options given below :

A. A-II, B-I, C-III, D-IV

B. A-IV, B-III, C-I, D-II

C. A-II, B-IV, C-I, D-III

D. A-IV, B-II, C-I, D-III

JEE Main 2023 (Online) 1st February Morning Shift

Q.16. An alternating voltage source $V=260\sin(628t)$ is connected across a pure inductor of $5mH$ Inductive reactance in the circuit is :

A. 6.28Ω

B. 0.318Ω

C. 0.5Ω

D. 3.14Ω

JEE Main 2023 (Online) 31st January Evening Shift

Q.17. If R, X_L, and X_C represent resistance, inductive reactance and capacitive reactance. Then which of the following is dimensionless :

A $\frac{R}{X_L X_C}$

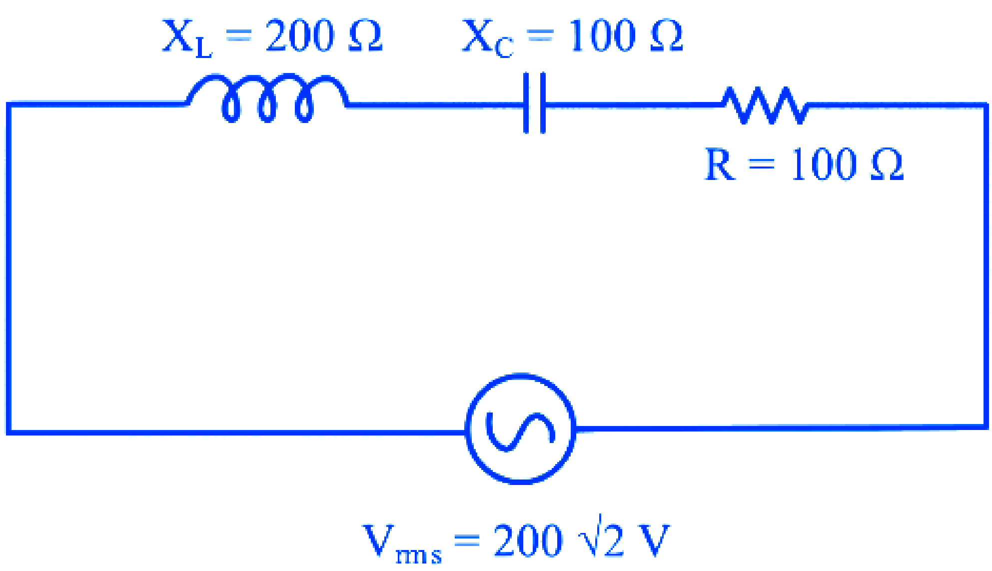
B $R X_L X_C$

C $\frac{R}{\sqrt{X_L X_C}}$

D $R \frac{X_L}{X_C}$

JEE Main 2023 (Online) 31st January Morning Shift

Q.18. In the given circuit, rms value of current (I_{rms}) through the resistor R is:



A $2\sqrt{2}$ A

B 2 A

C $\frac{1}{2}$ A

D 20 A

JEE Main 2023 (Online) 30th January Evening Shift

Q.19. In a series LR circuit with $X_L = R$, power factor P_1. If a capacitor of capacitance C with $X_C = X_L$ is added to the circuit the power factor becomes P_2. The ratio of P_1 to P_2 will be :

A $1 : \sqrt{2}$

B $1 : 3$

C $1 : 2$

D $1 : 1$

JEE Main 2023 (Online) 30th January Morning Shift

Q.20. A square loop of area 25 cm2 has a resistance of 10 Ω. The loop is placed in uniform magnetic field of magnitude 40.0 T. The plane of loop is perpendicular to the magnetic field. The work done in pulling the loop out of the magnetic field slowly and uniformly in 1.0 sec, will be

A 1.0×10^{-3} J

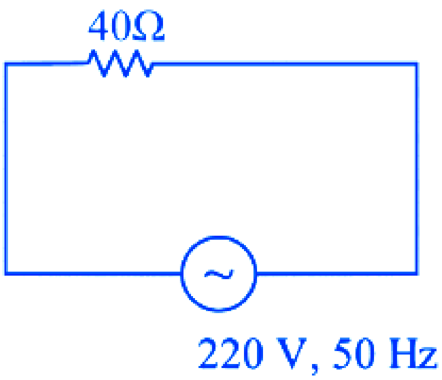
B 5×10^{-3} J

C 2.5×10^{-3} J

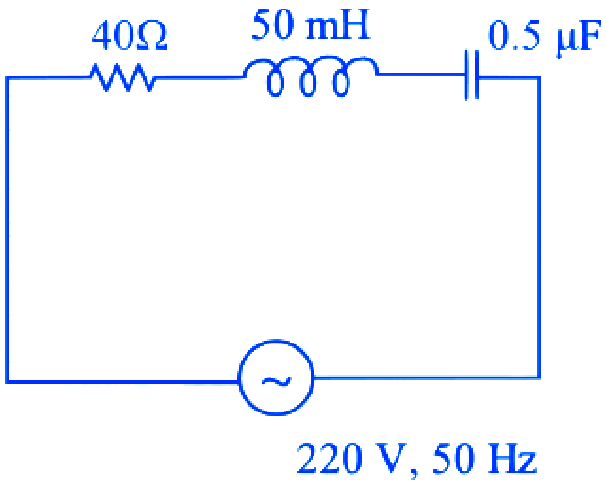
D 1.0×10^{-4} J

JEE Main 2023 (Online) 29th January Evening Shift

Q.21. For the given figures, choose the correct options :



(a)

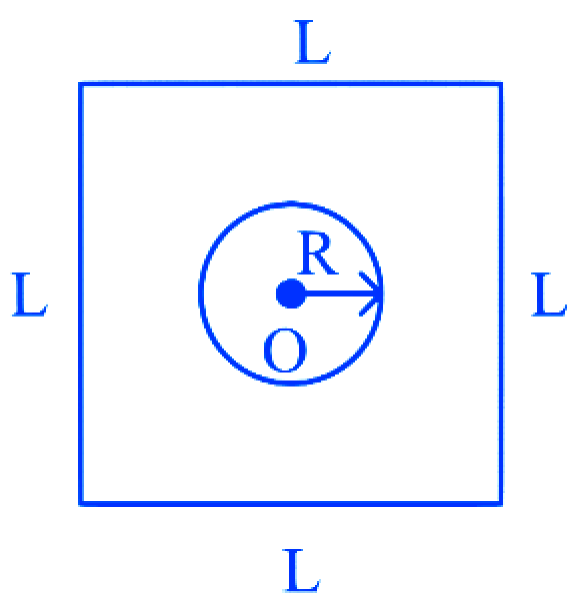


(b)

- **A** The rms current in circuit (b) can be larger than that in (a)
- **B** The rms current in figure (a) is always equal to that in figure (b)
- **C** The rms current in circuit (b) can never be larger than that in (a)
- **D** At resonance, current in (b) is less than that in (a)

JEE Main 2023 (Online) 29th January Evening Shift

Q.22. Find the mutual inductance in the arrangement, when a small circular loop of wire of radius 'R' is placed inside a large square loop of wire of side L ($L \gg R$). The loops are coplanar and their centres coincide :



A $M = \frac{\sqrt{2}\mu_0 R}{L^2}$

B $M = \frac{2\sqrt{2}\mu_0 R}{L^2}$

C $M = \frac{2\sqrt{2}\mu_0 R^2}{L}$

D $M = \frac{\sqrt{2}\mu_0 R^2}{L}$

JEE Main 2023 (Online) 29th January Morning Shift

Q.23. A wire of length 1m moving with velocity 8 m/s at right angles to a magnetic field of 2T. The magnitude of induced emf, between the ends of wire will be ___________.

A 20 V

B 8 V

C 16 V

D 12 V

JEE Main 2023 (Online) 25th January Evening Shift

Q.24. In an LC oscillator, if values of inductance and capacitance become twice and eight times, respectively, then the resonant frequency of oscillator becomes x times its initial resonant frequency W0. The value of x is :

A 1/4

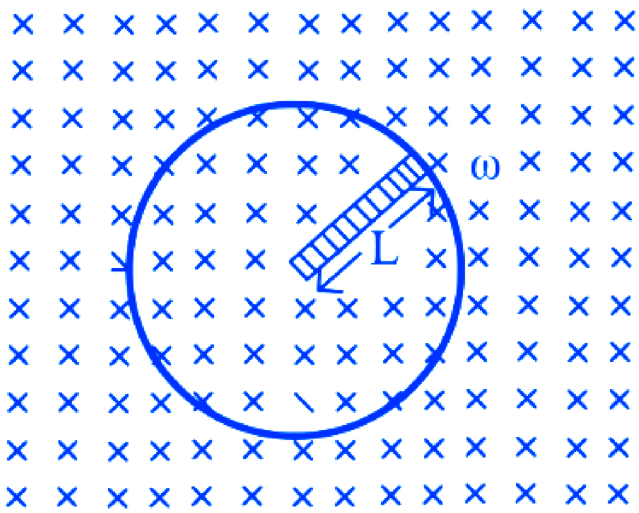
B 1/16

C 4

D 16

JEE Main 2023 (Online) 25th January Morning Shift

Q.25. A metallic rod of length 'L' is rotated with an angular speed of 'w' normal to a uniform magnetic field 'B' about an axis passing through one end of rod as shown in figure. The induced emf will be :



(A) $\frac{1}{2}B^2L^2\omega$

(B) $\frac{1}{2}BL^2\omega$

(C) $\frac{1}{4}BL^2\omega$

(D) $\frac{1}{4}B^2L\omega$

JEE Main 2023 (Online) 24th January Evening Shift

Q.26. A conducting circular loop of radius $\frac{10}{\sqrt{\pi}}$ cm is placed perpendicular to a uniform magnetic field of 0.5 T. The magnetic field is decreased to zero in 0.5 s at a steady rate. The induced emf in the circular loop at 0.25 s is :

(A) emf = 10 mV

(B) emf = 5 mV

(C) emf = 100 mV

(D) emf = 1 mV

JEE Main 2023 (Online) 24th January Morning Shift

Answer Key & Explanation

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1. Ans. (B)

Explanation

The correct matching of the electromagnetic waves with their corresponding wavelength ranges is:

(A) Microwave --> (IV) 0.1 m to 1 mm

(B) Ultraviolet --> (I) 400 nm to 1 nm

(C) X-Ray --> (II) 1 nm to 10^{-3} nm

(D) Infra-red --> (III) 1 mm to 700 nm

Therefore, the correct option is (A-IV, B-I, C-II, D-III).

2. Ans. (C)

Explanation

When the switch is closed, the circuit is a simple DC circuit and the current in the circuit is given by Ohm's law:

$I = \frac{V}{R} = \frac{12\text{V}}{6\Omega} = 2\text{A}$.

When the switch is opened, the current in the circuit drops to zero instantaneously.

However, the magnetic field generated by the current in the coil does not disappear immediately, and it continues to produce a back EMF that opposes the change in current.

This back EMF induces a voltage across the coil that can be calculated using Faraday's law of induction: $\mathcal{E} = -L\frac{\Delta I}{\Delta t}$, where $\mathcal{E}$ is the induced voltage, L is the inductance of the coil, and $\Delta I/\Delta t$ is the rate of change of current in the coil.

In this case, we know that the induced voltage is 20V and the rate of change of current is

$\Delta I/\Delta t = -2\text{A}/(1\text{ms}) = -2 \times 10^3\text{A/s}$.

Substituting these values into the equation above, we get: $20\text{V} = -L \times (-2 \times 10^3\text{A/s})$.

Solving for L, we get: $L = \frac{20\text{V}}{2\times10^3\text{A/s}} = 0.01\text{H}$.

Therefore, the inductance of the coil is 0.01H, or 10 mH.

3. Ans. (A)

Explanation

Statement I: An AC circuit undergoes electrical resonance if it contains either a capacitor or an inductor.

This statement is incorrect. Electrical resonance occurs in an AC circuit when the capacitive reactance and inductive reactance are equal, causing the impedance of the circuit to be minimum. This typically happens in a series RLC circuit or a parallel RLC circuit. If the circuit contains only a capacitor or an inductor, it cannot undergo electrical resonance as there is no counterpart reactance to balance the impedance.

Statement II: An AC circuit containing a pure capacitor or a pure inductor consumes high power due to its non-zero power factor.

This statement is also incorrect. An AC circuit containing a pure capacitor or a pure inductor will have a power factor of 0, not a non-zero power factor. The power factor of a capacitor is -1, and the power factor of an inductor is +1, but when only considering the reactive components, the power factor is 0. In such a circuit, no real power is consumed, and the circuit only has reactive power. The energy is alternately stored and released by the capacitor and inductor, but no energy is dissipated as heat or used to perform work.

As both statements are incorrect, the correct answer would be an option that states both statements are false.

4.Ans. (C)

Explanation

Let's match the layers of the atmosphere (List - I) with their approximate heights over the Earth's surface (List - II):

(A) F1 - Layer: This layer is part of the ionosphere, which is located within the thermosphere. The F1 layer is at an approximate height of 170 - 190 km. So, A matches with II.

(B) D - Layer: This layer is also part of the ionosphere and is the lowest layer of the ionosphere. The D layer is at an approximate height of 65 - 75 km. So, B matches with IV.

(C) Troposphere: This is the lowest layer of the Earth's atmosphere, where weather occurs, and it extends up to approximately 10 km over the Earth's surface. So, C matches with I.

(D) E - Layer: This layer is another part of the ionosphere, which is above the D layer and below the F1 layer. The E layer is at an approximate height of 100 km. So, D matches with III.

Thus, the correct matching is:

A - II, B - IV, C - I, D – III

5. Ans. (C)

Explanation

Maxwell's equations describe the behaviour of electric and magnetic fields. There are four equations, and each has a specific role. In the given options, Option C refers to Faraday's Law of Electromagnetic Induction, which is the only equation among the options that is not valid for static conditions.s

Option C: Faraday's Law of Electromagnetic Induction:

$$\oint \vec{E} \cdot \overrightarrow{dl} = -\frac{\partial \phi_B}{\partial t}$$

This equation states that a time-varying magnetic field (changing magnetic flux, ϕ_B) induces an electromotive force (EMF) in a closed conducting loop, creating an electric field. In static conditions, the magnetic field doesn't change over time, and there is no induced EMF. Therefore, Faraday's Law is valid for time-varying conditions but not for static conditions.

6. Ans. (C)

Explanation

Statement I is true because in a series LCR circuit, the current first increases as the frequency increases, reaching a maximum value when the circuit is at resonance. At resonance, the inductive reactance (XL) and capacitive reactance (XC) cancel each other out, resulting in the lowest impedance (Z) and the highest current. As the frequency continues to increase beyond resonance, the current in the circuit decreases.

Statement II is also true because, at resonance in a series LCR circuit, the inductive reactance (XL) and capacitive reactance (XC) are equal and cancel each other out. This results in the impedance (Z) being purely resistive. The power factor at resonance is given by the cosine of the phase angle (θ), and since the phase angle is 0° at resonance, the power factor is 1.

Thus, both statements are true, and the correct answer is Both Statement I and Statement II are true.

7. Ans. (C)

Explanation

$$X_C = \frac{1}{\omega C} = \frac{1}{(2\pi f)C}$$

$$\therefore X_C \propto \frac{1}{f}$$

$\therefore$ Curve A

$$X_L = \omega L = (2\pi f)L$$

$$\therefore X_L \propto f$$

$\therefore$ Curve B

8. Ans. (A)

Explanation

Statement I: If the number of turns in the coil of a moving coil galvanometer is doubled then the current sensitivity becomes double.

This statement is true. The formula for current sensitivity (I_s) of a moving coil galvanometer is given by:

$I_s = \frac{NAB}{k}$

where:

N is the number of turns in the coil,
A is the area of the coil,
B is the magnetic field strength, and
k is the spring constant of the coil.

From this formula, you can see that the current sensitivity is directly proportional to the number of turns (N). If N is doubled, then the current sensitivity will also double.

Statement II: Increasing current sensitivity of a moving coil galvanometer by only increasing the number of turns in the coil will also increase its voltage sensitivity in the same ratio.

This statement is false. The formula for voltage sensitivity (V_s) of a moving coil galvanometer is given by:

$$V_s = I_s R = \frac{NAB}{k} R$$

where:

R is the resistance of the coil.

From this formula, you can see that the voltage sensitivity is proportional to the number of turns (N) but also inversely proportional to the coil resistance (R). If you double the number of turns (N), you also double the length of the wire making up the coil, and thus, you double the resistance (R) of the coil. The doubling of N is offset by the doubling of R, so the overall voltage sensitivity remains the same.

Therefore, increasing the current sensitivity by only increasing the number of turns in the coil will not increase the voltage sensitivity in the same ratio.

9. Ans. (D)

Explanation

In a series LCR circuit connected to an AC source, resonance occurs at a particular frequency at which the inductive reactance is equal to the capacitive reactance, resulting in the minimum impedance of the circuit. At this frequency, the circuit draws maximum current from the source, and thus, the maximum power is dissipated in the circuit. Therefore, Statement I is true.

In a circuit containing only a resistor, the power dissipated is given by P = VI = I2R, where V is the voltage across the resistor, I is the current flowing through the resistor, and R is the resistance of the resistor. The voltage and current are in phase in a purely resistive circuit, which means that the power is maximized. Therefore, Statement II is also true.

10. Ans. (B)

Explanation

The emf induced in a rod moving through a magnetic field is given by Faraday's law of electromagnetic induction, specifically, in the form of motional emf, which states that:

$$\text{emf} = B \cdot L \cdot v$$

where:

(B) is the magnetic field strength,
(L) is the length of the rod, and
(v) is the velocity of the rod.

In this case, we are given the emf, (B), and (L), and we need to solve for (v). Rearranging the equation gives:

$$v = \frac{\text{emf}}{B \cdot L}$$

Substituting the given values:

$$v = \frac{0.08\,\text{V}}{0.4\,\text{T} \times 0.1\,\text{m}} = 2\,\text{m/s}$$

11. Ans. (A)

Explanation

The function of the non-magnetic metallic core in a galvanometer is to provide a path for the induced current generated by the moving coil in the magnetic field. This induced current opposes the motion of the coil and brings it to rest quickly due to the effect known as eddy current damping.

When the coil swings past its equilibrium position, a change in magnetic flux occurs. According to Faraday's law of electromagnetic induction, this change in magnetic flux generates an induced current, known as an eddy current. The eddy current creates its own magnetic field which opposes the original change in flux, causing the coil to quickly come to rest.

12. Ans. (D)

Explanation

For a capacitor connected to an AC source, the maximum current I_{max} can be calculated using the formula:

$$I_{\text{max}} = E_{\text{max}} \cdot \omega C$$

where E_{max} is the maximum voltage, ω is the angular frequency, and C is the capacitance.

Given the emf equation: $E = 36\sin(120\pi t)$ V, we can determine that $E_{\text{max}} = 36$ V and $\omega = 120\pi$ rad/s.

The capacitance is given as $150.0\,\mu\text{F} = 150.0 \times 10^{-6}$ F.

Now, we can calculate the maximum current:

$$I_{\text{max}} = 36 \cdot (120\pi) \cdot (150.0 \times 10^{-6})$$

$$I_{\text{max}} \approx 2\text{ A}$$

Thus, the correct answer is 2 A.

13. Ans. (B)

Explanation

If the coil is simply moved at uniform or non-uniform speed in a uniform magnetic field without changing the orientation of the coil or the area of the coil enclosed by the magnetic field, the magnetic flux through the coil does not change, and no emf is induced according to Faraday's Law of electromagnetic induction.

14. Ans. (B)

Explanation

The magnitude of magnetic flux is given by :

$$\Phi = BA\cos\theta$$

where B is the magnitude of the magnetic field, A is the area of the coil, and θ is the angle between the normal to the area and the direction of the magnetic field.

The correct option is A, B, and C only.

A. The magnetic flux through a coil can be changed by changing the magnitude of the magnetic field within the coil. A stronger magnetic field will increase the magnetic flux, while a weaker magnetic field will decrease the magnetic flux.

B. The magnetic flux through a coil can also be changed by changing the area of the coil within the magnetic field. A larger area of the coil will result in a greater magnetic flux, while a smaller area will result in a smaller magnetic flux.

C. The magnetic flux through a coil can also be changed by changing the angle between the direction of the magnetic field and the plane of the coil. When the angle is perpendicular to the plane of the coil, the magnetic flux is at its maximum. When the angle is parallel to the plane of the coil, the magnetic flux is zero.

D. Reversing the magnetic field direction abruptly without changing its magnitude will not change the magnetic flux through the coil. Magnetic flux is proportional to the dot product of the magnetic field and the area vector of the coil. If the magnitude of the magnetic field remains the same and the direction is reversed, the dot product remains the same and the magnetic flux remains unchanged.

15. Ans. (C)

Explanation

AC generator works on EMZ principle (A-II)

Transformer uses Mutual induction (B-IV)

Resonance occurs when both L and C are present (C-Z) and

quality factor determines sharpness of resonance (D-III)

16. Ans. (D)

Explanation

ω = 628 rad/s

$$X_L = L\omega$$

$$= 5\mathrm{mH} \times 628$$

$$= 3.14\Omega$$

17. Ans. (C)

Explanation

$R =$ Resistance

$$[X_L] = [R]$$

$$[X_C] = [R]$$

So, $\frac{R}{\sqrt{X_L X_C}}$ is dimensionless.

18. Ans. (B)

Explanation

$$I_{rms} = \frac{V_{rms}}{z} = \frac{200\sqrt{2}}{\sqrt{100^2+(200-100)^2}}$$

$$= \frac{200\sqrt{2}}{100\sqrt{2}}$$

= 2 A

19. Ans. (A)

Explanation

$$X_L = R$$

$$\Rightarrow P_1 = \frac{R}{\sqrt{X_L^2+R^2}} = \frac{1}{\sqrt{2}}$$

Now, $X_L = X_C = R$

$$\Rightarrow P_2 = \frac{R}{\sqrt{R^2+(X_L-X_C)^2}} = 1$$

$$\Rightarrow \frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$$

20. Ans. (A)

Explanation

From energy conservation

Work done to pull the loop out = Energy is lost in the resistance

Emf in the loop $= \frac{d\phi}{dt} = \frac{B\times A}{t} = \frac{40\times25\times10^{-4}}{1s} = 0.1\,V$

Energy lost $= \frac{emf^2}{R} = \frac{(0.1)^2}{10} = 10^{-3}\,J$

21. Ans. (C)

Explanation

For (a), $i=\frac{V}{R}=\frac{220}{40}=5.5\,A$

for (b), $X_C=\frac{1}{2\pi fC}=\frac{1}{2\pi\times50\times0.5\times10^{-6}}=\frac{10^6}{50\pi}\Omega$

$X_L=2\pi fL=2\pi\times50\times50\times10^{-3}=50\pi\,\Omega$

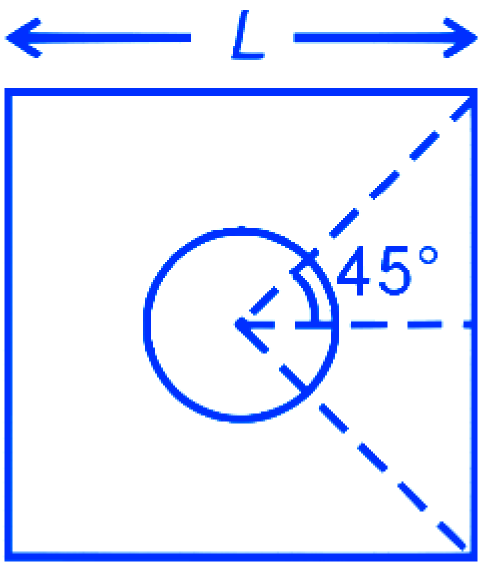
$X_C>X_L$, hence impedance is greater than 40 Ω.

$i_{rms}=\frac{220}{Z}$

$\therefore i_{rms}|_b<i_{rms}|_a$

22. Ans. (C)

Explanation



$$B \text{ at centre } = \frac{\mu_0 i}{4\pi\left(\frac{L}{2}\right)}\left(\frac{2}{\sqrt{2}}\right) \times 4$$

$$= \frac{\sqrt{2}\mu_0 i}{2\pi L} \times 4$$

$$= \left(\frac{2\sqrt{2}\mu_0 i}{\pi L}\right)$$

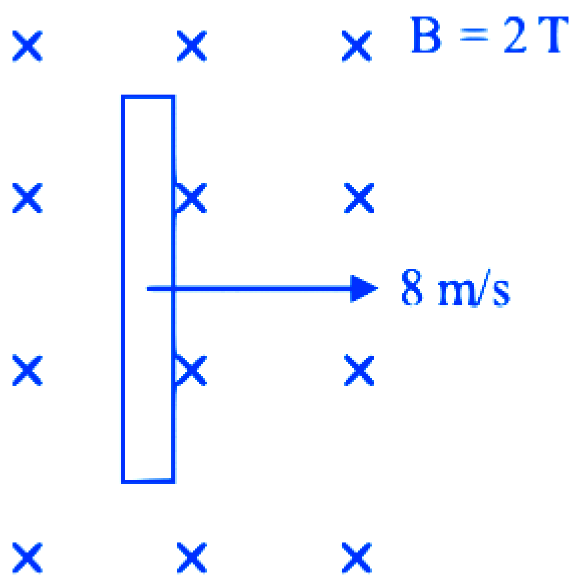
Mutual inductance $= \frac{B \cdot A}{i}$

$$= \frac{2\sqrt{2}\mu_0 i}{\pi L} \times \frac{\pi R^2}{i}$$

$$= \left(\frac{2\sqrt{2}\mu_0 R^2}{L}\right)$$

23. Ans. (C)

Explanation



Induced emf across the ends = Bvl

= 2 × 8 × 1 = 16 V

24. Ans. (A)

Explanation

The resonance frequency of LC oscillations circuit is

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

$$\mathrm{L} \rightarrow 2\,\mathrm{L}$$

$$\mathrm{C} \rightarrow 8\mathrm{C}$$

$$\omega = \frac{1}{\sqrt{2\,\mathrm{L} \times 8\mathrm{C}}} = \frac{1}{4\sqrt{\mathrm{LC}}}$$

$$\omega = \frac{\omega_0}{4}$$

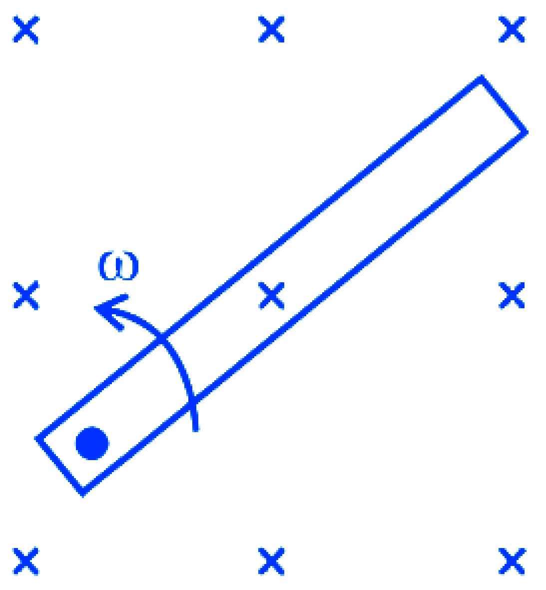
So $\mathrm{x} = \frac{1}{4}$

25. Ans. (B)

Explanation

Velocity of centre of $\mathrm{rod}\, v = \frac{\omega L}{2}$

So, $\mathrm{emf} = B \cdot vL = \frac{B\omega L^2}{2}$



26. Ans. (A)

Explanation

$$\mathrm{EMF} = \frac{\mathrm{d}\phi}{\mathrm{dt}} = \frac{\mathrm{BA} - 0}{\mathrm{t}}$$

$$\mathrm{A} = \pi \mathrm{r}^2 = \pi\left(\frac{0.1^2}{\pi}\right) = 0.01$$

$$\mathrm{B} = 0.5$$

$$\mathrm{EMF} = \frac{(0.5)(0.01)}{0.5} = 0.01\,\mathrm{V} = 10\,\mathrm{mV}$$

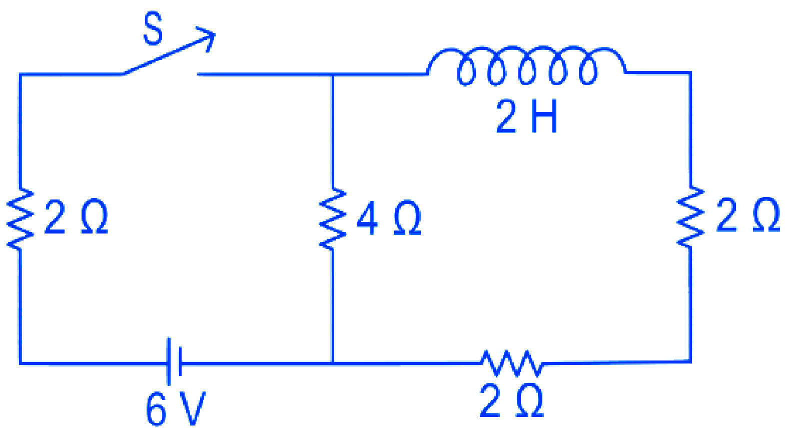
2022

Numerical

Q.1. A capacitor of capacitance 500 μF is charged completely using a dc supply of 100 V. It is now connected to an inductor of inductance 50 mH to form an LC circuit. The maximum current in LC circuit will be _______ A.

JEE Main 2022 (Online) 29th July Evening Shift

Q.2. For the given circuit the current through battery of 6 V just after closing the switch 'S' will be _________ A.



JEE Main 2022 (Online) 28th July Evening Shift

Q.3. The frequencies at which the current amplitude in an LCR series circuit becomes 1/2 times its maximum value, are $212 rad s^{-1}$ and $232 rad s^{-1}$. The value of resistance in the circuit is $R = 5\Omega$. The self-inductance in the circuit is __________ mH.

JEE Main 2022 (Online) 28th July Morning Shift

Q.4. A conducting circular loop is placed in X–Y plane in presence of magnetic field $\vec{B} = \left(3t^3 \hat{j} + 3t^2 \hat{k}\right)$ in SI unit. If the radius of the loop is 1 m, the induced emf in the loop, at time, $t = 2$ s is $n\pi$V. The value of n is ___________.

JEE Main 2022 (Online) 27th July Evening Shift

Q.5. To light, a 50 W,100 V lamp is connected, in series with a capacitor of capacitance $\frac{50}{\pi\sqrt{x}}\mu F$, with 200 V,50 HzAC source. The value of x will be

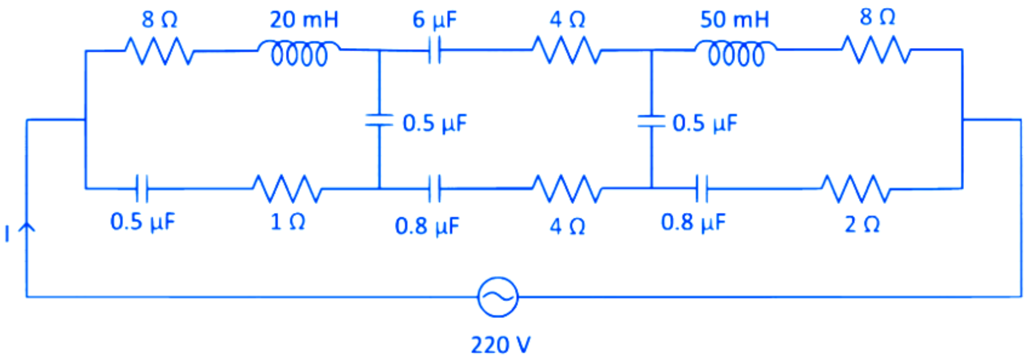
______.

JEE Main 2022 (Online) 27th July Morning Shift

Q.6. In a coil of resistance 8Ω, the magnetic flux due to an external magnetic field varies with time as $\phi = \frac{2}{3}(9 - t^2)$.The value of total heat produced in the coil, till the flux becomes zero, will be ____________ J.

JEE Main 2022 (Online) 26th July Evening Shift

Q.7. The effective current I in the given circuit at very high frequencies will be __________ A.



JEE Main 2022 (Online) 26th July Morning Shift

Q.8. Magnetic flux (in weber) in a closed circuit of resistance 20 Ω varies with time t(s) at $\phi = 8t^2 - 9t + 5$. The magnitude of the induced current at t = 0.25 s will be ___________ mA.

JEE Main 2022 (Online) 25th July Evening Shift

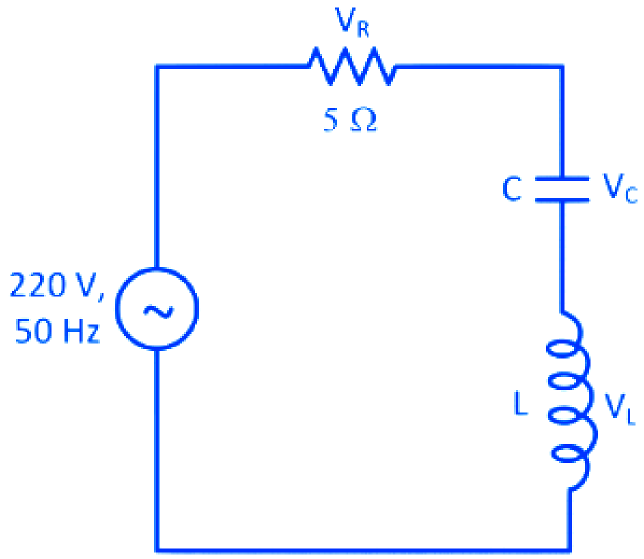
Q.9. A series LCR circuit with R=250/11 Ω and X_L=70/11Ω is connected across a 220 V, 50 Hz supply. The value of capacitance needed to maximize the average power of the circuit will be ________ μF. (Take: π=227)

JEE Main 2022 (Online) 30th June Morning Shift

Q.10. An inductor of 0.5 mH, a capacitor of 200 μF and a resistor of 2 Ω are connected in series with a 220 V ac source. If the current is in phase with the emf, the frequency of ac source will be ___________ × 10^2 Hz.

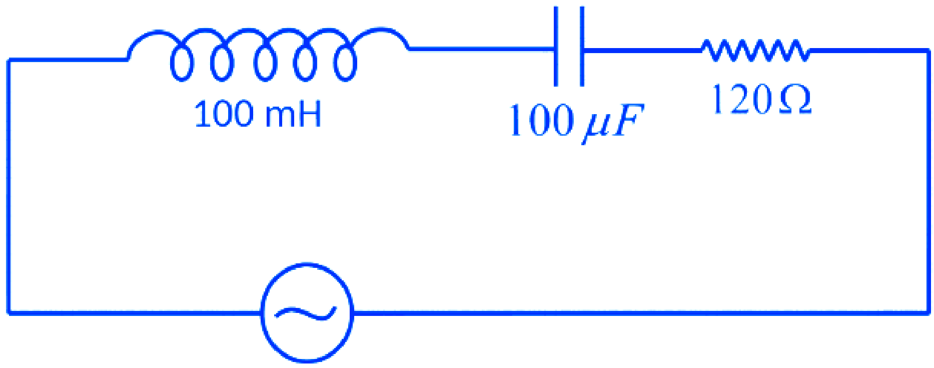
JEE Main 2022 (Online) 29th June Evening Shift

Q.11. In the given circuit, the magnitude of V_L and V_C are twice that of V_R. Given that f = 50 Hz, the inductance of the coil is $1/K\pi$ mH. The value of K is ___________.



JEE Main 2022 (Online) 28th June Evening Shift

Q.12. An AC source is connected to an inductance of 100 mH, a capacitance of 100 μF and a resistance of 120 Ω as shown in figure. The time in which the resistance having a thermal capacity 2 J/°C will get heated by 16°C is ____________ s.

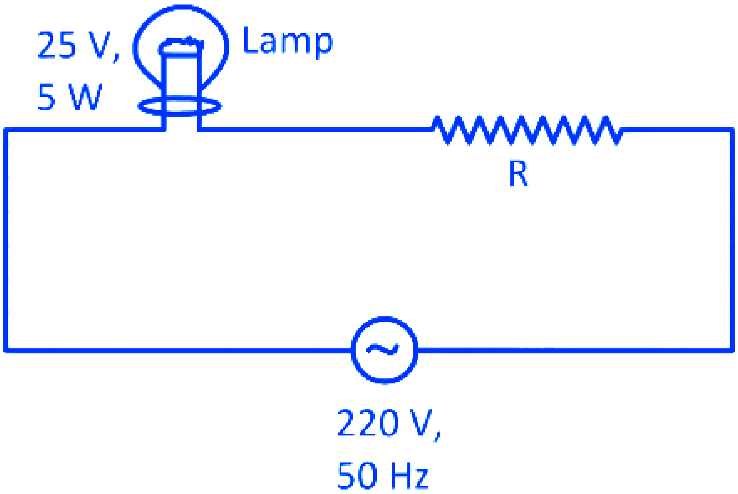


JEE Main 2022 (Online) 28th June Morning Shift

Q.13. A telegraph line of length 100 km has a capacity of 0.01 μF/km and it carries an alternating current at 0.5 kilo cycle per second. If minimum impedance is required, then the value of the inductance that needs to be introduced in series is ____________ mH. (if $\pi = \sqrt{10}$)

JEE Main 2022 (Online) 28th June Morning Shift

Q.14. A 220 V, 50 Hz AC source is connected to a 25 V, 5 W lamp and an additional resistance R in series (as shown in figure) to run the lamp at its peak brightness, then the value of R (in ohm) will be ____________.

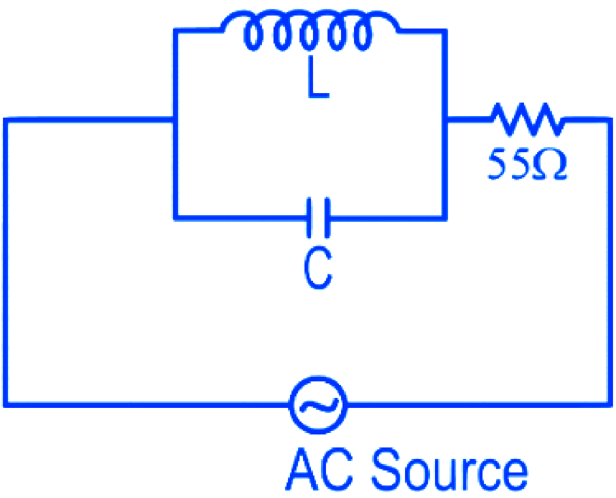


JEE Main 2022 (Online) 27th June Morning Shift

Q.15. A 10 Ω, 20 mH coil carrying constant current is connected to a battery of 20 V through a switch. Now after switch is opened current becomes zero in 100 μs. The average e.m.f. induced in the coil is ___________ V.

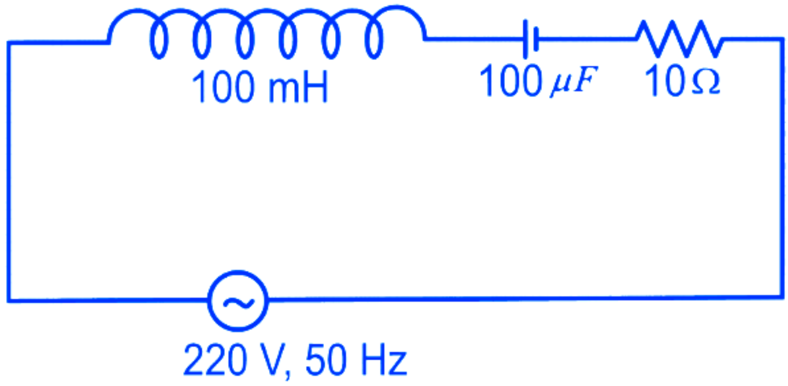
JEE Main 2022 (Online) 26th June Morning Shift

Q.16. A 110 V, 50 Hz, AC source is connected in the circuit (as shown in figure). The current through the resistance 55 Ω, at resonance in the circuit, will be _________ A.



JEE Main 2022 (Online) 26th June Morning Shift

Q.17. In a series LCR circuit, the inductance, capacitance and resistance are L = 100 mH, C = 100 μF and R = 10 Ω respectively. They are connected to an AC source of voltage 220 V and frequency of 50 Hz. The approximate value of current in the circuit will be __________ A.



JEE Main 2022 (Online) 25th June Evening Shift

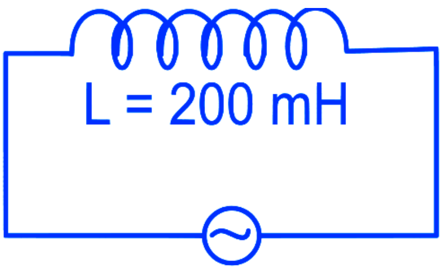
Q.18. The current in a coil of self inductance 2.0 H is increasing according to I = 2 sin(t^2) A. The amount of energy spent during the period when current changes from 0 to 2 A is __________ J.

JEE Main 2022 (Online) 25th June Morning Shift

Q.19. A circular coil of 1000 turns each with area 1m^2 is rotated about its vertical diameter at the rate of one revolution per second in a uniform horizontal magnetic field of 0.07T. The maximum voltage generation will be __________ V.

JEE Main 2022 (Online) 24th June Evening Shift

Q.20. As shown in the figure an inductor of inductance 200 mH is connected to an AC source of emf 220 V and frequency 50 Hz. The instantaneous voltage of the source is 0 V when the peak value of current is $\frac{\sqrt{a}}{\pi}$ A. The value of a is __________.



Answer key & Explanation

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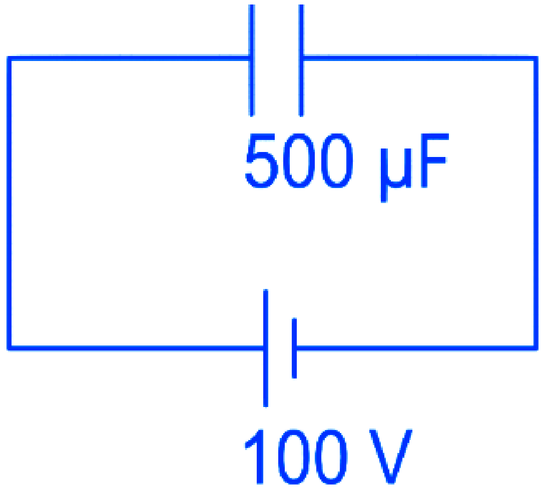
1. Ans. Correct answer is 10

Explanation

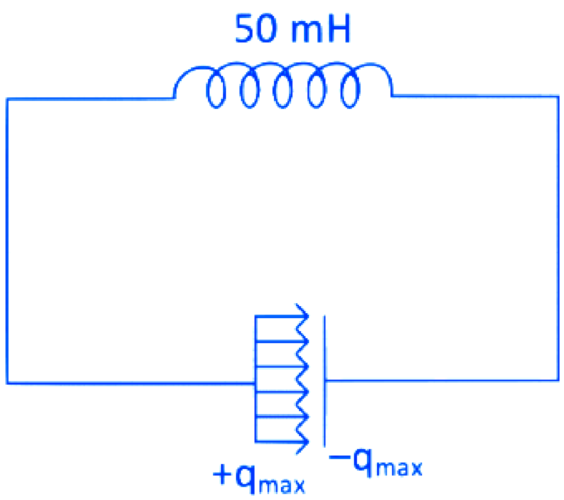


At steady state charge stored on the capacitor,

$$q_{\max} = CV$$

$$= 500 \times 10^{-6} \times 100$$

$$= 5 \times 10^{-2}\, C$$



Energy stored in the capacitor,

$U_{\max} = \frac{q_{\max}^2}{2C}$

Now, when electrostatic energy of capacitor converted to magnetic field energy then all energy of capacitor is transferrd to the inductor.

∴ Maximum energy stored in the inductor

$U_{L\ \max} = \frac{1}{2} L I_{\max}^2$

$\therefore \frac{1}{2} L I_{\max}^2 = \frac{q_{\max}^2}{2C}$

$\Rightarrow I_{\max} = \frac{q_{\max}}{\sqrt{LC}}$

$= \frac{5\times10^{-2}}{\sqrt{50\times10^{-3}\times500\times10^{-6}}}$

$= \frac{5\times10^{-2}}{5\times10^{-3}}$

$= 10\,A$

2. Ans. Correct answer is 1

Just after closing the switch, $i = \frac{6}{4+2} = 1\,A$

3. Ans. Correct answer is 250

Explanation

$\frac{i}{i_{\max}} = \frac{1}{\sqrt{2}}$

$= \frac{\frac{V_0}{Z}}{\frac{V_0}{R}}$

$\Rightarrow \frac{R}{Z} = \frac{1}{\sqrt{2}}$

and $\frac{1}{212C} - 212L = 232L - \frac{1}{232C}$

so $212L = \frac{1}{232C}$

so $\frac{R}{\sqrt{R^2+\left(232L+\frac{1}{232C}\right)^2}}=\frac{1}{\sqrt{2}}$

$\frac{R^2}{R^2+(20L)^2}=\frac{1}{2}$

$400L^2=R^2$

$L=\frac{5}{20}$

$H=\frac{5}{20}\times 1000\,\text{mH}$

$=250\,\text{mH}$

4. Ans. Correct answer is 12

Explanation

$B_{\perp}=3t^2$

$\frac{dB_{\perp}}{dt}=6t-12$ at $t=2$

$\frac{d\phi_1}{dt}=12\times\pi(1)^2=12\pi$

5. Ans. Correct answer is 3

Explanation

$X_C=\frac{1}{wc}=\frac{\pi\sqrt{x}}{2\pi\times 50\times 50}\times 10^6$

$v_R^2+v_C^2=(200)^2$

$v_C^2=200^2-100^2$

$v_C=100\sqrt{3}\,V$

$v_R=100\,V$

$P=\frac{V^2}{R}$

$R = \frac{100\times100}{50} = 200\,\Omega$

$i_{rm} = \frac{1}{2}\,A$

$\frac{1}{2} \times x_C = 100\sqrt{3} \Rightarrow 10^{-6} \times \frac{\sqrt{x}}{5000} \times \frac{1}{2} = 100\sqrt{3}$

$\frac{10^{-6}\sqrt{x}}{10000\times100} = \sqrt{3}$

$\sqrt{x} = \sqrt{3}$

$x = 3$

6. Ans. Correct answer is 2

Explanation

$R = 8\,\Omega$

$\phi = \frac{2}{3}(9 - t^2)$

At $t = 3, \phi = 0$

$\varepsilon = \left|-\frac{d\phi}{dt}\right| = \frac{4}{3}t$

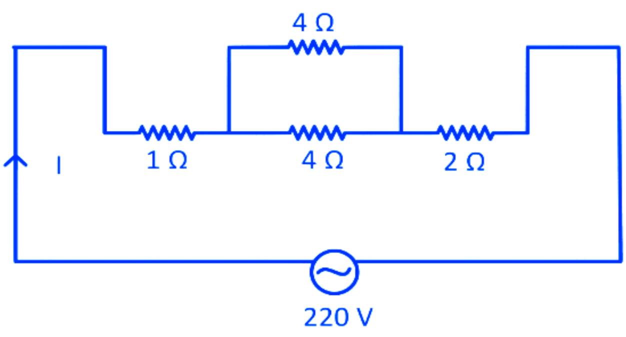
$H = \int_0^3 \frac{V^2}{R}dt = \int_0^3 \frac{1}{8} \times \frac{16}{9}t^2 dt$

$= \frac{2}{9} \times \left(\frac{t^3}{3}\right)_0^3 = \frac{2}{9\times3} \times 27 = 2\,J$

7. Ans. Correct answer is 44

Explanation

Equivalent circuit will be



$I=\frac{220}{5}=44\,A$

8. Ans. Correct answer is 250

Explanation

$R=20\,\Omega$

$\phi=8t^2-9t+5$

$\varepsilon=\left|-\frac{d\phi}{dt}\right|=|16t-9|=|16(0.25)-9|=5$

$i=\frac{\varepsilon}{R}=\frac{5}{20}=0.25\,A=\frac{0.25}{10^3}\times 10^3\,A=250\,mA$

9. Ans. Correct answer is 500

Explanation

For maximum power

$\text{power factor }=\cos\theta=1$

$\therefore \frac{R}{Z}=1$

$R^2=Z^2$

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

$\mathrm{X_L}=\mathrm{X_C}$

$\frac{70}{11}=\frac{1}{100\pi\times C}$

$\Rightarrow C=\frac{11}{7000\pi}=500\times 10^{-6}F=500\mu F$

10. Ans. Correct answer is 5

Explanation

Current will be in phase with emf when

$\omega L = \frac{1}{\omega C}$

$\Rightarrow \omega = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{5\times10^{-4}\times2\times10^{-4}}}$

$\Rightarrow \omega = \frac{10^4}{\sqrt{10}}$ rad/s

$\Rightarrow f = \frac{1}{2\pi} \times \frac{10^4}{\sqrt{10}}$ Hz

$\Rightarrow$ f $\simeq$ 500 Hz

11. Ans. Correct answer is 0

Explanation

$V_L = 2V_R$

So $\omega Li = 2\,Ri$

$\Rightarrow L = \frac{2R}{\omega} = \frac{2\times5}{2\pi\times50} = \frac{1}{10\pi}H = \frac{100}{\pi}H$

So $k = \frac{1}{100} \simeq 0$

12. Ans. Correct answer is 15

Explanation

L = 100 $\times$ 10^{-3} H

C = 100 $\times$ 10^{-6} F

R = 120 Ω

ωL = 10 Ω

$\frac{1}{\omega C} = \frac{1}{10^4\times10^{-6}} = 100\,\Omega$

$\Rightarrow X_C - X_L = 90\ \Omega$

$$\Rightarrow Z = \sqrt{90^2 + 120^2} = 150\,\Omega$$

$$\Rightarrow I_{rms} = \frac{20}{150} = \frac{2}{15} A$$

For heat resistance by 16°C heat required = 32 J

$$\Rightarrow \left(\frac{2}{15}\right)^2 \times (120) \times t = 32$$

$$t = \frac{32\times15\times15}{4\times120} = 15$$

13. Ans. Correct answer is 100

Explanation

Total capacitance = 0.01 $\times$ 100 = 1 μF

ω = 500 $\times$ 2π = 1000π rad/s

$$\omega L = \frac{1}{\omega C}$$

$$\Rightarrow L = \frac{1}{\omega^2 C} = \frac{1}{10^6\pi^2\times10^{-6}} = \frac{1}{10} H$$ = 100 mH

14. Ans. Correct answer is 975

Explanation

$$R_b = \frac{(25)^2}{5} = 125\,\Omega$$

$$I_{rms} = \sqrt{\frac{5}{125}} = \frac{1}{5} A$$

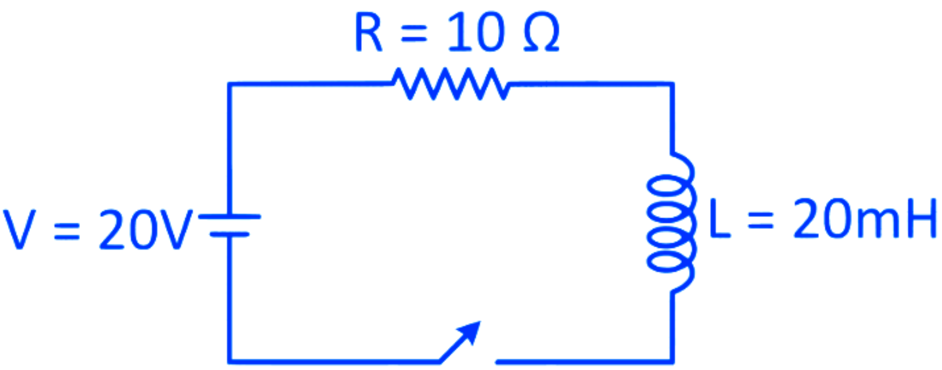
$$\Rightarrow \frac{220}{R+125} = \frac{1}{5}$$

$$\Rightarrow R = 1100 - 125$$

$$= 975\,\Omega$$

15. Ans. Correct answer is 400

Explanation



Initially current, $I_0 = \frac{20}{10} = 2A$ (when initially switch closed)

average emf induced in coil $= \frac{Ldi}{dt}$

$\Rightarrow e_{avg} = \frac{20\times10^{-3}\times(2-0)}{100\times10^{-6}}$

$e_{avg} = 400\,V$

16. Ans. Correct answer is 0

Explanation

$\frac{1}{Z} = \sqrt{\left(\frac{1}{X_L} - \frac{1}{X_C}\right)^2}$

At resonance, $\mathrm{X_L} = \mathrm{X_C} \& \mathrm{Z} \rightarrow \infty$

$\therefore \mathrm{Z}_{\text{total circuit}} \quad \rightarrow \infty$

i.e, $\mathrm{I} = 0$

17. Ans. Correct answer is 22

Explanation

$Z = \sqrt{R^2 + (x_L + x_C)^2}$

$= \sqrt{10^2 + \left[10\pi - \frac{100}{\pi}\right]^2}\,\Omega$

$\simeq 10\,\Omega$

$\Rightarrow$ Current $= \frac{220}{10}$ A = 22 A

18. Ans. Correct answer is 4

Explanation

$U = \frac{1}{2}LI^2$

$= \frac{1}{2}2 \times 2^2 = 4$ J

19. Ans. Correct answer is 440

Explanation

$V_{\max} = NAB\omega$

$= 1000 \times 1 \times 0.07 \times (2\pi \times 1)$

$\simeq 440$ volts

20. Ans. Correct answer is 242

Explanation

$I_{rms} = \frac{V_{rms}}{z}$

$z = X_2 = \omega_2$

$= 2\pi \times 50 \times \frac{200}{1000}$

$= 20\,\pi$

$\therefore I_{rms} = \frac{220}{20\pi} = \frac{11}{\pi}$

$= \frac{\sqrt{2 \times 121}}{\pi}$

$= \frac{\sqrt{242}}{\pi}$

MCQ (Single Correct Answer)

Q.1. A circuit element X when connected to an a.c. supply of peak voltage 100 V gives a peak current of 5 A which is in phase with the voltage. A second element Y when connected to the same a.c. supply also gives the same value of peak current which lags behind the voltage by π/2. If X and Y are connected in series to the same supply, what will be the rms value of the current in ampere?

A $\frac{10}{\sqrt{2}}$

B $\frac{5}{\sqrt{2}}$

C $5\sqrt{2}$

D $\frac{5}{2}$

JEE Main 2022 (Online) 29th July Evening Shift

Q.2. An alternating emf $\mathrm{E}=440 \sin 100 \pi \mathrm{t}$ is applied to a circuit containing an inductance of $\frac{\sqrt{2}}{\pi} \mathrm{H}$. If an a.c. ammeter is connected in the circuit, its reading will be :

A 4.4 A

B 1.55 A

C 2.2 A

D 3.11 A

JEE Main 2022 (Online) 29th July Morning Shift

Q.3. A coil of inductance 1 H and resistance 100Ω is connected to a battery of 6 V. Determine approximately :

(a) The time elapsed before the current acquires half of its steady - state value.

(b) The energy stored in the magnetic field associated with the coil at an instant 15 ms after the circuit is switched on.
(Given $\ln 2 = 0.693, \mathrm{e}^{-3/2} = 0.25$)

A. t = 10 ms; U = 2 mJ

B. t = 10 ms; U = 1 mJ

C. t = 7 ms; U = 1 mJ

D. t = 7 ms; U = 2 mJ

JEE Main 2022 (Online) 29th July Morning Shift

Q.4. A transformer operating at primary voltage 8kV and secondary voltage 160 V serves a load of 80 kW. Assuming the transformer to be ideal with purely resistive load and working on unity power factor, the loads in the primary and secondary circuit would be

(A) $800\,\Omega$ and $1.06\,\Omega$

(B) $10\,\Omega$ and $500\,\Omega$

(C) $800\,\Omega$ and $0.32\,\Omega$

(D) $1.06\,\Omega$ and $500\,\Omega$

JEE Main 2022 (Online) 28th July Evening Shift

Q.5. The equation of current in a purely inductive circuit is $5\sin(49\,\pi t - 30^\circ)$. If the inductance is 30mH then the equation for the voltage across the inductor, will be :

$\{\text{Let } \pi = \frac{22}{7}\}$

(A) $1.47\sin(49\pi t - 30^\circ)$

(B) $1.47\sin(49\pi t + 60^\circ)$

(C) $23.1\sin(49\pi t - 30^\circ)$

(D) $23.1\sin(49\pi t + 60^\circ)$

JEE Main 2022 (Online) 28th July Morning Shift

Q.6. A series LCR circuit has L=0.01H,R=10Ω and C=1μF and it is connected to ac voltage of amplitude (Vm)50 V. At frequency 60% lower than resonant frequency, the amplitude of current will be approximately :

A 466 mA

B 312 mA

C 238 mA

D 196 mA

JEE Main 2022 (Online) 27th July Evening Shift

Q.7. A direct current of $4\ A$ and an alternating current of peak value $4\ A$ flow through resistance of 3Ω and 2Ω respectively. The ratio of heat produced in the two resistances in same interval of time will be :

A 3 : 2

B 3 : 1

C 3 : 4

D 4 : 3

JEE Main 2022 (Online) 27th July Morning Shift

Q.8. In a series LR circuit $X_L=R$ and power factor of the circuit is P_1. When capacitor with capacitance C such that $X_L=X_C$ is put in series, the power factor becomes P_2. The ratio P_1/P_2 is:

A $\frac{1}{2}$

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

C $\frac{\sqrt{3}}{\sqrt{2}}$

D 2 : 1

JEE Main 2022 (Online) 26th July Morning Shift

Q.9. The electric current in a circular coil of 2 turns produces a magnetic induction B_1 at its centre. The coil is unwound and in rewound into a circular coil of 5 tuns and the same current produces a magnetic induction B_2 at its centre. The ratio of B_2/B_1 is

A $\frac{5}{2}$

B $\frac{25}{4}$

C $\frac{5}{4}$

D $\frac{25}{2}$

JEE Main 2022 (Online) 25th July Evening Shift

Q.10. When you walk through a metal detector carrying a metal object in your pocket, it raises an alarm. This phenomenon works on :

(A) Electromagnetic induction

(B) Resonance in ac circuits

(C) Mutual induction in ac circuits

(D) Interference of electromagnetic waves

JEE Main 2022 (Online) 25th July Evening Shift

Q.11. To increase the resonant frequency in series LCR circuit,

(A) source frequency should be increased.

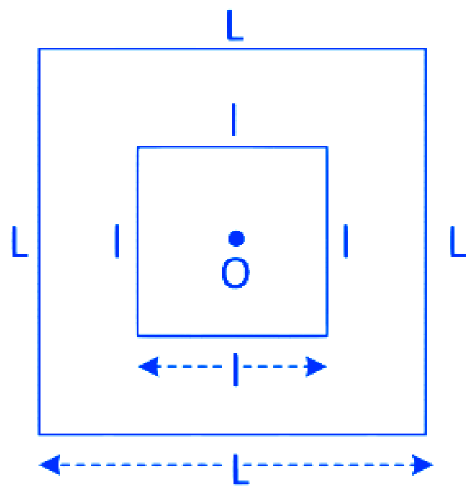
(B) another resistance should be added in series with the first resistance.

(C) another capacitor should be added in series with the first capacitor.

(D) the source frequency should be decreased.

JEE Main 2022 (Online) 25th July Morning Shift

Q.12. A small square loop of wire of side l is placed inside a large square loop of wire $L (L >> l)$. Both loops are coplanar and their centres coincide at point O as shown in figure. The mutual inductance of the system is :



A $\frac{2\sqrt{2}\mu_0 L^2}{\pi l}$

B $\frac{\mu_0 l^2}{2\sqrt{2}\pi L}$

C $\frac{2\sqrt{2}\mu_0 l^2}{\pi L}$

D $\frac{\mu_0 L^2}{2\sqrt{2}\pi l}$

JEE Main 2022 (Online) 25th July Morning Shift

Q.13. The rms value of conduction current in a parallel plate capacitor is 6.9 μ A. The capacity of this capacitor, if it is connected to 230 V ac supply with an angular frequency of 600rad/s, will be :

A 5 pF

B 50 pF

C 100 pF

D 200 pF

JEE Main 2022 (Online) 25th July Morning Shift

Q.14. An expression for oscillating electric field in a plane electromagnetic wave is given as $E_z = 300 \sin(5\pi \times 10^3 x - 3\pi \times 10^{11} t)$ Vm^{-1}

Then, the value of magnetic field amplitude will be :

(Given : speed of light in Vacuum $c = 3 \times 10^8$ ms^{-1})

A 1×10^{-6} T

B 5×10^{-6} T

C 18×10^{9} T

D 21×10^{9} T

JEE Main 2022 (Online) 30th June Morning Shift

Q.15. In series RLC resonator, if the self inductance and capacitance become double, the new resonant frequency (f_2) and new quality factor (Q_2) will be :

(f_1 = original resonant frequency, Q_1 = original quality factor)

A. $f_2 = \frac{f_1}{2}$ and $Q_2 = Q_1$

B. $f_2 = f_1$ and $Q_2 = \frac{Q_1}{Q_2}$

C. $f_2 = 2f_1$ and $Q_2 = Q_1$

D. $f_2 = f_1$ and $Q_2 = 2Q_1$

JEE Main 2022 (Online) 30th June Morning Shift

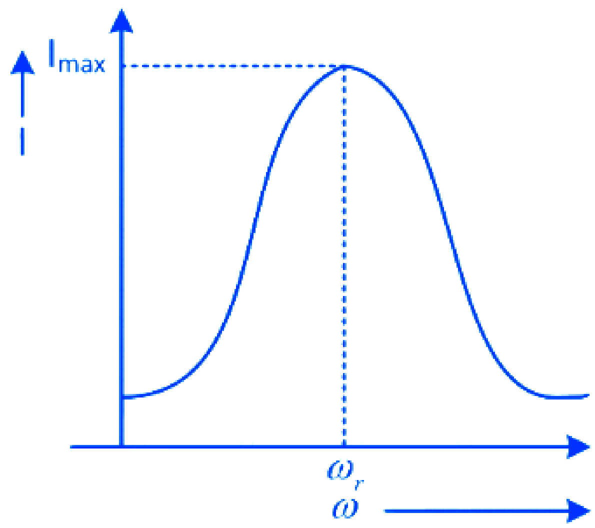
Q.16. For a series LCR circuit, I vs ω curve is shown :

(a) To the left of ω_r, the circuit is mainly capacitive.

(b) To the left of ω_r, the circuit is mainly inductive.

(c) At ω_r, impedance of the circuit is equal to the resistance of the circuit.

(d) At ω_r, impedance of the circuit is 0.



Choose the most appropriate answer from the options given below :

A (a) and (d) only.

B (b) and (d) only.

C (a) and (c) only.

D (b) and (c) only.

JEE Main 2022 (Online) 29th June Morning Shift

Q.17. A coil is placed in a time varying magnetic field. If the number of turns in the coil were to be halved and the radius of wire doubled, the electrical power dissipated due to the current induced in the coil would be :

(Assume the coil to be short circuited.)

A Halved

B Quadrupled

C The same

D Doubled

JEE Main 2022 (Online) 28th June Evening Shift

Q.18. If L, C and R are the self inductance, capacitance and resistance respectively, which of the following does not have the dimension of time?

A RC

B $\frac{L}{R}$

C $\sqrt{LC}$

D $\frac{L}{C}$

JEE Main 2022 (Online) 27th June Evening Shift

Q.19. The current flowing through an ac circuit is given by

$I = 5 \sin(120\pi t)A$

How long will the current take to reach the peak value starting from zero?

A $\frac{1}{60}$ s

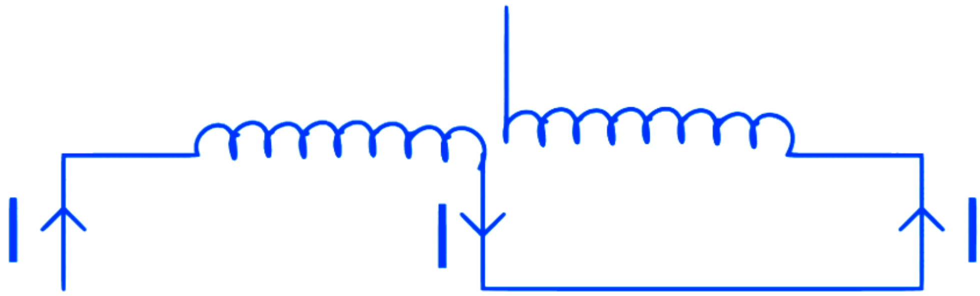
B 60 s

C $\frac{1}{120}$ s

D $\frac{1}{240}$ s

JEE Main 2022 (Online) 27th June Morning Shift

Q.18. Two coils of self inductance L_1 and L_2 are connected in series combination having mutual inductance of the coils as M. The equivalent self inductance of the combination will be :



A $\frac{1}{L_1}+\frac{1}{L_2}+\frac{1}{M}$

B L_1+L_2+M

C L_1+L_2+2M

D L_1+L_2-2M

JEE Main 2022 (Online) 26th June Evening Shift

Q.19. A metallic conductor of length 1 m rotates in a vertical plane parallel to east-west direction about one of its end with angular velocity 5 rad s^{-1}. If the horizontal component of earth's magnetic field is 0.2×10^{-4} T, then emf induced between the two ends of the conductor is :

A 5 μV

B 50 μV

C 5 mV

D 50 mv

JEE Main 2022 (Online) 26th June Evening Shift

Q.20. The magnetic flux through a coil perpendicular to its plane is varying according to the relation $\phi = (5t^3 + 4t^2 + 2t - 5)$ Weber. If the resistance of the coil is 5 ohm, then the induced current through the coil at t = 2 s will be,

A 15.6 A

B 16.6 A

C 17.6 A

D 18.6 A

JEE Main 2022 (Online) 26th June Morning Shift

Q.21. A sinusoidal voltage V(t) = 210 sin 3000 t volt is applied to a series LCR circuit in which L = 10 mH, C = 25 μF and R = 100 Ω. The phase difference (Φ) between the applied voltage and resultant current will be :

A $\tan^{-1}(0.17)$

B $\tan^{-1}(9.46)$

C $\tan^{-1}(0.30)$

D $\tan^{-1}(13.33)$

JEE Main 2022 (Online) 25th June Evening Shift

Q.22. Match List-I with List-II.

	List - I		List -II
(A)	AC generator	(I)	Detects the presence of current in the circuit
(B)	Galvanometer	(II)	Converts mechanical energy into electrical energy
(C)	Transformer	(III)	Works on the principle of resonance in AC circuit
(D)	Metal detector	(IV)	Changes an alternating voltage for smaller or greater value

Choose the correct answer from the options given below :

A (A) - (II), (B) - (I), (C) - (IV), (D) - (III)

B (A) - (II), (B) - (I), (C) - (III), (D) - (IV)

C (A) - (III), (B) - (IV), (C) - (II), (D) - (I)

D (A) - (III), (B) - (I), (C) - (II), (D) - (IV)

JEE Main 2022 (Online) 25th June Morning Shift

Q.23. If wattless current flows in the AC circuit, then the circuit is :

A Purely Resistive circuit

B Purely Inductive circuit

C LCR series circuit

D RC series circuit only

JEE Main 2022 (Online) 25th June Morning Shift

Q.24. Given below are two statements :

Statement I : The reactance of an ac circuit is zero. It is possible that the circuit contains a capacitor and an inductor.

Statement II : In ac circuit, the average power delivered by the source never becomes zero.

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

A. Both Statement I and Statement II are true.

B. Both Statement I and Statement II are false.

C. Statement I is true but Statement II is false.

D. Statement I is false but Statement II is true.

JEE Main 2022 (Online) 24th June Evening Shift

Q.25. A resistance of 40 Ω is connected to a source of alternating current rated 220 V, 50 Hz. Find the time taken by the current to change from its maximum value to the rms value :

A. 2.5 ms

B. 1.25 ms

C. 2.5 s

D. 0.25 s

Answer Key & Explanation

---

1. Ans. (D)

Explanation

Element X should be resistive with, $R = \frac{100}{5} = 20\Omega$

Element Y should be inductive with, $X_L = \frac{100}{5} = 20\Omega$

When X and Y are connector in series,

$$Z = \sqrt{20^2 + 20^2} = 20\sqrt{2}\Omega$$

$$I = \frac{100}{Z} = \frac{100}{20\sqrt{2}} = \frac{5}{\sqrt{2}}$$

$$i_{\text{rms}} = \frac{1}{\sqrt{2}} I$$

$$= \frac{5}{2}$$

2. Ans. (C)

Explanation

$I = \frac{V}{\omega L}$

$$= \frac{440}{100\pi \times \frac{\sqrt{2}}{\pi}} = \frac{44}{10\sqrt{2}}$$

$$\Rightarrow I_{rms} = \frac{I}{\sqrt{2}} = \frac{44}{20} = 2.2\,A$$

3. Ans. (C)

Explanation

$i(t) = \frac{V}{R}(1 - e^{-Rt/L})$ ...... (1)

$\frac{L}{R} = \frac{1}{100}s \Rightarrow \frac{L}{R} = 10\,ms$ ...... (2)

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

$$\Rightarrow e^{-Rt/L} = \frac{1}{2} \Rightarrow t = \frac{L}{R}\ln 2 = 6.93\,ms$$

$$U = \frac{1}{2}Li^2 = \frac{1}{2}[1 - e^{-15/10}]^2 \left[\frac{6}{100}\right]^2$$

$$= \frac{1}{2}[1 - 0.25]^2 \times 36 \times 10^{-4}$$

$$= 1\,mJ$$

4. Ans. (C)

Explanation

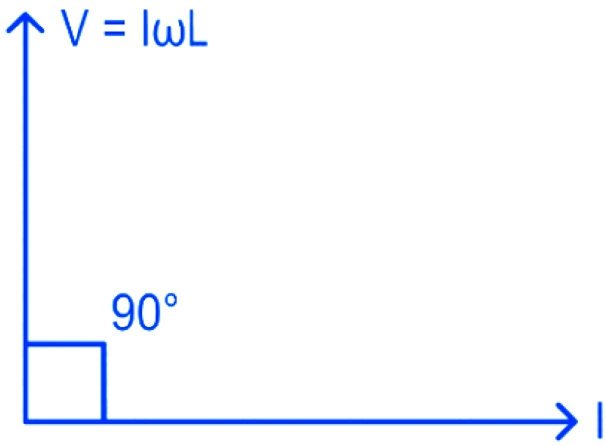
$V_1 i_1 = V_2 i_2 = 80$ kW

$\Rightarrow i_1 = 10\,A$ and $i_2 = \frac{80 \times 1000}{160} = 500\,A$

$\Rightarrow R_1 = \frac{V_1}{i_1} = 800\,\Omega$ and $R_2 = \frac{160}{500} = 0.32\,\Omega$

5. Ans. (D)

Explanation



$$V(t) = I\omega L \sin(49\pi t - 30^\circ + 90^\circ)$$

$$= 5 \times 49\pi \times \frac{30}{1000} \sin(49\pi t + 60^\circ)$$

$$= 23.1 \sin(49\pi t + 60^\circ)$$

6. Ans. (C)

Explanation

$\omega = 0.4\omega_0$ ...... (i)

$\Rightarrow I = \frac{V}{Z} = \frac{50}{\sqrt{R^2 + \left(\omega L - \frac{1}{\omega C}\right)^2}}$ ..... (ii)

$\Rightarrow I = 238$ mA

7. Ans. (B)

Explanation

Ratio = $\frac{i_1^2 R_1}{\left(\frac{i_2}{\sqrt{2}}\right)^2 R_2} = \frac{4^2 \times 3}{\left(\frac{4}{\sqrt{2}}\right)^2 \times 2}$

$\Rightarrow$ Ratio = 3 : 1

8. Ans. (B)

Explanation

$P_1 = \cos\phi = \frac{1}{\sqrt{2}}(X_L = R)$

$P_2 = \cos\phi' = 1$ (will become resonance circuit)

So, $\frac{P_1}{P_2} = \frac{1}{\sqrt{2}}$

9. Ans. (B)

Explanation

$B = \frac{n\mu_0 I}{2R}$

$B_1 = \frac{2\mu_0 I}{2R_1}$

$B_2 = \frac{5\mu_0 I}{2R_2}$

$R_2 = \frac{2R_1}{5}$

$\Rightarrow \frac{B_2}{B_1} = \frac{5}{2} \times \frac{R_1}{R_2} = \frac{25}{4}$

10. Ans. (B)

Explanation

Metal detector works on the principle of resonance in ac circuits.

11. Ans. (C)

Explanation

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

$\Rightarrow$ If we decrease C, ω_0 would increase

$\Rightarrow$ Another capacitor should be added in series.

12. Ans. (C)

Explanation

We know $\phi = Mi$

Let i current be flowing in the larger loop

$$\Rightarrow \phi \simeq \left[4 \times \frac{\mu_0 i}{4\pi(L/2)}\left[\sin 45^\circ + \sin 45^\circ\right]\right] \times \text{Area}$$

$$= \frac{2\sqrt{2}\mu_0 i}{\pi L} \times I^2$$

$$\Rightarrow M = \frac{\phi}{i} = \frac{2\sqrt{2}\mu_0 I^2}{\pi L}$$

13. Ans. (B)

Explanation

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

$$\Rightarrow \frac{1}{\omega C} = \frac{230}{6.9}\, M\,\Omega$$

$$\Rightarrow C = \frac{6.9}{230\,\omega}\, \mu F$$

$$= \frac{6.9}{230 \times 600}\, \mu F$$

$$C = 50\, pF$$

14. Ans. (B)

Explanation

Given, Equation of electromagnetic wave,

$$E_z = 300 \sin\left(5\pi \times 10^3 x - 3\pi \times 10^{11}\, t\right) \text{ V m}^{-1}$$

We know, velocity of wave $(v) = \frac{w}{k}$

here, $w = 3\pi \times 10^{11}$

$k = 5\pi \times 10^3$

$\therefore$ Velocity of wave $(v) = \frac{3\pi \times 10^{11}}{5\pi \times 10^3}$

$= 0.6 \times 10^8$ m/s

We also know,

$E_0 = CB_0$

$\Rightarrow B_0 = \frac{E_0}{C} = \frac{300}{0.6 \times 10^8} = 5 \times 10^{-6}$ T

15. Ans. (A)

Explanation

We know,

Quality factor (Q factor)

$Q_1 = \frac{w_1}{\Delta w}$

$= \frac{1}{\sqrt{LC}} \times \frac{L}{R}$

$= \frac{1}{R}\sqrt{\frac{L}{C}}$

Now, when $L' = 2L$ and $C' = 2C$ then $Q_2 = \frac{1}{R}\sqrt{\frac{2L}{2C}} = \frac{1}{R}\sqrt{\frac{L}{C}} = Q_1$

$\therefore Q_2$ remains same as Q_1.

Also, as $w_1 = \frac{1}{\sqrt{LC}}$

$\Rightarrow 2\pi f_1 = \frac{1}{\sqrt{LC}}$

$\Rightarrow f_1 = \frac{1}{2\pi\sqrt{LC}}$

$\therefore$ When $L' = 2L$ and $C' = 2C$ then new resonating frequency

$f_2 = \frac{1}{2\pi\sqrt{2L \times 2C}} = \frac{1}{2\pi \times 2\sqrt{LC}} = \frac{1}{2} \times f_1$

16. Ans. (C)

Explanation

We know that $X_C = \frac{1}{\omega C}$ and $X_L = \omega L$

Also, at $\omega = \omega_r : X_L = X_C$

$\Rightarrow$ For $\omega < \omega_r$: capacitive

and $\omega = \omega_r : z = \sqrt{R^2 + (X_L - X_C)^2} = R$

17. Ans. (C)

Explanation

$$\mathrm{P} = \frac{e^2}{\mathrm{R}}$$

$$e = \text{ induced emf } = \frac{\mathrm{N} d\phi_B}{dt} = \mathrm{NA}\frac{d\,\mathrm{B}}{dt}$$

and $\mathrm{R} = \frac{el}{\pi r^2}$ where r is the radius of the wire

$$\mathrm{P} = \frac{\left(\mathrm{NA}\frac{d\,\mathrm{B}}{dt}\right)^2}{\frac{el}{\pi r^2}}$$

$$\Rightarrow \quad \mathrm{P} \propto \mathrm{N}^2 r^2$$

$$\Rightarrow \quad \mathrm{P}' \propto \left(\frac{\mathrm{N}}{2}\right)^2 (2r)^2$$

$$\Rightarrow \quad \mathrm{P}' = \mathrm{P}$$

18. Ans. (D)

Explanation

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

So, $\left[\frac{L}{C}\right] = \frac{V^2}{i^2} = R^2$ is not the dimension of time.

19. Ans. (D)

Explanation

$\omega = 120\pi$

$\Rightarrow T = \frac{1}{60}\,\text{sec}$

The current will take its peak value in $\frac{T}{4}$ time

So $t = \frac{T}{4}$

$= \frac{1}{240}\,s$

20. Ans. (D)

Explanation

Self inductances are in series but their mutual inductances are linked oppositely so equivalent self inductance

$L = L_1 + L_2 - M - M = L_1 + L_2 - 2M$

21. Ans. (B)

Explanation

$Emf = \frac{1}{2}B\omega l^2$

$= \frac{1}{2} \times 0.2 \times 10^{-4} \times 5 \times 1^2$ V

= 0.5×10^{-4} V

= 50 μV

22. Ans. (A)

Explanation

$\phi = 5t^3 + 4t^2 + 2t - 5$

$|e| = \frac{d\phi}{dt} = 15t^2 + 8t + 2$

At $t = 2, |e| = 15 \times 2^2 + 8 \times 2 + 2$

$\Rightarrow e = 78\,V$

$\Rightarrow I = \frac{e}{R} = \frac{78}{5} = 15.60$

23. Ans. (A)

Explanation

$X_L = 3000 \times 10 \times 10^{-3} = 30\,\Omega$

$X_C = \frac{1}{3000 \times 25} \times 10^6 = \frac{40}{3}\,\Omega$

So $X_L - X_C = 30 - \frac{40}{3} = \frac{50}{3}\,\Omega$

$\tan\theta = \frac{X_L - X_C}{R} = \frac{50/3}{100} = \frac{1}{6}$

So $\theta = \tan^{-1}(0.17)$

24. Ans. (A)

Explanation

AC generator	→	Converts mechanical energy into electrical energy
Galvanometer	→	Detects the presence of current in the circuit
Transformer	→	Change AC voltage for smaller or greater value
Metal detector	→	Works on the principle of resonance in AC circuit

25. Ans. (B)

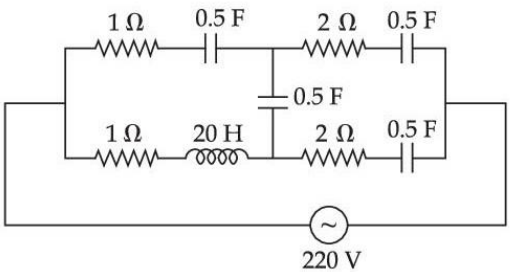
Explanation

For wattless current to flow in AC circuit the circuit will be Purely Inductive circuit.

2021

Numerical

Q.1 At very high frequencies, the effective impendence of the given circuit will be _____________ Ω.



31st Aug Evening Shift 2021

Q.2 An ac circuit has an inductor and a resistor resistance R in series, such that $X_L = 3R$. Now, a capacitor is added in series such that $X_C = 2R$. The ratio of new power factor with the old power factor of the circuit is $\sqrt{5} : x$ The value of x is _________.

27th Aug Evening Shift 2021

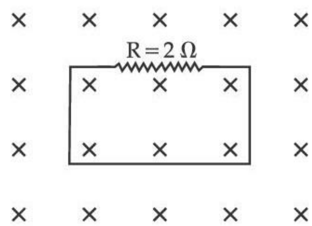
Q.3 The alternating current is given by $i = \left\{\sqrt{42}\sin\left(\frac{2\pi}{T}t\right) + 10\right\} A$

The r.m.s. value of of this current is .... A.

27th Aug Morning Shift 2021

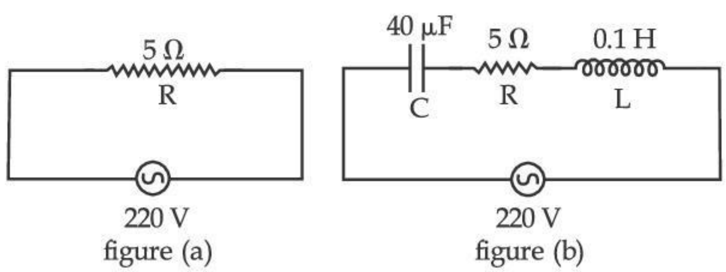
Q.4 In the given figure the magnetic flux through the loop increases according to the relation $\phi_B(t) = 10t^2 + 20t$, where ϕ_B is in milliwebers and t is in seconds.

The magnitude of current through R = 2Ω resistor at t = 5 s is __________ mA.



27th July Evening Shift 2021

Q.5 Two circuits are shown in the figure (a) & (b). At a frequency of ___________ rad/s the average power dissipated in one cycle will be same in both the circuits.



25th July Evening Shift 2021

Q.6 An inductor of 10 mH is connected to a 20V battery through a resistor of 10 kΩ and a switch. After a long time, when maximum current is set up in the circuit, the current is switched off. The current in the circuit after 1 μs is $\frac{x}{100}$ mA. Then x is equal to __________. (Take $e^{-1} = 0.37$)

25th July Morning Shift 2021

Q.7 A series LCR circuit of R = 5Ω, L = 20 mH and C = 0.5 μF is connected across an AC supply of 250 V, having variable frequency. The power dissipated at resonance condition is _____________ × 10^2 W.

20th July Evening Shift 2021

Q.8 In an LCR series circuit, an inductor 30 mH and a resistor 1 Ω are connected to an AC source of angular frequency 300 rad/s. The value of capacitance for which, the current leads the voltage by 45° is $\frac{1}{x}$ ×10−3 F. Then the value of x is __________.

20th July Morning Shift 2021

Q.9 A sinusoidal voltage of peak value 250 V is applied to a series LCR circuit, in which R = 8Ω, L = 24 mH and C = 60 μF. The value of power dissipated at resonant condition is 'x' kW. The value of x to the nearest integer is __________.

16th Mar Morning Shift 2021

Q.10 In a series LCR resonant circuit, the quality factor is measured as 100. If the inductance is increased by two fold and resistance is decreased by two fold, then the quality factor after this change will be _________.

26th Feb Morning Shift 2021

Q.11 A transmitting station releases waves of wavelength 960 m. A capacitor of 2.56 μF is used in the resonant circuit. The self inductance of coil necessary for resonance is _________ × 10^{-8} H.

25th Feb Morning Shift 2021

Q.12 A coil of inductance 2 H having negligible resistance is connected to a source of supply whose voltage is given by V = 3t volt. (where t is in second). If the voltage is applied when t = 0, then the energy stored in the coil after 4 s is ______J.

25th Feb Morning Shift 2021

Q.13 A series L-C-R circuit is designed to resonate at an angular frequency ω_0 = 10^5 rad/s. The circuit draws 16W power from 120V source at resonance. The value of resistance 'R' in the circuit is ________ Ω.

24th Feb Evening Shift 2021

Q.14 A resonance circuit having inductance and resistance 2 × 10^{-4} H and 6.28Ω respectively oscillates at 10 MHz frequency. The value of quality factor of this resonator is __________.

[π = 3.14]

24th Feb Morning Shift 2021

Q.15 A common transistor radio set requires 12 V (D.C.) for its operation. The D.C. source is constructed by using a transformer and a rectifier circuit, which are operated at 220 V (A.C.) on standard domestic A.C. supply. The number of turns of secondary coil are 24, then the number of turns of primary are ___________.

24th Feb Morning Shift 2021

Numerical Answer Key

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1. **Ans. (2)**
2. **Ans. (1)**
3. **Ans. (11)**
4. **Ans. (60)**
5. **Ans. (500)**
6. **Ans. (74)**
7. **Ans. (125)**
8. **Ans. (3)**
9. **Ans. (4)**
10. **Ans. (282.84)**
11. **Ans. (10)**
12. **Ans. (144)**
13. **Ans. (900)**
14. **Ans. (2000)**
15. **Ans. (440)**

Numerical Explanation

Ans 1.

$X_L = 2\pi fL$

f is very large

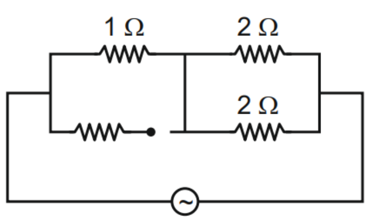
$\therefore X_L$ is very large hence open circuit.

$$X_C = \frac{1}{2\pi fC}$$

f is very large.

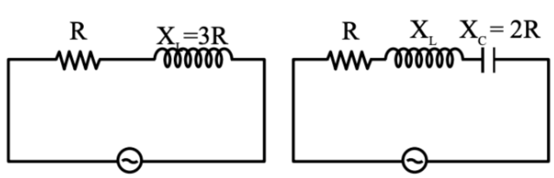
$\therefore X_C$ is very small, hence short circuit.

Final circuit



$$\therefore Z_{eq} = 1 + \frac{2\times 2}{2+2} = 2$$

Ans 2.



$\cos\phi = \frac{R}{\sqrt{R^2+3R^2}}$

$= \frac{1}{\sqrt{10}}$

$\cos\phi' = \frac{R}{\sqrt{R^2+R^2}}$

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

$\frac{\cos\phi'}{\cos\phi} = \frac{\sqrt{10}}{\sqrt{2}} = \frac{\sqrt{5}}{1}$

$\therefore$ x = 1

Ans 3.

$f_{rms}^2 = f_{1\,rms}^2 + f_{2\,rms}^2$

$= \left(\frac{\sqrt{42}}{\sqrt{2}}\right)^2 + 10^2$

$= 121 \Rightarrow f_{rms}$ = 11 A

Ans 4.

$|\in| = \frac{d\phi}{dt}$ = 20t + 20 mV

$|i| = \frac{|\in|}{R}$ = 10t + 10 mA

at t = 5

$|i|$ = 60 mA

Ans 5. For figure (a)

$$P_{avg} = \frac{v_{rms}^2}{R}$$

$$\frac{v_{rms}^2}{Z^2} \times R = \frac{v_{rms}^2}{R} \times 1$$

$$R^2 = Z^2$$

$$25 = \left(\sqrt{(x_C - x_L)^2 + 5^2}\right)^2$$

$$= 25(x_C - x_L)^2 + 25$$

$$x_C = x_L \Rightarrow \frac{1}{\omega C} = \omega L$$

$$\omega^2 = \frac{1}{LC} = \frac{10^6}{0.1 \times 40}$$

$$\omega = 500$$

Ans 6.

$$I_{\max} = \frac{V}{R} = \frac{20V}{10K\Omega} = 2\text{ mA}$$

For LR - decay circuit

$$I = I_{\max} e^{-Rt/L}$$

$$I = 2mAe^{\frac{-10\times10^3\times1\times10^{-6}}{10\times10^{-3}}}$$

I = 2mA e^{-1}

I = 2 $\times$ 0.37 mA

$I = \frac{74}{100}$ mA

x = 74

Ans 7.

$X_L = X_C$ (due to resonance)

Z = R so $i_{rms} = \frac{V}{Z} = \frac{V}{R}$

$\frac{V^2}{R} = \frac{250 \times 250}{5} = 125 \times 10^2 W$

Ans 9. At resonance power (P)

$P = \frac{(V_{rms})^2}{R}$

$\therefore P = \frac{(250/\sqrt{2})^2}{8}$

⇒ P = 3906.25 w

⇒ P $\cong$ 4 Kw

Ans 10.

Quality factor = $\frac{X_L}{R} = \frac{\omega L}{R}$

$Q = \frac{1}{\sqrt{LC}} \frac{L}{R}$

$Q = \left(\frac{1}{\sqrt{C}}\right) \frac{\sqrt{L}}{R}$

$Q = \frac{XL}{R} = \frac{\omega L}{R} = \frac{1}{\sqrt{LC}} \frac{L}{R} = \frac{1}{R} \frac{\sqrt{L}}{\sqrt{C}}$

$Q' = \frac{\sqrt{2L}}{\left(\frac{R}{2}\right)\sqrt{C}} = 2\sqrt{2}Q$

Q' = 282.84

Ans 11.

λ = 960 m

C = 2.56 μF = 2.56 $\times$ 10^{-6} F

c = 3 $\times$ 10^8 m/s

L = ?

Now at resonance, $\omega_0 = \frac{1}{\sqrt{LC}}$

[Resonant frequency]

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

On substituting $f_0 = \frac{c}{\lambda}$, we have $2\pi \frac{c}{\lambda} = \frac{1}{\sqrt{LC}}$

Squaring both sides : $4\pi^2 \frac{c^2}{\lambda^2} = \frac{1}{LC}$

$$= \frac{4\times10\times(3\times10^8)^2}{(960)^2} = \frac{1}{L\times2.56\times10^{-6}}$$

$$\Rightarrow \frac{1}{L} = \frac{4\times10\times9\times10^{16}\times2.56\times10^{-6}}{960\times960}$$

$$\Rightarrow L = 10 \times 10^{-8} \text{ H}$$

Ans 12.

$$L\frac{di}{dt} = \varepsilon$$

$$= 3t$$

$$L\int di = 3\int t dt$$

$$Li = \frac{3t^2}{2}$$

$$i = \frac{3t^2}{2L}$$

energy, $E = \frac{1}{2}Li^2$

$$= \frac{1}{2}L\left(\frac{3t^2}{2L}\right)^2$$

$$= \frac{1}{2} \times \frac{9t^4}{4L}$$

$$= \frac{9}{8} \times \frac{(4)^4}{4\times2} = 144 \text{ J}$$

Ans 13. Given, angular frequency at resonance, $\omega_0 = 10^5$ rads^{-1}

Power drawn from circuit, P = 16 W

and supply voltage, V = 120 V

Let resistance of circuit = R.

As, $P = V^2/R$

$$\Rightarrow R = V^2/P = \frac{120 \times 100}{16}$$

= 30 × 30 = 900Ω

Ans 14.

Given, L = 2×10^{-4} H, R = 6.28 Ω, f_0 = 10 MHz = 10×10^6 Hz

$$\therefore \text{Quality factor} = \omega_0 \frac{L}{R} = 2\pi f_0 \frac{L}{R}$$

$$= 2\pi \times 10 \times 10^6 \times \frac{2 \times 10^{-4}}{6.28}$$

$$= 2 \times 10^3 = 2000$$

Ans 15. In a transformer,

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

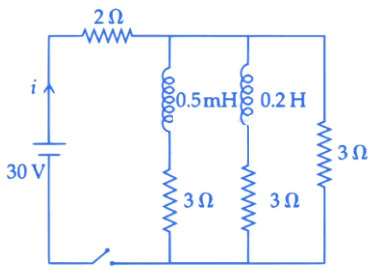
where, N_p = number of turns in primary circuit, N_s = number of turns in secondary circuit = 24, V_p = potential of primary circuit = 220 V and V_s = potential of secondary circuit = 12 V

$$\Rightarrow \frac{N_p}{24} = \frac{220}{12}$$

$$\Rightarrow N_p = 440$$

MCQ (Single Correct Answer)

Q.1 For the given circuit the current i through the battery when the key in closed and the steady state has been reached is ________.



A 6 A

B 25 A

C 10 A

D 0 A

1st Aug Evening Shift 2021

Q.2 Statement - I:

To get a steady dc output from the pulsating voltage received from a full wave rectifier we can connect a capacitor across the output parallel to the load RL.

Statement - II:

To get a steady dc output from the pulsating voltage received from a full wave rectifier we can connect an inductor in series with RL.

In the light of the above statements, choose the most appropriate answer from the options given below:

A Statement I is true but Statement II is false

B Statement I is false but Statement II is true

C Both Statement I and Statement II are false

D Both Statement I and Statement II are true

31st Aug Morning Shift 2021

Q.3 In an ac circuit, an inductor, a capacitor and a resistor are connected in series with $X_L = R = X_C$. Impedance of this circuit is :

A $2R^2$

B Zero

C R

D $R\sqrt{2}$

31st Aug Morning Shift 2021

Q.4 A small square loop of side 'a' and one turn is placed inside a larger square loop of side b and one turn (b >> a). The two loops are coplanar with their centres coinciding. If a current I is passed in the square loop of side 'b', then the coefficient of mutual inductance between the two loops is :

A $\frac{\mu_0}{4\pi} 8\sqrt{2} \frac{a^2}{b}$

B $\frac{\mu_0}{4\pi} \frac{8\sqrt{2}}{a}$

C $\frac{\mu_0}{4\pi} 8\sqrt{2} \frac{b^2}{a}$

D $\frac{\mu_0}{4\pi} \frac{8\sqrt{2}}{b}$

31st Aug Morning Shift 2021

Q.5 Electric field in a plane electromagnetic wave is given by E = 50 sin$(500x - 10 \times 10^{10} t)$ V/m The velocity of electromagnetic wave in this medium is :

(Given C = speed of light in vacuum)

A $\frac{3}{2}C$

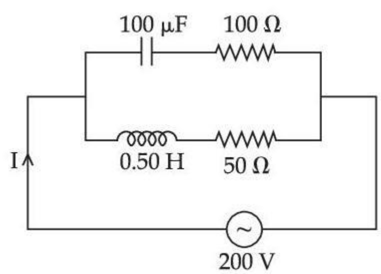
B C

C $\frac{2}{3}C$

D $\frac{C}{2}$

27th Aug Morning Shift 2021

Q.6 In the given circuit the AC source has $\omega = 100$ rad s^{-1}. Considering the inductor and capacitor to be ideal, what will be the current I flowing through the circuit?



A 5.9 A

B 3.16 A

C 0.94 A

D 6 A

26th Aug Evening Shift 2021

Q.7 A series LCR circuit driven by 300 V at a frequency of 50 Hz contains a resistance R = 3 kΩ, an inductor of inductive reactance $X_L = 250\ \pi\Omega$ and an unknown capacitor. The value of capacitance to maximize the average power should be :
(Take $\pi^2 = 10$)

A $4\ \mu F$

B $25\ \mu F$

C $400\ \mu F$

D $40\ \mu F$

26th Aug Morning Shift 2021

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

A 0.4

B 0.8

C 0.125

D 0.2

26th Aug Morning Shift 2021

Q.9 A 100Ω resistance, a 0.1 μF capacitor and an inductor are connected in series across a 250 V supply at variable frequency. Calculate the value of inductance of inductor at which resonance will occur. Given that the resonant frequency is 60 Hz.

A 0.70 H

B 70.3 mH

C 7.03×10^{-5} H

D 70.3 H

27th July Evening Shift 2021

Q.10 A 0.07 H inductor and a 12ΩΩ resistor are connected in series to a 220V, 50 Hz ac source. The approximate current in the circuit and the phase angle between current and source voltage are respectively.

[Take π as $\frac{22}{7}$]

A 8.8 A and $\tan^{-1}\left(\frac{11}{6}\right)$

B 88 A and $\tan^{-1}\left(\frac{11}{6}\right)$

C 0.88 A and $\tan^{-1}\left(\frac{11}{6}\right)$

D 8.8 A and $\tan^{-1}\left(\frac{11}{6}\right)$

27th July Morning Shift 2021

Q.11 A 10 Ω resistance is connected across 220V – 50 Hz AC supply. The time taken by the current to change from its maximum value to the rms value is:

A 2.5 ms

B 1.5 ms

C 3.0 ms

D 4.5 ms

25th July Evening Shift 2021

Q.12 Match List - I with List – II

	List - I		List - II
(a)	$\omega L > \frac{1}{\omega C}$	(i)	Current is in phase with emf
(b)	$\omega L = \frac{1}{\omega C}$	(ii)	Current lags behind the applied emf
(c)	$\omega L < \frac{1}{\omega C}$	(iii)	Maximum current occurs
(d)	Resonant frequency	(iv)	Current leads the emf

Choose the correct answer from the options given below

A a(ii), b(i), c(iv), d(iii)

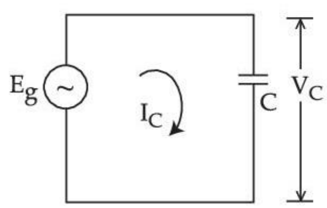
B a(ii), b(i), c(iii), d(iv)

C a(iii), b(i), c(iv), d(ii)

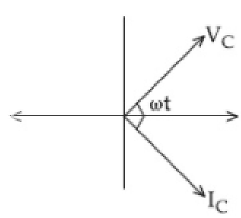
D a(iv), b(iii), c(ii), d(i)

22th July Evening Shift 2021

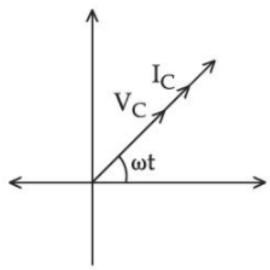
Q.13 In a circuit consisting of a capacitance and a generator with alternating emf $E_g = E_{g0}$ sinωt, V_C and I_C are the voltage and current. Correct phasor diagram for such circuit is



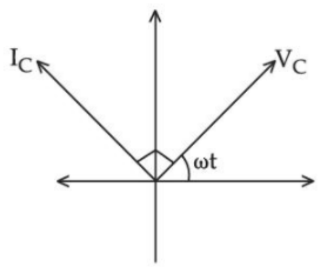
A



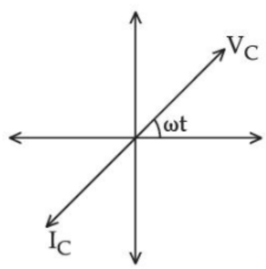
B



C



D



22th July Evening Shift 2021

Q.14 For a series LCR circuit with R = 100 Ω, L = 0.5 mH and C = 0.1 pF connected across 220V−50 Hz AC supply, the phase angle between current and supplied voltage and the nature of the circuit is :

A 0°, resistive circuit

B $\approx 90^\circ$, predominantly inductive circuit

C 0°, resonance circuit

D $\approx 90^\circ$, predominantly capacitive circuit

20th July Evening Shift 2021

Q.15 The time taken for the magnetic energy to reach 25% of its maximum value, when a solenoid of resistance R, inductance L is connected to a battery, is :

A infinite

B $\frac{L}{R}$ In10

C $\frac{L}{R}$ In2

D $\frac{L}{R}$ In5

18th Mar Evening Shift 2021

Q.16 In a series LCR circuit, the inductive reactance (X_L) is 10Ω and the capacitive reactance (X_C) is 4Ω. The resistance (R) in the circuit is 6Ω. The power factor of the circuit is :

A $\frac{1}{2}$

B $\frac{\sqrt{3}}{2}$

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

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

18th Mar Evening Shift 2021

Q.17 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 2.5 ms

B 25 ms

C 2.5 s

D 0.25 ms

18th Mar Morning Shift 2021

Q.18 In a series LCR resonance circuit, if we change the resistance only, from a lower to higher value:

(A) The bandwidth of resonance circuit will increase.

(B) The resonance frequency will increase.

(C) The quality factor will increase.

(D) The quality factor and the resonance frequency will remain constant.

18th Mar Morning Shift 2021

Q.19 What happens to the inductive reactance and the current in a purely inductive circuit if the frequency is halved?

(A) Both, inducting reactance and current will be doubled.

(B) Inductive reactance will be doubled and current will be halved.

(C) Both, inductive reactance and current will be halved.

(D) Inductive reactance will be halved and current will be doubled.

17th Mar Evening Shift 2021

Q.20 Match List - I with List – II

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

Choose the most appropriate answer from the options given below :

A. (a)-(ii), (b)-(iii), (c)-(i), (d)-(iv)

B. (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)

C. (a)-(ii), (b)-(iii), (c)-(iv), (d)-(i)

D. (a)-(ii), (b)-(iv), (c)-(iii), (d)-(i)

17th Mar Evening Shift 2021

Q.21 An AC current is given by I = I_1 sinωt + I_2 cosωt. A hot wire ammeter will give a reading:

A. $\frac{I_1+I_2}{\sqrt{2}}$

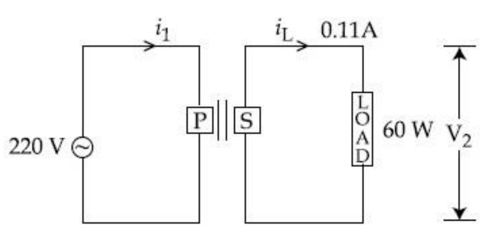
B. $\sqrt{\frac{I_1^2-I_2^2}{2}}$

C. $\sqrt{\frac{I_1^2+I_2^2}{2}}$

D. $\frac{I_1+I_2}{2\sqrt{2}}$

17th Mar Morning Shift 2021

Q.22 For the given circuit, comment on the type of transformer used.



A. Auxiliary transformer

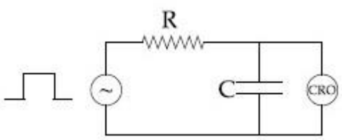
B. Step down transformer

C. Step-up transformer

D. Auto transformer

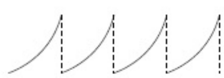
16th Mar Evening Shift 2021

Q.23 An RC circuit as shown in the figure is driven by a AC source generating a square wave. The output wave pattern monitored by CRO would look close to :



A. 

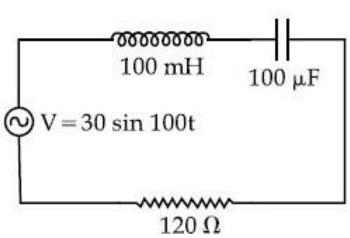
B. 

C. 

D. 

16th Mar Morning Shift 2021

Q.24 Find the peak current and resonant frequency of the following circuit (as shown in figure).



A. 2 A and 100 Hz

B. 2 A and 50 Hz

C. 0.2 A and 100 Hz

D. 0.2 A and 50 Hz

26th Feb Evening Shift 2021

Q.25 An alternating current is given by the equation i = i_1 sin ωt + i_2 cos ωt. The rms current will be:

A. $\frac{1}{\sqrt{2}}\left(i_1^2 + i_2^2\right)^{\frac{1}{2}}$

B. $\frac{1}{\sqrt{2}}(i_1 + i_2)$

C. $\frac{1}{\sqrt{2}}(i_1 + i_2)^2$

D. $\frac{1}{2}\left(i_1^2 + i_2^2\right)^{\frac{1}{2}}$

26th Feb Morning Shift 2021

Q.26 Match List I with List II.

	List I		List II
(a)	Rectifier	(i)	Used either for stepping up or stepping down the a.c. voltage
(b)	Stabilizer	(ii)	Used to convert a.c. voltage into d.c. voltage
(c)	Transformer	(iii)	Used to remove any ripple in the rectified output voltage
(d)	Filter	(iv)	Used for constant output voltage even when the input voltage or load current change

Choose the correct answer from the options given below:

A (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)

B (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)

C (a)-(ii), (b)-(i), (c)-(iv), (d)-(iii)

D (a)-(ii), (b)-(i), (c)-(iii), (d)-(iv)

25th Feb Evening Shift 2021

Q.27 An LCR circuit contains resistance of 110Ω and a supply of 220 V at 300 rad/s angular frequency. If only capacitance is removed from the circuit, current lags behind the voltage by 45°. If on the other hand, only inductor is removed the current leads by 45°° with the applied voltage. The rms current flowing in the circuit will be:

A 1 A

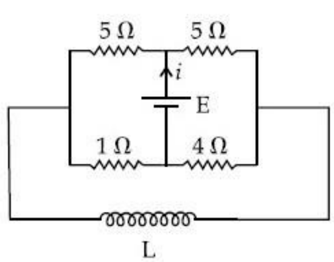
B 2.5 A

C 2 A

D 1.5 A

25th Feb Evening Shift 2021

Q.28 The current (i) at time t = 0 and t = ∞∞ respectively for the given circuit is :



A $\frac{18E}{55}, \frac{5E}{18}$

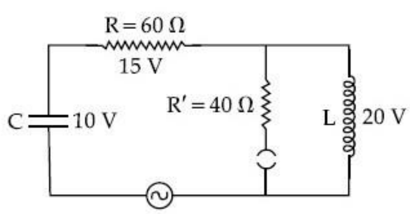
B $\frac{5E}{18}, \frac{18E}{55}$

C $\frac{5E}{18}, \frac{10E}{33}$

D $\frac{10E}{33}, \frac{5E}{18}$

25th Feb Morning Shift 2021

Q.29 The angular frequency of alternating current in a L-C-R circuit is 100 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 H and 150 μF

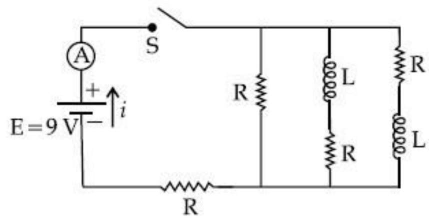
B 0.8 H and 250 μF

C 1.33 H and 150 μF

D 1.33 H and 250 μF

25th Feb Morning Shift 2021

Q.30 Figure shows a circuit that contains four identical resistors with resistance R = 2.0Ω, two identical inductors with inductance L = 2.0 mH and an ideal battery with emf E = 9V. The current 'i' just after the switch 'S' is closed will be :



A 3.0 A

B 3.37 A

C 9 A

D 2.25 A

24th Feb Evening Shift 2021

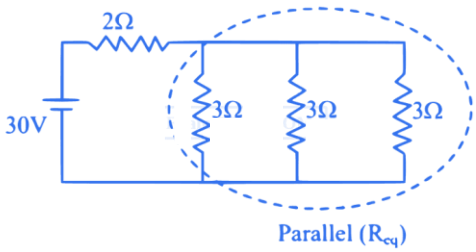
MCQ Answer Key

1. Ans. (c)
2. Ans. (d)
3. Ans. (c)
4. Ans. (a)
5. Ans. (c)
6. Ans. (b)
7. Ans. (a)
8. Ans. (d)
9. Ans. (d)
10. Ans. (a)
11. Ans. (a)
12. Ans. (a)
13. Ans. (c)
14. Ans. (d)
15. Ans. (c)
16. Ans. (c)
17. Ans. (a)
18. Ans. (a)
19. Ans. (d)
20. Ans. (a)
21. Ans. (c)
22. Ans. (c)
23. Ans. (d)
24. Ans. (d)
25. Ans. (a)
26. Ans. (a)
27. Ans. (c)
28. Ans. (c)
29. Ans. (b)
30. Ans. (d)

MCQ Explanation

Ans 1. We know in study state potential difference across inductor = 0

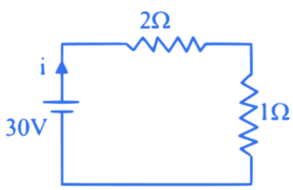
So, equivalent circuit becomes



$\frac{1}{R_{eq}} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = 1$

$\Rightarrow R_{eq} = 1\Omega$

⇒ Circuit becomes



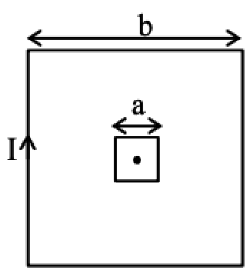
$\Rightarrow i = \frac{30}{3} = 10\,\text{A}$

Ans 2. To convert pulsating dc into steady dc both of mentioned method are correct.

Ans 3.

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

Ans 4.



$$B=\left[\frac{\mu_0}{4\pi}\frac{I}{b/2}\times 2\sin 45\right]\times 4$$

$$\phi=2\sqrt{2}\frac{\mu_0}{\pi}\frac{I}{b}\times a^2$$

$$\therefore M=\frac{\phi}{I}=\frac{2\sqrt{2}\mu_0 a^2}{\pi b}=\frac{\mu_0}{4\pi}8\sqrt{2}\frac{a^2}{b}$$

Ans 5.

$$V=\frac{\omega}{K}=\frac{10\times 10^{10}}{500}=2\times 10^8$$

$$V=\frac{2C}{3}.$$

Ans 6.

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

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

$$Z_C=\sqrt{(100)^2+(100)^2}$$

$$=100\sqrt{2}$$

$$Z_L=\sqrt{(\omega L)^2+R^2}$$

$$\sqrt{(100\times 0.5)^2+50^2}$$

$$=50\sqrt{2}$$

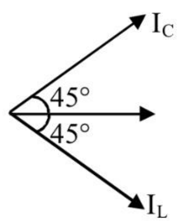
$$i_C=\frac{200}{Z_C}=\frac{200}{100\sqrt{2}}=\sqrt{2}$$

$i_C = \frac{200}{Z_C} = \frac{200}{100\sqrt{2}} = \sqrt{2}$

$i_L = \frac{200}{Z_L} = \frac{200}{50\sqrt{2}} = 2\sqrt{2}$

$\cos\phi_1 = \frac{100}{10\sqrt{2}} = \frac{1}{\sqrt{2}} \Rightarrow \phi_1 = 45^{\circ}$

$\cos\phi_2 = \frac{50}{50\sqrt{2}} = \frac{1}{\sqrt{2}} \Rightarrow \phi_2 = 45^{\circ}$



$I = \sqrt{I_C^2 + I_L^2}$

$= \sqrt{2+8}$

$= \sqrt{10}$

I = 3.16 A

Ans 7. From maximum average power

$X_L = X_C$

$250\pi = \frac{1}{2\pi(50)C}$

$\Rightarrow C = 4 \times 10^{-6}$

Ans 8.

$U = \frac{1}{2}Li^2 = 64 \Rightarrow L = 2$

$i^2R = 640$

$$R = \frac{640}{(8)^2} = 10$$

$$\tau = \frac{L}{R} = \frac{1}{5} = 0.2$$

Ans 9.

C = 0.1 μF = 10^{-7} F

Resonant frequency = 60 Hz.

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

$$2\pi f_0 = \frac{1}{\sqrt{LC}} \Rightarrow L = \frac{1}{4\pi^2 f_0^2 C}$$

by putting values L≃70.3 Hz

Ans 10.

$$\phi = \tan^{-1}\left(\frac{X_L}{R}\right)$$

$$X_L = \omega L$$

$$X_L = 2 \times \frac{22}{7} \times 50 \times 0.07 = 22\Omega$$

$$\phi = \tan^{-1}\left(\frac{22}{12}\right)$$

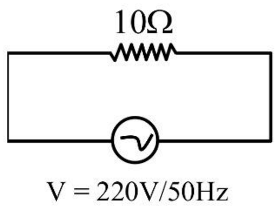
$$R = 12\Omega$$

$$\phi = \tan^{-1}\left(\frac{11}{6}\right)$$

$$Z = \sqrt{X_L^2 + R^2} = 25.059$$

$$I = \frac{V}{Z} = \frac{220}{25.059} = 8.77A$$

Ans 11.



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

when i = i_0

$i_0 = i_0 \sin\omega t_1 \Rightarrow \omega t_1 = \frac{\pi}{2}$ ..... (i)

When i = $\frac{i_1}{\sqrt{2}}$

$\frac{i_1}{\sqrt{2}} = i_0 \sin\omega t_2 \Rightarrow \omega t_2 = \frac{\pi}{4}$ ...... (ii)

Time taken by current from maximum value to rms value

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

$= \frac{1}{8\times 50}$

$\frac{1}{400}$ sec

= 2.5 ms

Ans 12.

$\omega L = \frac{1}{\omega C}, X_L = X_C$

So current in phase with EMF

At resonance, current have maximum value.

Ans 13. In capacitor, current lead voltage by $\frac{\pi}{2}$

Ans 14.

R = 100Ω

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

$$X_C = \frac{1}{\omega C} = \frac{10^{11}}{100\pi}$$

$$X_C >> X_L$$

& $|X_C - X_L| >> R$

Ans 15.

Magnetic energy, U = $\frac{1}{2}LI_0^2$

Given: U = 25% of U_0.

$$\Rightarrow \frac{1}{2}LI^2 = \frac{1}{4} \times \frac{1}{2}LI_0^2$$

$$\Rightarrow I^2 = \frac{I_0^2}{4} \Rightarrow I = \frac{I_0}{2}$$

$$\therefore I = I_0(1 - e^{-t/\tau})$$

$$\Rightarrow \frac{I_0}{2} = I_0(1 - e^{-t/\tau})$$

$$\Rightarrow \frac{1}{2} = e^{-t/\tau}$$

$$\Rightarrow e^{t/\tau} = 2$$

$$\Rightarrow t = \tau \ln 2$$

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

Ans 16. Given:

$X_L = 10\Omega$

$X_C = 4\Omega$

$R = 6\Omega$

$\therefore$ Power factor = $\cos\theta = \frac{R}{Z}$

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

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

$$= \frac{6}{6\sqrt{2}} = \frac{1}{\sqrt{2}}$$

Ans 17.

$$I = I_0 \sin \omega t$$

$$\Rightarrow \frac{I_M}{\sqrt{2}} = I_M \sin \omega t$$

$$\Rightarrow \omega t = \frac{\pi}{4}$$

$$\Rightarrow t = \frac{\pi}{4\omega} = \frac{\pi}{4(2\pi f)}$$

$\Rightarrow$ t = $\frac{1}{8\times 30} = \frac{1}{400}$ = 25 ms

Ans 18.

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

$\Rightarrow 2\pi f = \frac{1}{\sqrt{LC}}$

$\Rightarrow f = \frac{1}{2\pi\sqrt{LC}}$

f does not depends on resistance(R).

Quality factor, $Q = \frac{\omega L}{R}$

$\Rightarrow Q \propto \frac{1}{R}$

So if R increase then Q will decrease.

Also, $Q = \frac{\omega L}{R} = \frac{\omega}{\Delta\beta}$

where $\Delta\beta$ = bandwidth

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

So if R increase then $\Delta\beta$ will increase too.

Ans 19.

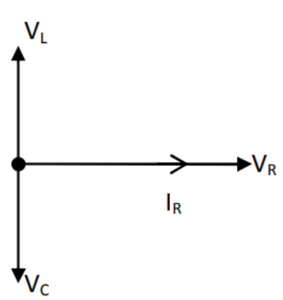
$X_L = \omega L$

$X_L' = \left(\frac{X_L}{2}\right)$

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

& $I' = \frac{2V}{X_L} = 2I$

Ans 20.



(a) phase difference b/w current & voltage in a purely resistive AC circuit is zero

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

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

(d) phase difference b/w current & voltage in an LCR series circuit is

$= \tan^{-1}\left(\frac{X_C - X_L}{R}\right)$

Ans 21.

$$I_{RMS} = \sqrt{\frac{\int I^2 dt}{\int dt}}$$

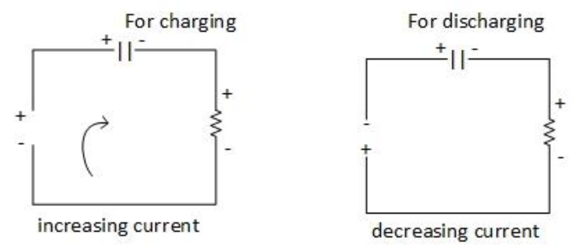
$$I_{RMS}^2 = \int_0^T \frac{(I_1 \sin \omega t + I_2 \cos \omega t)^2 dt}{T}$$

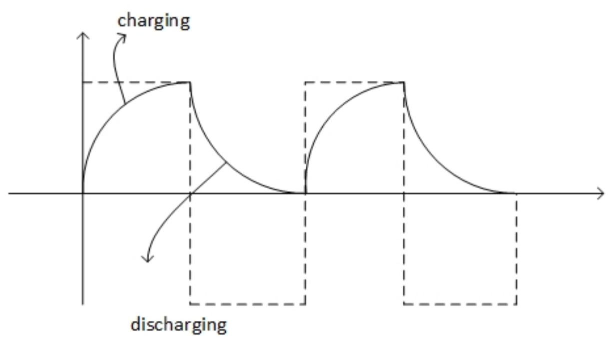
$$= \frac{1}{T}\int_0^T (I_1^2 \sin^2 \omega t + I_2^2 \cos^2 \omega t + 2 I_1 I_2 \sin \omega t \cos \omega t) dt$$

$$= \frac{I_1^2}{2} + \frac{I_2^2}{2} + 0$$

$$I_{RMS} = \sqrt{\frac{I_1^2 + I_2^2}{2}}$$

Ans 23. Assuming AC start with positive voltage, when +ve voltage is across input then the capacitor start charging, trying to reach saturation value, till there is +ve voltage across input, when −ve voltage of AC appears across input, the capacitor starts discharging till there is −ve voltage across input and this process of charging and discharging keeps on going alternatively.





Ans 24.

We know, z = $\sqrt{(x_L - x_C)^2 + R^2}$

$$x_L = \omega_L = 100 \times 100 \times 10^{-3} = 10\Omega$$

$$x_C = \frac{1}{\omega_C} = \frac{1}{100 \times 100 \times 10^{-6}} = 10\Omega$$

$$\therefore z = \sqrt{(10 - 100)^2 + R^2} = \sqrt{90^2 + 120^2}$$

$$= 30 \times 5 = 150\Omega$$

$$i_{peak} = \frac{\Delta v}{z} = \frac{30}{150} = \frac{1}{5} amp = 0.2 \text{ amp}$$

For resonant frequency,

$\omega L = \frac{1}{\omega C} \Rightarrow \omega^2 = \frac{1}{LC} \Rightarrow \omega = \frac{1}{\sqrt{LC}}$

& $f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\pi\sqrt{100\times10^{-3}\times100\times10^{-6}}}$

$= \frac{100\sqrt{10}}{2\pi} = \frac{100\pi}{2\pi} = 50$ Hz

as $\sqrt{10} \approx \pi$

Ans 25.

$$I_0 = \sqrt{I_1^2 + I_2^2 + 2I_1I_2\cos\theta}$$

$$I_0 = \sqrt{I_1^2 + I_2^2 + 2I_1I_2\cos 90^\circ}$$

$$I_0 = \sqrt{I_1^2 + I_2^2 + 2I_1I_2(0)} = \sqrt{I_1^2 + I_2^2}$$

We know that,

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

So, $I_{rms} = \frac{\sqrt{I_1^2+I_2^2}}{\sqrt{2}}$

Ans 26.

(a) Rectifier: used to convert a a.c. voltage into d.c. voltage.

(b) Stabilizer: used for constant output voltage even when the input voltage or load current change

(c) Transformer: used either for stepping up or stepping down the a.c. voltage.

(d) Filter: used to remove any ripple in the rectified output voltage.

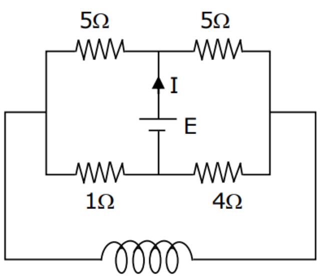
Ans 27. Since ϕ remain same, circuit is in resonance

$\therefore I_{rms} = \frac{v_{rms}}{z} = \frac{v_{rms}}{R}$

$= \frac{220}{110}$

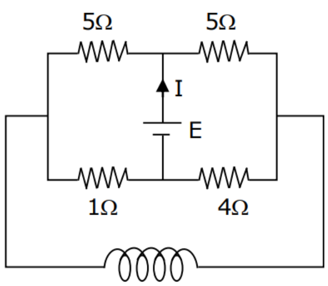
$\Rightarrow I_{rms} = 2A$

Ans 28.



at t = 0, inductor is removed, so circuit will look like this

at t = 0

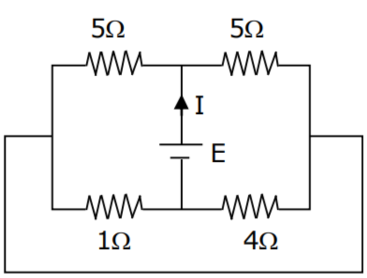


$R_{eq} = \frac{6 \times 9}{6+9} = \frac{54}{15}$

$I(t = 0) = \frac{E \times 15}{54} = \frac{5E}{18}$

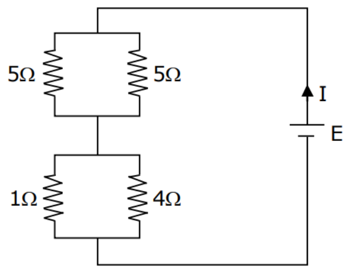
at t = ∞, inductor is replaced by plane wire, so circuit will look like this

at t = ∞,



$$I(t=\infty)=\frac{E}{\frac{5}{2}+\frac{4}{5}}=\frac{10E}{33}$$

Now,

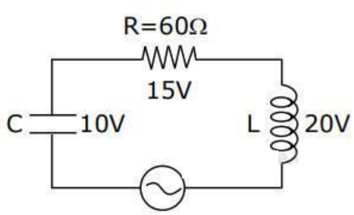


$$R_{eq}=\frac{1\times4}{1+4}+\frac{5\times5}{5+5}$$

$$=\frac{4}{5}+\frac{5}{2}=\frac{8+25}{10}=\frac{33}{10}$$

$$I=\frac{E}{R_{eq}}=\frac{10E}{33}$$

Ans 29.



Since key is open, circuit is series

$15 = i_{rms}$ (60)

$\therefore i_{rms} = \frac{1}{4}$A

Now, $20 = \frac{1}{4} X_L = \frac{1}{4}(\omega L)$

$\therefore L = \frac{4}{5} = 0.8$ H

and $10 = \frac{1}{4}\frac{1}{(100C)}$

$C = \frac{1}{4000}$F $= 250\mu$F

Ans 30. Given, resistance, $R = 2\Omega$,

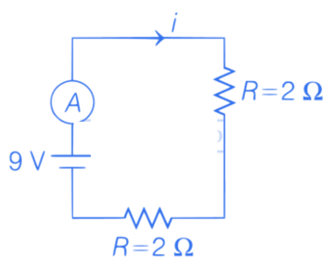
Inductance, $L = 2$ mH,

emf, $E = 9$ V

and i be the current.

$\because$ At $t = 0$ when switch is closed, inductors behave as open circuit.

$\therefore$ Effective circuit will be



By using Ohm's law, $V = i R_{eq}$

$\Rightarrow i = V/R_{eq}$

where, R_{eq} is equivalent resistance of series resistors,

i.e., $R_{eq} = R + R = 2R = 2 \times 2 = 4\ \Omega$

$\therefore i = \frac{9}{4} = 2.25\text{A}$

TOPIC 1 Alternating Current, Voltage and Power

1. An alternating voltage $v(t) = 220 \sin 100$Àt volt is applied to a purely resistive load of 50Ω. The time taken for the current to rise from half of the peak value to the peak value is : **[8 April 2019 I]**

(a) 5 ms (b) 2.2 ms (c) 7.2 ms (d) 3.3 ms

2. A small circular loop of wire of radius a is located at the centre of a much larger circular wire loop of radius b. The two loops are in the same plane. The outer loop of radius b carries an alternating current $I = I_o \cos(\omega t)$. The emf induced in the smaller inner loop is nearly : **[Online April 8, 2017]**

(a) $\frac{\pi\mu_0 I_o}{2} \cdot \frac{a^2}{b} \omega \sin(\omega t)$ (b) $\frac{\pi\mu_0 I_o}{2} \cdot \frac{a^2}{b} \omega \cos(\omega t)$

(c) $\pi\mu_0 I_o \frac{a^2}{b} \omega \sin(\omega t)$ (d) $\frac{\pi\mu_0 I_o b^2}{a} \omega \cos(\omega t)$

3. A sinusoidal voltage $V(t) = 100 \sin(500t)$ is applied across a pure inductance of $L = 0.02$ H. The current through the coil is: **[Online April 12, 2014]**

(a) $10 \cos(500\,t)$ (b) $-10 \cos(500t)$

(c) $10 \sin(500t)$ (d) $-10 \sin(500t)$

4. In an a.c. circuit the voltage applied is $E = E_0 \sin \omega t$. The resulting current in the circuit is $I = I_0 \sin\left(\omega t - \frac{\pi}{2}\right)$. The power consumption in the circuit is given by **[2007]**

(a) $P = \sqrt{2} E_0 I_0$ (b) $P = \frac{E_0 I_0}{\sqrt{2}}$

(c) $P = \text{zero}$ (d) $P = \frac{E_0 I_0}{2}$

5. In a uniform magnetic field of induction B a wire in the form of a semicircle of radius r rotates about the diameter of the circle with an angular frequency ω. The axis of rotation is perpendicular to the field. If the total resistance of the circuit is R, the mean power generated per period of rotation is **[2004]**

(a) $\frac{(B\pi r\omega)^2}{2R}$ (b) $\frac{(B\pi r^2\omega)^2}{8R}$

(c) $\frac{B\pi r^2\omega}{2R}$ (d) $\frac{(B\pi r\omega^2)^2}{8R}$

6. Alternating current can not be measured by D.C. ammeter because **[2004]**

(a) Average value of current for complete cycle is zero

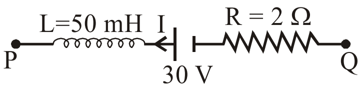
(b) A.C. Changes direction

(c) A.C. can not pass through D.C. Ammeter

(d) D.C. Ammeter will get damaged.

TOPIC 2 AC Circuit, LCR Circuit, Quality and Power Factor

7. A part of a complete circuit is shown in the figure. At some instant, the value of current I is 1 A and it is decreasing at a rate of $10^2 A\, s^{-1}$. The value of the potential difference $V_P - V_Q$, (in volts) at that instant, is ______. **[NA Sep. 06, 2020 (I)]**



8. An AC circuit has $R = 100\ \Omega$, $C = 2\ \mu F$ and $L = 80$ mH, connected in series. The quality factor of the circuit is : **[Sep. 06, 2020 (I)]**

(a) 2 (b) 0.5

(c) 20 (d) 400

9. In a series LR circuit, power of 400 W is dissipated from a source of 250 V, 50 Hz. The power factor of the circuit is 0.8. In order to bring the power factor to unity, a capacitor of value C is added in series to the L and R. Taking the value C as $\left(\frac{n}{3\pi}\right)\mu F$, then value of n is ______. **[NA Sep. 06, 2020 (II)]**

10. A series L-R circuit is connected to a battery of emf V. If the circuit is switched on at $t = 0$, then the time at which the energy stored in the inductor reaches $\left(\frac{1}{n}\right)$ times of its maximum value, is : **[Sep. 04, 2020 (II)]**

(a) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$ (b) $\frac{L}{R}\ln\left(\frac{\sqrt{n}+1}{\sqrt{n}-1}\right)$

(c) $\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}+1}\right)$ (d) $\frac{L}{R}\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$

11. A 750 Hz, 20 V (rms) source is connected to a resistance of 100 Ω, an inductance of 0.1803 H and a capacitance of 10 μF all in series. The time in which the resistance (heat capacity 2 J/°C) will get heated by 10°C. (assume no loss of heat to the surroundings) is close to : **[Sep. 03, 2020 (I)]**

(a) 418 s (b) 245 s

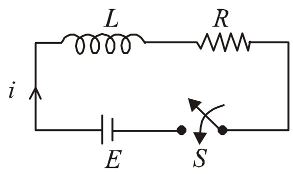
(c) 365 s (d) 348 s

12. An inductance coil has a reactance of 100 Ω. When an AC signal of frequency 1000 Hz is applied to the coil, the applied voltage leads the current by 45°. The self-inductance of the coil is : **[Sep. 02, 2020 (II)]**

(a) 1.1×10^{-2} H (b) 1.1×10^{-1} H

(c) 5.5×10^{-5} H (d) 6.7×10^{-7} H

13. Consider the LR circuit shown in the figure. If the switch S is closed at t = 0 then the amount of charge that passes through the battery between t = 0 and $t = \frac{L}{R}$ is : **[12 April 2019 II]**



(a) $\frac{2.7EL}{R^2}$ (b) $\frac{EL}{2.7R^2}$

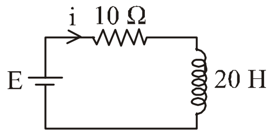
(c) $\frac{7.3EL}{R^2}$ (d) $\frac{EL}{7.3R^2}$

14. A coil of self inductance 10 mH and resistance 0.1 Ω is connected through a switch to a battery of internal resistance 0.9 Ω. After the switch is closed, the time taken for the current to attain 80% of the saturation value is [take ln 5 = 1.6] **[10 April 2019 II]**

(a) 0.324 s (b) 0.103 s

(c) 0.002 s (d) 0.016 s

15. A 20 Henry inductor coil is connected to a 10 ohm resistance in series as shown in figure. The time at which rate of dissipation of energy (Joule's heat) across resistance is equal to the rate at which magnetic energy is stored in the inductor, is : **[8 April 2019 I]**



(a) $\frac{2}{ln\, 2}$ (b) $\frac{1}{2} ln\, 2$

(c) $2\, ln\, 2$ (d) $ln\, 2$

16. A circuit connected to an *ac* source of *emf* $e = e_0 \sin(100t)$ with *t* in seconds, gives a phase difference of $\frac{\pi}{4}$ between the *emf e* and current *i*. Which of the following circuits will exhibit this ? **[8 April 2019 II]**

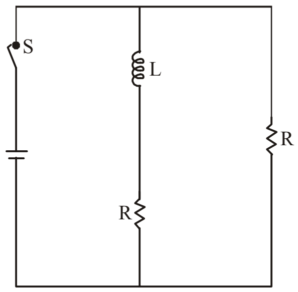
(a) RL circuit with R = 1 kΩ and L = 10 mH

(b) RL circuit with R = 1 kΩ and L = 1 mH

(d) RC circuit with R = 1 kΩ and C = 1 μF

(d) RC circuit with R = 1 kΩ and C = 10 μF.

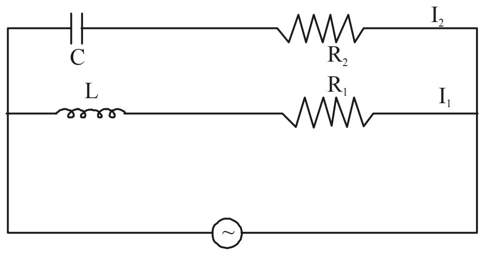
17. In the figure shown, a circuit contains two identical resistors with resistance R = 5 Ω and an inductance with L = 2 mH. An ideal battery of 15 V is connected in the circuit. What will be the current through the battery long after the switch is closed? **[12 Jan. 2019 I]**



(a) 5.5 A (b) 7.5 A

(c) 3 A (d) 6 A

18.

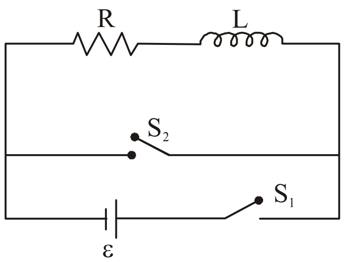


In the above circuit, $C = \frac{\sqrt{3}}{2}$ μF, $R_2 = 20\,\Omega$, $L = \frac{\sqrt{3}}{10}$ H and $R_1 = 10\,\Omega$. Current in L-R_1 path is I_1 and in C-R_2 path it is I_2. The voltage of A.C source is given by, $V = 200\sqrt{2}$ sin (100 t) volts. The phase difference between I_1 and I_2 is : **[12 Jan. 2019 II]**

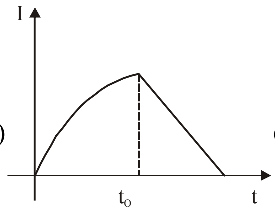
(a) 60° (b) 30°

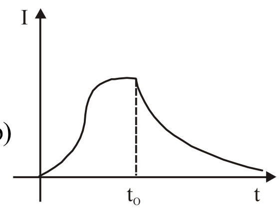
(c) 90° (d) 0

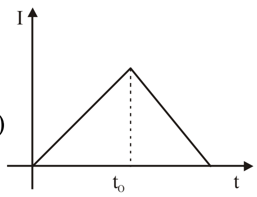
19. In the circuit shown,

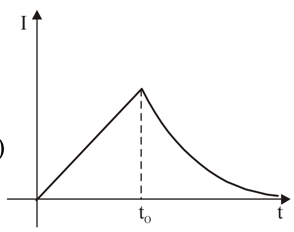


the switch S_1 is closed at time t = 0 and the switch S_2 is kept open. At some later time (t_0), the switch S_1 is opened and S_2 is closed. the behaviour of the current I as a function of time 't' is given by: **[11 Jan. 2019 II]**

(a)


(b)


(c)


(d)


20. A series AC circuit containing an inductor (20 mH), a capacitor (120 μF) and a resistor (60 Ω) is driven by an AC source of 24 V/50 Hz. The energy dissipated in the circuit in 60 s is: **[9 Jan. 2019 I]**

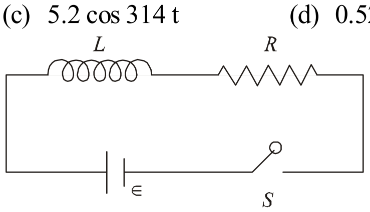
(a) 5.65×10^2 J (b) 2.26×10^3 J

(c) 5.17×10^2 J (d) 3.39×10^3 J

21. In LC circuit the inductance L = 40 mH and capacitance C = 100 μF. If a voltage $V(t) = 10 \sin(314\,t)$ is applied to the circuit, the current in the circuit is given as: **[9 Jan. 2019 II]**

(a) 0.52 cos 314 t (b) 10 cos 314 t

(c) 5.2 cos 314 t (d) 0.52 sin 314 t

22.


As shown in the figure, a battery of emf ∈ is connected to an inductor L and resistance R in series. The switch is closed at $t = 0$. The total charge that flows from the battery, between $t = 0$ and $t = t_c$ (t_c is the time constant of the circuit) is: **[8 Jan. 2020 II]**

(a) $\frac{\in R}{eL^2}$ (b) $\frac{\in L}{R^2}\left(1-\frac{1}{e}\right)$

(c) $\frac{\in L}{R^2}$ (d) $\frac{\in R}{eL^2}$

23. A LCR circuit behaves like a damped harmonic oscillator. Comparing it with a physical spring-mass damped oscillator having damping constant 'b', the correct equivalence would be: **[7 Jan. 2020 I]**

(a) $L \leftrightarrow m, C \leftrightarrow k, R \leftrightarrow b$

(b) $L \leftrightarrow \frac{1}{b}, C \leftrightarrow \frac{1}{m}, R \leftrightarrow \frac{1}{k}$

(c) $L \leftrightarrow k, C \leftrightarrow b, R \leftrightarrow m$

(d) $L \leftrightarrow m, C \leftrightarrow \frac{1}{k}, R \leftrightarrow b$

24. An emf of 20 V is applied at time $t = 0$ to a circuit containing in series 10 mH inductor and 5 Ω resistor. The ratio of the currents at time $t = \infty$ and at $t = 40$ s is close to:

(Take $e^2 = 7.389$) **[7 Jan. 2020 II]**

(a) 1.06 (b) 1.15

(c) 1.46 (d) 0.84

25. In an a.c. circuit, the instantaneous e.m.f. and current are given by

$e = 100 \sin 30\,t$

$i = 20 \sin\left(30\text{t} - \frac{\pi}{4}\right)$

In one cycle of a.c., the average power consumed by the circuit and the wattless current are, respectively: **[2018]**

(a) 50W, 10A (b) $\frac{1000}{\sqrt{2}}$ W, 10A

(c) $\frac{50}{\sqrt{2}}$ W, 0 (d) 50W, 0

26. For an RLC circuit driven with voltage of amplitude v_m and frequency $\omega_0 = \frac{1}{\sqrt{LC}}$ the current exhibits resonance. The quality factor, Q is given by: **[2018]**

(a) $\frac{\omega_0 L}{R}$ (b) $\frac{\omega_0 R}{L}$ (c) $\frac{R}{(\omega_0 C)}$ (d) $\frac{CR}{\omega_0}$

27. A sinusoidal voltage of peak value 283 V and angular frequency 320/s is applied to a series LCR circuit. Given that R = 5 Ω, L = 25 mH and C = 1000 μF. The total impedance, and phase difference between the voltage across the source and the current will respectively be : **[Online April 9, 2017]**

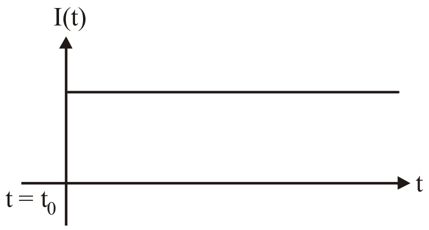
(a) 10 Ω and $\tan^{-1}\left(\frac{5}{3}\right)$ (b) 7 Ω and 45°

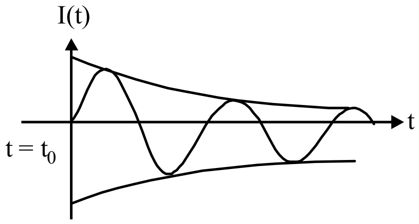
(c) 10 Ω and $\tan^{-1}\left(\frac{8}{3}\right)$ (d) 7 Ω and $\tan^{-1}\left(\frac{5}{3}\right)$

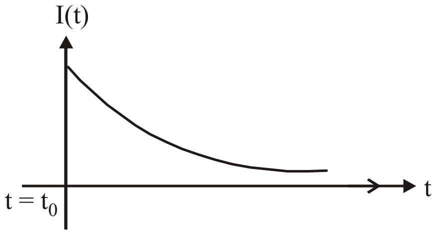
28. An arc lamp requires a direct current of 10 A at 80 V to function. If it is connected to a 220 V (rms), 50 Hz AC supply, the series inductor needed for it to work is close to : **[2016]**

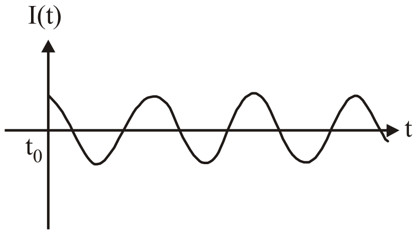
(a) 0.044 H (b) 0.065 H
(c) 80 H (d) 0.08 H

29. A series LR circuit is connected to a voltage source with $V(t) = V_0 \sin\omega t$. After very large time, current $I(t)$ behaves as $\left(t_0 >> \frac{L}{R}\right)$: **[Online April 9, 2016]**

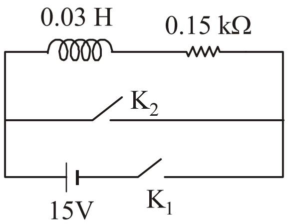
(a)


(b)


(c)


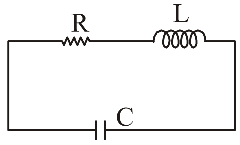
(d)


30. An inductor (L = 0.03 H) and a resistor (R = 0.15 kΩ) are connected in series to a battery of 15V emf in a circuit shown below. The key K_1 has been kept closed for a long time. Then at t = 0, K_1 is opened and key K_2 is closed simultaneously. At t = 1 ms, the current in the circuit will be : $(e^5 \cong 150)$ **[2015]**

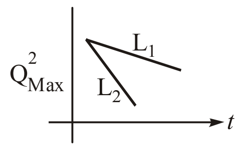


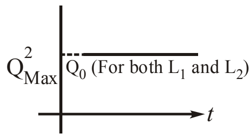
(a) 6.7 mA (b) 0.67 mA
(c) 100 mA (d) 67 mA

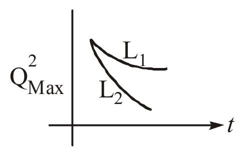
31. An LCR circuit is equivalent to a damped pendulum. In an LCR circuit the capacitor is charged to Q_0 and then connected to the L and R as shown below :

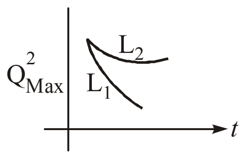


If a student plots graphs of the square of maximum charge $\left(Q^2_{Max}\right)$ on the capacitor with time(t) for two different values L_1 and L_2 $(L_1 > L_2)$ of L then which of the following represents this graph correctly ? (*plots are schematic and not drawn to scale*) **[2015]**

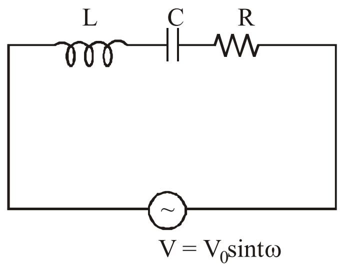
(a)


(b)


(c)


(d)


32. For the LCR circuit, shown here, the current is observed to lead the applied voltage. An additional capacitor C', when joined with the capacitor C present in the circuit, makes the power factor of the circuit unity. The capacitor C', must have been connected in : **[Online April 11, 2015]**



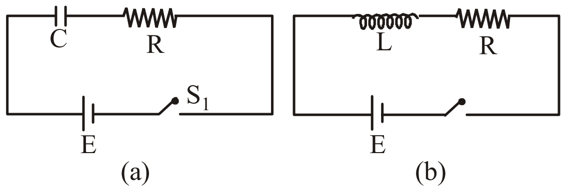
(a) series with C and has a magnitude $\frac{C}{(\omega^2 LC - 1)}$

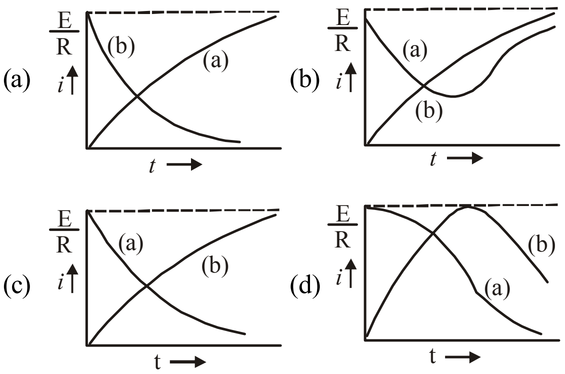
(b) series with C and has a magnitude $\frac{1-\omega^2 LC}{\omega^2 L}$

(c) parallel with C and has a magnitude $\frac{1-\omega^2 LC}{\omega^2 L}$

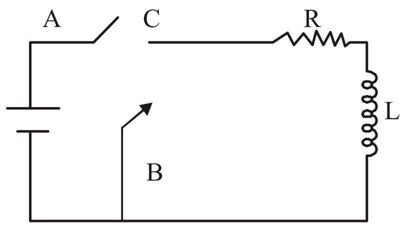
(d) parallel with C and has a magnitude $\frac{C}{(\omega^2 LC - 1)}$

33. In the circuits (a) and (b) switches S_1 and S_2 are closed at $t = 0$ and are kept closed for a long time. The variation of current in the two circuits for $t \geq 0$ are roughly shown by figure (figures are schematic and not drawn to scale) : **[Online April 10, 2015]**





34. In the circuit shown here, the point 'C' is kept connected to point 'A' till the current flowing through the circuit becomes constant. Afterward, suddenly, point 'C' is disconnected from point 'A' and connected to point 'B' at time t = 0. Ratio of the voltage across resistance and the inductor at t = L/R will be equal to: **[2014]**

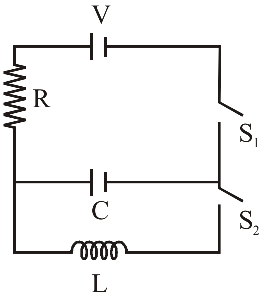


(a) $\frac{e}{1-e}$ (b) 1 (c) –1 (d) $\frac{1-e}{e}$

35. When the rms voltages V_L, V_C and V_R are measured respectively across the inductor L, the capacitor C and the resistor R in a series LCR circuit connected to an AC source, it is found that the ratio $V_L : V_C : V_R = 1 : 2 : 3$. If the rms voltage of the AC sources is 100 V, the V_R is close to: **[Online April 9, 2014]**

(a) 50 V (b) 70 V (c) 90 V (d) 100 V

36. In an LCR circuit as shown below both switches are open initially. Now switch S_1 is closed, S_2 kept open. (q is charge on the capacitor and $\tau = RC$ is Capacitive time constant). Which of the following statement is correct ? **[2013]**



(a) Work done by the battery is half of the energy dissipated in the resistor
(b) At, $t = \tau$, $q = CV/2$
(c) At, $t = 2\tau$, $q = CV(1 - e^{-2})$
(d) At, $t = 2\tau$, $q = CV(1 - e^{-1})$

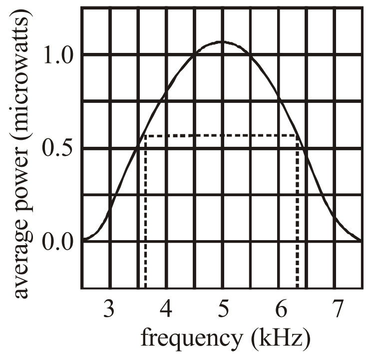
37. A series LR circuit is connected to an ac source of frequency ω and the inductive reactance is equal to 2R. A capacitance of capacitive reactance equal to R is added in series with L and R. The ratio of the new power factor to the old one is : **[Online April 25, 2013]**

(a) $\sqrt{\frac{2}{3}}$ (b) $\sqrt{\frac{2}{5}}$ (c) $\sqrt{\frac{3}{2}}$ (d) $\sqrt{\frac{5}{2}}$

38. When resonance is produced in a series LCR circuit, then which of the following is not correct ? **[Online April 25, 2013]**

(a) Current in the circuit is in phase with the applied voltage.
(b) Inductive and capacitive reactances are equal.
(c) If R is reduced, the voltage across capacitor will increase.
(d) Impedance of the circuit is maximum.

39. The plot given below is of the average power delivered to an LRC circuit versus frequency. The quality factor of the circuit is : **[Online April 23, 2013]**

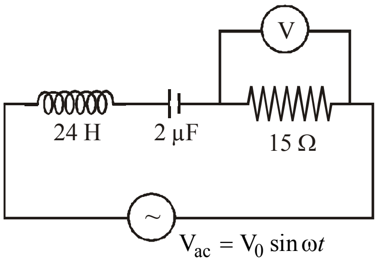


(a) 5.0 (b) 2.0 (c) 2.5 (d) 0.4

40. In a series L-C-R circuit, $C = 10^{-11}$ Farad, $L = 10^{-5}$ Henry and $R = 100$ Ohm, when a constant D.C. voltage E is applied to the circuit, the capacitor acquires a charge 10^{-9} C. The D.C. source is replaced by a sinusoidal voltage source in which the peak voltage E_0 is equal to the constant D.C. voltage E. At resonance the peak value of the charge acquired by the capacitor will be : **[Online April 22, 2013]**

(a) 10^{-15} C (b) 10^{-6}C (c) 10^{-10}C (d) 10^{-8} C

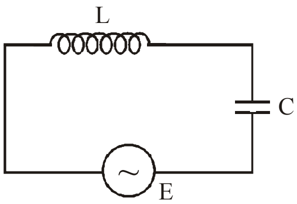
41. An LCR circuit as shown in the figure is connected to a voltage source V_{ac} whose frequency can be varied.



The frequency, at which the voltage across the resistor is maximum, is : **[Online April 22, 2013]**

(a) 902 Hz (b) 143 Hz (c) 23 Hz (d) 345 Hz

42. In the circuit shown here, the voltage across E and C are respectively 300 V and 400 V. The voltage E of the ac source is : **[Online April 9, 2013]**



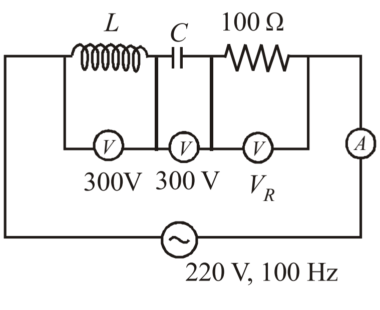
(a) 400 Volt (b) 500 Volt (c) 100 Volt (d) 700 Volt

43. A resistance R and a capacitance C are connected in series to a battery of negligible internal resistance through a key. The key is closed at $t = 0$. If after t sec the voltage across the capacitance was seven times the voltage across R, the value of t is **[Online May 12, 2012]**

(a) $3RC\,\ell n\,2$ (b) $2\,RC\,\ell n\,2$

(c) $2\,RC\,\ell n\,7$ (d) $3\,RC\,\ell n\,7$

44. In an LCR circuit shown in the following figure, what will be the readings of the voltmeter across the resistor and ammeter if an $a.c.$ source of 220V and 100 Hz is connected to it as shown? **[Online May 7, 2012]**



(a) 800 V, 8 A (b) 110 V, 1.1 A

(c) 300 V, 3 A (d) 220V, 2.2 A

45. A fully charged capacitor C with initial charge q_0 is connected to a coil of self inductance L at $t = 0$. The time at which the energy is stored equally between the electric and the magnetic fields is: **[2011]**

(a) $\frac{\pi}{4}\sqrt{LC}$ (b) $2\pi\sqrt{LC}$

(c) $\sqrt{LC}$ (d) $\pi\sqrt{LC}$

46. A resistor 'R' and 2μF capacitor in series is connected through a switch to 200 V direct supply. Across the capacitor is a neon bulb that lights up at 120 V. Calculate the value of R to make the bulb light up 5 s after the switch has been closed. ($\log_{10} 2.5 = 0.4$) **[2011]**

(a) $1.7 \times 10^5\,\Omega$ (b) $2.7 \times 10^6\,\Omega$

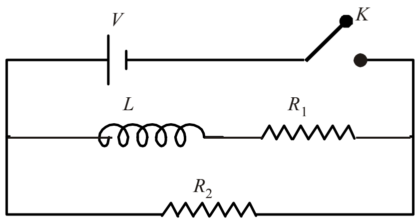
(c) $3.3 \times 10^7\,\Omega$ (d) $1.3 \times 10^4\,\Omega$

47. Combination of two identical capacitors, *a* resistor R and *a dc* voltage source of voltage 6V is used in an experiment on a (C-R) circuit. It is found that for a parallel combination of the capacitor the time in which the voltage of the fully charged combination reduces to half its original voltage is 10 second. For series combination the time for needed for reducing the voltage of the fully charged series combination by half is **[2011 RS]**

(a) 10 second (b) 5 second

(c) 2.5 second (d) 20 second

48. In the circuit shown below, the key K is closed at $t = 0$. The current through the battery is **[2010]**



(a) $\frac{VR_1R_2}{\sqrt{R_1^2 + R_2^2}}$ at $t = 0$ and $\frac{V}{R_2}$ at $t = \infty$

(b) $\frac{V}{R_2}$ at $t = 0$ and $\frac{V(R_1 + R_2)}{R_1R_2}$ at $t = \infty$

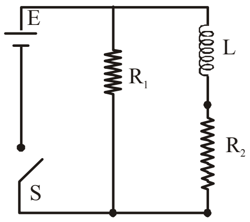
(c) $\frac{V}{R_2}$ at $t = 0$ and $\frac{VR_1R_2}{\sqrt{R_1^2 + R_2^2}}$ at $t = \infty$

(d) $\frac{V(R_1 + R_2)}{R_1R_2}$ at $t = 0$ and $\frac{V}{R_2}$ at $t = \infty$

49. In a series LCR circuit $R = 200\Omega$ and the voltage and the frequency of the main supply is 220V and 50 Hz respectively. On taking out the capacitance from the circuit the current lags behind the voltage by 30°. On taking out the inductor from the circuit the current leads the voltage by 30°. The power dissipated in the LCR circuit is **[2010]**

(a) 305 W (b) 210 W (c) Zero W (d) 242 W

50.



An inductor of inductance L = 400 mH and resistors of resistance $R_1 = 2\Omega$ and $R_2 = 2\Omega$ are connected to a battery of emf 12 V as shown in the figure. The internal resistance of the battery is negligible. The switch S is closed at $t = 0$. The potential drop across L as a function of time is **[2009]**

(a) $\frac{12}{t}e^{-3t}$ V (b) $6\left(1-e^{-t/0.2}\right)$ V

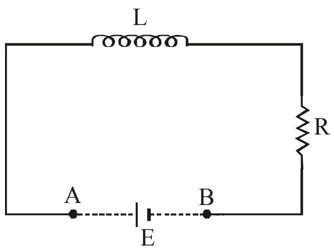
(c) $12e^{-5t}$ V (d) $6e^{-5t}$ V

51. In a series resonant LCR circuit, the voltage across R is 100 volts and R = 1 kΩ with C = 2μF. The resonant frequency ω is 200 rad/s. At resonance the voltage across L is **[2006]**

(a) 2.5×10^{-2} V (b) 40 V

(c) 250 V (d) 4×10^{-3} V

52. An inductor (L = 100 mH), a resistor (R = 100 Ω) and a battery (E = 100 V) are initially connected in series as shown in the figure. After a long time the battery is disconnected after short circuiting the points A and B. The current in the circuit 1 ms after the short circuit is **[2006]**



(a) 1/eA (b) eA (c) 0.1 A (d) 1 A

53. In an AC generator, a coil with N turns, all of the same area A and total resistance R, rotates with frequency ω in a magnetic field B. The maximum value of emf generated in the coil is **[2006]**

(a) N.A.B.R.ω (b) N.A.B

(c) N.A.B.R. (d) N.A.B.ω

54. The phase difference between the alternating current and emf is $\frac{\pi}{2}$. Which of the following cannot be the constituent of the circuit? **[2005]**

(a) R, L (b) C alone (c) L alone (d) L, C

55. A circuit has a resistance of 12 ohm and an impedance of 15 ohm. The power factor of the circuit will be **[2005]**

(a) 0.4 (b) 0.8 (c) 0.125 (d) 1.25

56. A coil of inductance 300 mH and resistance 2 Ω is connected to a source of voltage 2V. The current reaches half of its steady state value in **[2005]**

(a) 0.1 s (b) 0.05 s (c) 0.3 s (d) 0.15 s

57. The self inductance of the motor of an electric fan is 10 H. In order to impart maximum power at 50 Hz, it should be connected to a capacitance of **[2005]**

(a) 8μF (b) 4μF (c) 2μF (d) 1μF

58. In an LCR series a.c. circuit, the voltage across each of the components, L, C and R is 50V. The voltage across the LC combination will be **[2004]**

(a) 100 V (b) $50\sqrt{2}$ V

(c) 50 V (d) 0 V (zero)

59. In a LCR circuit capacitance is changed from C to 2 C. For the resonant frequency to remain unchanged, the inductance should be changed from L to **[2004]**

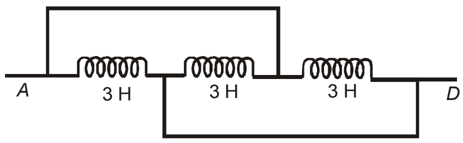
(a) L/2 (b) 2 L (c) 4 L (d) L/4

60. The power factor of an AC circuit having resistance (R) and inductance (L) connected in series and an angular velocity ω is **[2002]**

(a) $R/\omega L$ (b) $R/(R^2 + \omega^2L^2)^{1/2}$

(c) $\omega L/R$ (d) $R/(R^2 - \omega^2L^2)^{1/2}$

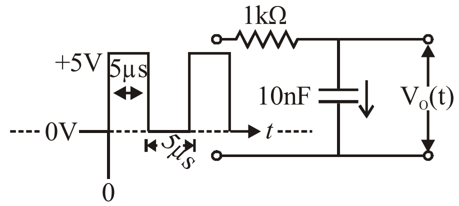
61. The inductance between A and D is **[2002]**



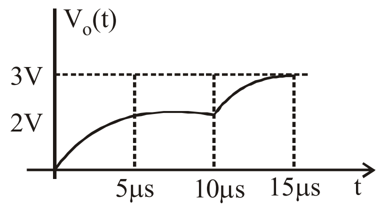
(a) 3.66 H (b) 9 H
(c) 0.66 H (d) 1 H

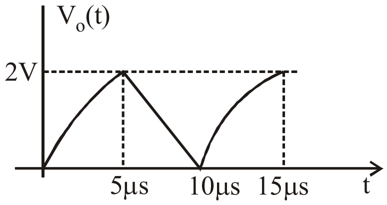
TOPIC 3 Transformers and LC Oscillations

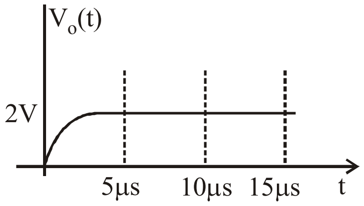
62. For the given input voltage waveform $V_{in}(t)$, the output voltage waveform $V_o(t)$, across the capacitor is correctly depicted by : **[Sep. 06, 2020 (I)]**

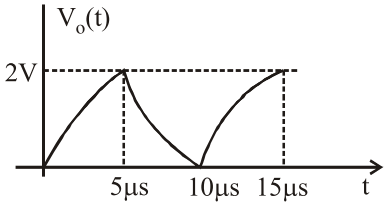


(a)



(b)


(c)


(d)


63. A transformer consisting of 300 turns in the primary and 150 turns in the secondary gives output power of 2.2kW. If the current in the secondary coil is 10 A, then the input voltage and current in the primary coil are : **[10 April 2019 I]**

(a) 220 V and 20 A (b) 440 V and 20 A
(c) 440 V and 5 A (d) 220 V and 10 A

64. A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns. The output power is delivered at 230 V by the transformer. If the current in the primary of the transformer is 5A and its efficiency is 90%, the output current would be: **[9 Jan. 2019 II]**

(a) 50 A (b) 45 A (c) 35 A (d) 25 A

65. A power transmission line feeds input power at 2300 V to a step down transformer with its primary windings having 4000 turns, giving the output power at 230 V. If the current in the primary of the transformer is 5 A, and its efficiency is 90%, the output current would be: **[Online April 16, 2018]**

(a) 20 A (b) 40 A (c) 45 A (d) 25 A

66. In an oscillating LC circuit the maximum charge on the capacitor is Q. The charge on the capacitor when the energy is stored equally between the electric and magnetic field is **[2003]**

(a) $\frac{Q}{2}$ (b) $\frac{Q}{\sqrt{3}}$ (c) $\frac{Q}{\sqrt{2}}$ (d) Q

67. The core of any transformer is laminated so as to **[2003]**

(a) reduce the energy loss due to eddy currents
(b) make it light weight
(c) make it robust and strong
(d) increase the secondary voltage

68. In a transformer, number of turns in the primary coil are 140 and that in the secondary coil are 280. If current in primary coil is 4 A, then that in the secondary coil is **[2002]**

(a) 4 A (b) 2 A (c) 6 A (d) 10 A.

Hints & Solutions

1. **(d)** As $V(t) = 220 \sin 100\,\pi t$

so, $I(t) = \dfrac{220}{50} \sin 100\,\pi t$

i.e., $I = I_m = \sin(100\,\pi t)$

For $I = I_m$

$$t_1 = \frac{\pi}{2} \times \frac{1}{100\pi} = \frac{1}{200} \text{ sec.}$$

and for $I = \dfrac{I_m}{2}$

$$\Rightarrow \frac{I_m}{2} = I_m \sin(100\,\pi t_2) \;\Rightarrow\; \frac{\pi}{6} = 100\,\pi t_2$$

$$\Rightarrow t_2 = \frac{1}{600} s$$

$$\therefore t_{\text{req}} = \frac{1}{200} - \frac{1}{600} = \frac{2}{600} = \frac{1}{300} s = 3.3 \text{ ms}$$

2. **(a)** For two concentric circular coil,

Mutual Inductance $M = \dfrac{\mu_0 \pi N_1 N_2 a^2}{2b}$

here, $N_1 = N_2 = 1$

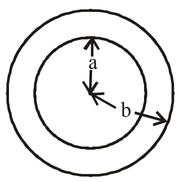
Hence, $M = \dfrac{\mu_0 \pi a^2}{2b}$ ..... (i)

and given $I = I_0 \cos \omega t$ ..... (ii)

Now according to Faraday's second law induced emf

$$e = -M\frac{dI}{dt}$$

From eq. (ii),



$$e = \frac{-\mu_0 \pi a^2}{2b}\frac{d}{dt}(I_0 \cos \omega t)$$

$$e = \frac{\mu_0 \pi a^2}{2b} I_0 \sin \omega t\, (\omega)$$

$$e = \frac{\pi \mu_0 I_0}{2}.\frac{a^2}{b}\omega \sin \omega t$$

3. **(b)** In a pure inductive circuit current always lags behind the emf by $\dfrac{\pi}{2}$.

If $v(t) = v_0 \sin \omega t$

then $I = I_0 \sin\left(\omega t - \dfrac{\pi}{2}\right)$

Now, given $v(t) = 100 \sin(500\,t)$

and $I_0 = \dfrac{E_0}{\omega L} = \dfrac{100}{500 \times 0.02}$ $[\because L = 0.02H]$

$$I_0 = 10 \sin\left(500t - \frac{\pi}{2}\right)$$

$$I_0 = -10 \cos(500t)$$

4. **(c)** We know that power consumed in a.c. circuit is given by,

$P = E_{rms}.I_{rms} \cos \phi$

Here, $E = E_0 \sin \omega t$

$I = I_0 \sin\left(\omega t - \dfrac{\pi}{2}\right)$

This means the phase difference, is $\phi = \dfrac{\pi}{2}$

$$\because \cos \phi = \cos\frac{\pi}{2} = 2$$

$$\therefore P = E_{rms}.I_{rms}.\cos\frac{\pi}{2} = 0$$

5. **(b)** $\phi = \vec{B}.\vec{A}$; $\phi = BA \cos \omega t$

$$\varepsilon = -\frac{d\phi}{dt} = \omega BA \sin \omega t \;;\; i = \frac{\omega BA}{R} \sin \omega t$$

$$P_{inst} = i^2 R = \left(\frac{\omega BA}{R}\right)^2 \times R \sin^2 \omega t$$

$$P_{avg} = \frac{\int_0^T P_{inst} \times dt}{\int_0^T dt} = \frac{(\omega BA)^2}{R} \frac{\int_0^T \sin^2 \omega t dt}{\int_0^T dt} = \frac{1}{2}\frac{(\omega BA)^2}{R}$$

$$\therefore P_{avg} = \frac{(\omega B \pi r^2)^2}{8R} \qquad \left[A = \frac{\pi r^2}{2}\right]$$

6. **(a)** D.C. ammeter measure average value of current. In AC current, average value of current in complete cycle is zero. Hence reading will be zero.

7. **(33)**

Here, $L = 50 \text{ mH} = 50 \times 10^{-3}$ H; $I = 1$ A, $R = 2\Omega$

$$V_P - L\frac{dl}{dt} - 30 + RI = V_Q$$

$$\Rightarrow V_P - V_Q = 50 \times 10^{-3} \times 10^2 + 30 - 1 \times 2$$

$$= 5 + 30 - 2 = 33 \text{ V.}$$

8. **(a)** Quality factor,

$$Q=\frac{1}{R}\sqrt{\frac{L}{C}}=\frac{1}{100}\sqrt{\frac{80\times10^{-3}}{2\times10^{-6}}}$$

$$=\frac{1}{100}\sqrt{40\times10^{3}}=\frac{200}{100}=2$$

9. **(400)**

Given: Power $P = 400$ W, Voltage $V = 250$ V

$$P=V_m\cdot I_{\text{rms}}\cdot\cos\phi$$

$$\Rightarrow 400=250\times I_{\text{rms}}\times0.8\Rightarrow I_{\text{rms}}=2\,\text{A}$$

Using $P=I_{\text{rms}}^2R$

$$(I_{\text{rms}})^2\cdot R=P\Rightarrow 4\times R=400$$

$$\Rightarrow R=100\Omega$$

Power factor is,

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

$$\Rightarrow 0.8=\frac{100}{\sqrt{100^2+X_L^2}}\Rightarrow 100^2+X_L^2=\left(\frac{100}{0.8}\right)^2$$

$$\Rightarrow X_L=\sqrt{-100^2+\left(\frac{100}{0.8}\right)^2}\Rightarrow X_L=75\Omega$$

When power factor is unity,

$$X_C=X_L=75\Rightarrow\frac{1}{\omega C}=75$$

$$\Rightarrow C=\frac{1}{75\times2\pi\times50}=\frac{1}{7500\pi}F$$

$$=\left(\frac{10^6}{2500}\times\frac{1}{3\pi}\right)\mu F=\frac{400}{3\pi}\mu F$$

$N = 400$

10. **(a)** Potential energy stored in the inductor

$$U=\frac{1}{2}LI^2$$

During growth of current,

$$i=I_{\max}\left(1-e^{-Rt/L}\right)$$

For U to be $\frac{U_{\max}}{n}$; i has to be $\frac{I_{\max}}{\sqrt{n}}$

$$\therefore\quad \frac{I_{\max}}{\sqrt{n}}=I_{\max}(1-e^{-Rt/L})$$

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

$$\Rightarrow -\frac{Rt}{L}=\ln\left(\frac{\sqrt{n}-1}{\sqrt{n}}\right)$$

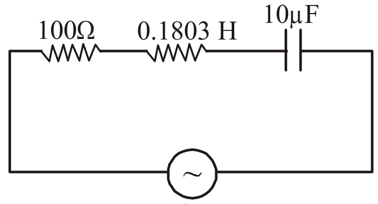
$$\Rightarrow t=\frac{L}{R}\ln\left(\frac{\sqrt{n}}{\sqrt{n}-1}\right)$$

11. **(d)** Here, $R = 100, X_L = L\omega = 0.1803 \times 750 \times 2\pi = 850\Omega$,

$$X_C=\frac{1}{C\omega}=\frac{1}{10^{-5}\times2\pi\times750}=21.23\Omega$$

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

$$=\sqrt{100^2+(850-21.23)^2}=834.77\simeq835$$



$$H=i_{\text{rms}}^2Rt=\left(\frac{V_{\text{rms}}}{|Z|}\right)^2RT=(ms)\Delta t$$

$$\Rightarrow\frac{20}{835}\times\frac{20}{835}\times100t=(2)\times10$$

$\because V_{\text{rms}}=20$ V and $\Delta t = 10°C$

$\therefore$ Time, $t = 348.61$ s.

12. **(a)** Given,

Reactance of inductance coil, $Z = 100\Omega$

Frequency of AC signal, $v = 1000$ Hz

Phase angle, $\phi = 45°$

$$\tan\phi=\frac{X_L}{R}=\tan45°=1$$

$$\Rightarrow X_L=R$$

Reactance, $Z=100=\sqrt{X_L^2+R^2}$

$$\Rightarrow 100=\sqrt{R^2+R^2}$$

$$\Rightarrow\sqrt{2}R=100\Rightarrow R=50\sqrt{2}$$

$$\therefore X_L=50\sqrt{2}$$

$$\Rightarrow L\omega=50\sqrt{2}\qquad(\because X_L=\omega L)$$

$$\Rightarrow L=\frac{50\sqrt{2}}{2\pi\times1000}\qquad(\because\omega=2\pi v)$$

$$=\frac{25\sqrt{2}}{\pi}\text{ mH}$$

$$=1.1\times10^{-2}\text{ H}$$

13. **(b)** We have, $i = i_0(1 - e^{-t/c}) = \frac{\varepsilon}{R}(1 - e^{-t/c})$

Charge, $q = \int_0^{\tau} i dt$

$= \frac{\varepsilon}{R}\int_0^{\tau}(1 - e^{-t/\tau})dt = \frac{E}{R}\frac{\tau}{e} = \frac{E}{R} \times \frac{(L/R)}{e} = \frac{EL}{2.7R^2}$

14. **(d)** $I = I_0\left(1 - e^{-\frac{Rt}{L}}\right)$ Here $R = R_L + r = 1\Omega$

$0.8I_0 = I_0\left(1 - e^{-\frac{t}{.01}}\right)$

$\Rightarrow 0.8 = 1 - e^{-100t}$

$\Rightarrow e^{-100t} = 0.2 = \left(\frac{1}{5}\right)$

$\Rightarrow 100t = \ln 5 \Rightarrow t = \frac{1}{100}\ln 5 = 0.016$ s

15. **(c)** $i^2 R = \left(\tau\frac{di}{dt}\right)i$

$\Rightarrow \frac{di}{dt} = \frac{i}{\tau}$

$\Rightarrow t = \tau\, ln2 = 2ln2 \left[\text{as}\, \tau = \frac{L}{R} = \frac{20}{10} = 2\right]$

16. **(d)** $\omega = 100$ rad/s
We know that

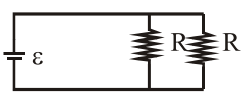
$\tan\phi = \frac{X_C}{R} = \frac{1}{\omega CR}$

or $\tan 45° = \frac{1}{\omega CR}$

or $\omega CR = 1$

LHS: $\omega CR = 10 \times 10 \times 10^{-6} \times 10^3 = 1$

17. **(d)** Long time after switch is closed, the inductor will be idle so, the equivalent diagram will be as below



$I = \frac{\varepsilon}{\left(\frac{R \times R}{R + R}\right)} = \frac{2\varepsilon}{R} = \frac{2 \times 15}{5} = 6$ A

18. **(Bonus)**
Capacitive reactance,

$X_c = \frac{1}{\omega C} = \frac{4}{10^{-6} \times \sqrt{3} \times 100} = \frac{2 \times 10^4}{\sqrt{3}}$

$\tan\theta_1 = \frac{X_C}{R_2} = \frac{10^3}{\sqrt{3}}$

θ_1 is close to 90°

For L-R circuit

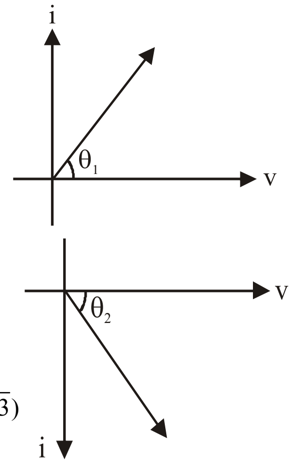
$X_L = \omega L = 100 \times \frac{\sqrt{3}}{10} = 10\sqrt{3}$

$R_1 = 10$

$\tan\theta_2 = \frac{X_L}{R_1}$

$\tan\theta_2 = \sqrt{3} \Rightarrow \theta_2 = \tan^{-1}(\sqrt{3})$

$\theta_2 = 60°$



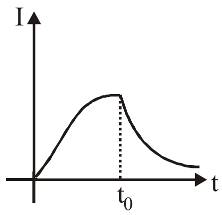
So, phase difference comes out 90° + 60° = 150°

If R_2 is 20 KΩ

then phase difference comes out to be 60 + 30 = 90°.

Therefore Ans. is **Bonus**

19. **(b)**



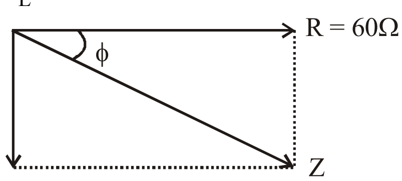
The current will grow for the time t = 0 to $t = t_0$ and after that decay of current takes place.

20. **(c)** Given: $R = 60\Omega$, f = 50 Hz, $\omega = 2\pi f = 100\pi$ and v = 24v
$C = 120\ \mu f = 120 \times 10^{-6} f$

$x_C = \frac{1}{\omega C} = \frac{1}{100\pi \times 120 \times 10^{-6}} = 26.52\Omega$

$x_L = \omega L = 100\pi \times 20 \times 10^{-3} = 2\pi\Omega$

$x_C - x_L = 20.24 \approx 20$



$z = \sqrt{R^2 + (x_C - x_L)^2}$

$z = 20\sqrt{10}\Omega$

$\cos\phi = \frac{R}{z} = \frac{60}{20\sqrt{10}} = \frac{3}{\sqrt{10}}$

$P_{avg} = VI\cos\phi, I = \frac{v}{z} = \frac{v^2}{z}\cos\phi = 8.64$ watt

Energy dissipated (Q) in time t = 60s is
$Q = P.t = 8.64 \times 60 = 5.17 \times 10^2 J$

21. **(a)** Given, Inductance, $L = 40$ mH
Capacitance, $C = 100\ \mu F$
Impedance, $Z = X_C - X_L$

$\Rightarrow \; Z = \dfrac{1}{\omega C} - \omega L \quad \left(\because X_c = \dfrac{1}{\omega C} \text{ and } X_L = \omega L\right)$

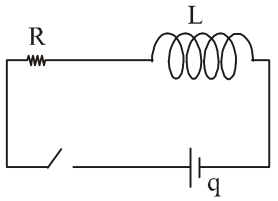
$= \dfrac{1}{314 \times 100 \times 10^{-6}} - 314 \times 40 \times 10^{-3}$

$= 19.28\Omega$

Current, $i = \dfrac{V_0}{Z}\sin(\omega t + \pi/2)$

$\Rightarrow \; i = \dfrac{10}{19.28}\cos\omega t = 0.52\cos(314\,t)$

22. **(a)** For series connection of a resistor and inductor, time variation of current is $I = I_0(1 - e^{-t/T_c})$



Here, $T_C = \dfrac{L}{R}$

$q = \int_0^{T_c} i\,dt$

$\Rightarrow \int dq = \int \dfrac{E}{R}\left(1 - e^{-t/t_c}\right)dt$

$\Rightarrow q = \dfrac{\in}{R}\left[t + t_C e^{-t/t_c}\right]_0^{t_c}$

$\Rightarrow q = \dfrac{\in}{R}\left[t_C + \dfrac{t_C}{e} - t_C\right]$

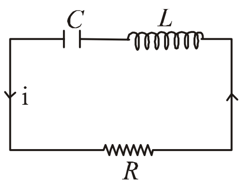
$\Rightarrow q = \dfrac{\in}{R}\dfrac{L}{\text{Re}}$

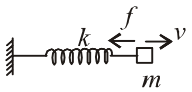
$\therefore q = \dfrac{\in L}{R^2 e}$

23. **(d)** In damped harmonic oscillation,

$\dfrac{md^2x}{dt^2} = -kx - bv$

$\Rightarrow \; \dfrac{md^2x}{dt^2} + b\dfrac{dx}{dt} + kx = 0 \quad$ ....(i)





In LCR circuit, $\dfrac{-q}{C} - iR - \dfrac{Ldi}{dt} = 0$

$L\dfrac{d^2}{dt^2} + R\dfrac{dq}{dt} + \dfrac{q}{C} = 0$ ...(ii)

Comparing equations (i) & (ii)

$L \leftrightarrow m,\; C \leftrightarrow \dfrac{1}{k},\; R \leftrightarrow b$

24. **(a)** The current (I) in LR series circuit is given by

$I = \dfrac{V}{R}\left(1 - e^{-\frac{tR}{L}}\right)$

At $t = \infty$,

$I_\infty = \dfrac{20}{5}\left(I - e^{\frac{-\infty}{L/R}}\right) = 4 \quad$ ...(i)

At $t = 40$s,

$\left(1 - e^{\frac{-40 \times 5}{10 \times 10^{-3}}}\right) = 4(1 - e^{-20{,}000}) \quad$ ...(ii)

Dividing (i) by (ii) we get

$\Rightarrow \quad \dfrac{I_\infty}{I_{40}} = \dfrac{1}{1 - e^{-20{,}000}},$

25. **(b)** As we know, average power $P_{avg} = V_{rms} I_{rms} \cos\theta$

$= \left(\dfrac{V_0}{\sqrt{2}}\right)\left(\dfrac{I_0}{\sqrt{2}}\right)\cos\theta = \left(\dfrac{100}{\sqrt{2}}\right)\left(\dfrac{20}{\sqrt{2}}\right)\cos 45° \quad (\because \theta = 45°)$

$P_{avg} = \dfrac{1000}{\sqrt{2}}$ watt

Wattless current $I = I_{rms}\sin\theta$

$= \dfrac{I_0}{\sqrt{2}}\sin\theta = \dfrac{20}{\sqrt{2}}\sin 45° = 10\text{A}$

26. **(a)** Quality factor $Q = \dfrac{\omega_0}{2\Delta\omega} = \dfrac{\omega_0 L}{R}$

27. **(b)** Given,

$V_0 = 283$ volt, $\omega = 320$, $R = 5\,\Omega$, $L = 25$ mH, $C = 1000\,\mu$F

$x_L = \omega L = 320 \times 25 \times 10^{-3} = 8\,\Omega$

$x_C = \dfrac{1}{\omega C} = \dfrac{1}{320 \times 1000 \times 10^{-6}} = 3.1\,\Omega$

Total impedance of the circuit :

$Z = \sqrt{R^2 + (X_L - X_C)^2} = \sqrt{25 + (4.9)^2} = 7\,\Omega$

Phase difference between the voltage and current

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

$\tan\phi = \dfrac{4.9}{5} \approx 1 \Rightarrow \phi = 45°$

28. **(b)** Here

$i = \dfrac{e}{\sqrt{R^2 + X_L^2}} = \dfrac{e}{\sqrt{R^2 + \omega^2 L^2}} = \dfrac{e}{\sqrt{R^2 + 4\pi^2 v^2 L^2}}$

$10 = \dfrac{220}{\sqrt{64 + 4\pi^2 (50)^2 L}}$

$[\because R = \dfrac{V}{I} = \dfrac{80}{10} = 8]$

On solving we get

$L = 0.065$ H

29. **(d)**

30. **(b)** $I(0)=\dfrac{15\times100}{0.15\times10^{3}}=0.1A$

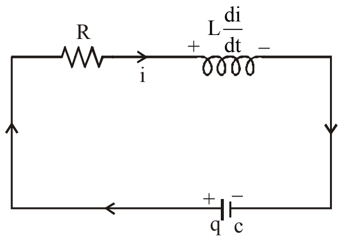
$I(\infty)=0$

$I(t)=[\mathrm{I}(0)-\mathrm{I}(\infty)]\,e^{\frac{-t}{L/R}}+i(\infty)$

$I(t)=0.1\,e^{\frac{-t}{L/R}}=0.1\,e^{\frac{R}{L}}$

$I(t)=0.1\,e^{\frac{0.15\times1000}{0.03}}=0.67mA$

31. **(c)** From KVL at any time t



$\dfrac{q}{c}-iR-L\dfrac{di}{dt}=0$

$i=-\dfrac{dq}{dt}\Rightarrow\dfrac{q}{c}+\dfrac{dq}{dt}R+\dfrac{Ld^2q}{dt^2}=0$

$\dfrac{d^2q}{dt^2}+\dfrac{R}{L}\dfrac{dq}{dt}+\dfrac{q}{Lc}=0$

From damped harmonic oscillator, the amplitude is given

by A $=A_o e-\dfrac{dt}{2m}$

Double differential equation

$\dfrac{d^2x}{dt^2}+\dfrac{b}{m}\dfrac{dx}{dt}+\dfrac{k}{m}x=0$

$Q_{\max}=Q_o e^{-\frac{Rt}{2L}}\Rightarrow Q_{\max}^2=Q_o^2 e^{-\frac{Rt}{L}}$

Hence damping will be faster for lesser self inductance.

32. **(c)** Power factor

$\cos\phi=\dfrac{R}{\sqrt{R^2+\left[\omega L-\dfrac{1}{\omega(C+C')}\right]^2}}=1$

On solving we get,

$\omega L=\dfrac{1}{\omega(C+C')}$

$C'=\dfrac{1-\omega^2LC}{\omega^2L}$

Hence option (c) is the correct answer.

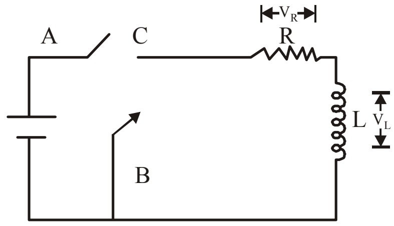
33. **(c)** For capacitor circuit, $i=i_0e^{-t/RC}$

For inductor circuit, $i=i_0\left(1-e^{-\frac{Rt}{L}}\right)$

Hence graph (c) correctly depicts i versus t graph.

34. **(c)** Applying Kirchhoff's law of voltage in closed loop

$-V_R-V_C=0\ \Rightarrow\ \dfrac{V_R}{V_C}=-1$



35. **(c)** Given, $V_L:V_C:V_R=1:2:3$

$V=100\,V$

$V_R=?$

As we know,

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

Solving we get, $V_R\simeq90V$

36. **(c)** Charge on he capacitor at any time t is given by $q=CV\,(1-e^{t/\tau})$

at $t=2\tau$

$q=CV\,(1-e^{-2})$

37. **(d)** Power factor $_{(old)}$

$=\dfrac{R}{\sqrt{R^2+X_L^2}}=\dfrac{R}{\sqrt{R^2+(2R)^2}}=\dfrac{R}{\sqrt{5}R}$

Power factor$_{(new)}$

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

$\therefore\ \dfrac{\text{New power factor}}{\text{Old power factor}}=\dfrac{\dfrac{R}{\sqrt{2}R}}{\dfrac{R}{\sqrt{5}R}}=\sqrt{\dfrac{5}{2}}$

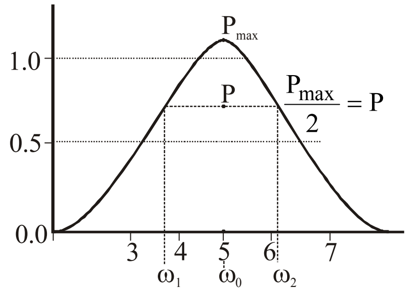
38. **(d)** Impedance (Z) of the series LCR circuit is

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

At resonance, $X_L=X_C$

Therefore, $Z_{\text{minimum}}=R$

39. **(b)**



Quality factor of the circuit

$=\dfrac{\omega_0}{\omega_2-\omega_1}=\dfrac{5}{2.5}=2.0$

40. **(d)**

41. **(c)** Frequency $f = \frac{1}{2\pi\sqrt{LC}} = \frac{1}{2\times 3.4\sqrt{24\times 2\times 10^{-6}}}$

$\simeq 23$Hz

42. **(c)** Voltage E of the ac source

$E = V_C - V_L = 400\text{ V} - 300\text{ V} = 100\text{ V}$

43. **(a)** $t = 3\,RC\,ln\,2$

44. **(d)** In case of series RLC circuit, Equation of voltage is given by

$$V^2 = V_R^2 + (V_L - V_C)^2$$

Here, $V = 220$ V; $V_L = V_C = 300$ V

$\therefore V_R = \sqrt{V^2} = 220\text{V}$

Current $i = \frac{V}{R} = \frac{220}{100} = 2.2\text{A}$

45. **(a)** Energy stored in magnetic field $= \frac{1}{2}Li^2$

Energy stored in electric field $= \frac{1}{2}\frac{q^2}{C}$

Energy will be equal when

$\therefore \frac{1}{2}Li^2 = \frac{1}{2}\frac{q^2}{C}$

$\tan\omega t = 1$

$q = q_0\cos\omega t$

$\Rightarrow \frac{1}{2}L(\omega q_0\sin\omega t)^2 = \frac{(q_0\cos\omega t)^2}{2C}$

$\Rightarrow \omega = \frac{1}{\sqrt{LC}} \quad \Rightarrow \omega t = \frac{\pi}{4}$

$\Rightarrow t = \frac{\pi}{4}\sqrt{LC}$

46. **(b)** We have, $V = V_0(1 - e^{-t/RC})$

$\Rightarrow 120 = 200(1 - e^{-t/RC})$

$e^{-t/r} = \frac{200-120}{200} = \frac{80}{200}$

$t = \log_e(2.5)$

$\Rightarrow t = RC\,\text{in}\,(2.5) \qquad [\because r = RC]$

$\Rightarrow R = 2.71\times 10^6\,\Omega$

47. **(c)** Time constant for parallel combination $= 2RC$

Time constant for series combination $= \frac{RC}{2}$

In first case :

$V = V_0\left(1 - e^{-\frac{t}{CR}}\right) \Rightarrow \frac{V_0}{2} = V_0 - V_0e^{-\frac{t}{CR}}$

$V = V_0e^{-\frac{t_1}{2RC}} = \frac{V_0}{2}$ ...(1)

In second case :

In series grouping, equivalent capacitance $= \frac{C}{2}$

$V = V_0e^{-\frac{t_2}{(RC/2)}} = \frac{V_0}{2}$ ....(2)

From (1) and (2)

$\frac{t_1}{2RC} = \frac{t_2}{(RC/2)}$

$\Rightarrow t_2 = \frac{t_1}{4} = \frac{10}{4} = 2.5$ sec.

48. **(c)** At $t = 0$, no current will flow through L and R_1 as inductor will offer infinite resistance.

$\therefore$ Current through battery, $i = \frac{V}{R_2}$

At $t = \infty$, inductor behave as conducting wire

Effective resistance, $R_{eff} = \frac{R_1R_2}{R_1 + R_2}$

$\therefore$ Current through battery $= \frac{V}{R_{eff}} = \frac{V(R_1 + R_2)}{R_1R_2}$

49. **(d)** When only the capacitance is removed phase difference between current and voltage is

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

$\Rightarrow \tan\phi = \frac{\omega L}{R}$

$\Rightarrow \omega L = R\tan\phi = 200\times\frac{1}{\sqrt{3}} = \frac{200}{\sqrt{3}}$

When only inductor is removed, phase difference between current and voltage is

$\therefore \quad \tan\phi = \frac{1}{\omega CR}$

$\Rightarrow \frac{1}{\omega C} = R\tan\phi = 200\times\frac{1}{\sqrt{3}} = \frac{200}{\sqrt{3}}$

Impedance of the circuit,

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

$$= \sqrt{(200)^2 + \left(\frac{200}{\sqrt{3}} - \frac{200}{\sqrt{3}}\right)^2} = 200\,\Omega$$

Power dissipated in the circuit $= V_{rms}I_{rms}\cos\phi$

$= V_{rms}\cdot\frac{V_{rms}}{Z}\cdot\frac{R}{Z}\left(\because \cos\phi = \frac{R}{Z}\right) = \frac{V^2_{rms}R}{Z^2}$

$= \frac{(220)^2\times 200}{(200)^2} = \frac{220\times 220}{200} = 242$ W

50. **(c)** Growth in current in branch containing L and R_2 when switch is closed is given by

$i = \frac{E}{R_2}[1 - e^{-R_2t/L}]$

$\Rightarrow \frac{di}{dt} = \frac{E}{R_2}\cdot\frac{R_2}{L}\cdot e^{-R_2t/L} = \frac{E}{L}e^{-\frac{R_2t}{L}}$

Hence, potential drop across L

$$V_L = \frac{Ldi}{dt} = \left(\frac{E}{L} e^{-R_2 t/L}\right) L$$

$$= Ee^{-R_2 t/L} = 12e^{-\frac{2t}{400 \times 10^{-3}}} = 12e^{-5t} \text{V}$$

51. **(c)** Across resistor, $I = \frac{V}{R} = \frac{100}{1000} = 0.1\,A$

At resonance,

$$X_L = X_C = \frac{1}{\omega C} = \frac{1}{200 \times 2 \times 10^{-6}} = 2500$$

Voltage across L is

$I X_L = 0.1 \times 2500 = 250\,\text{V}$

52. **(a)** Initially, when steady state is achieved,

$$i = \frac{E}{R}$$

Let E is short circuited at $t = 0$. Then

At $t = 0$

Maximum current, $i_0 = \frac{E}{R} = \frac{100}{100} = 1A$

Let during decay of current at any time the current flowing is $-L\frac{di}{dt} - iR = 0$

$$\Rightarrow \frac{di}{i} = -\frac{R}{L} dt$$

$$\Rightarrow \int_{i_0}^{i} \frac{di}{i} = \int_0^t -\frac{R}{L} dt$$

$$\Rightarrow \log_e \frac{i}{i_0} = -\frac{R}{L} t$$

$$\Rightarrow i = i_0\, e^{-\frac{R}{L}t}$$

$$\Rightarrow i = \frac{E}{R} e^{-\frac{R}{L}t} = 1 \times e^{\frac{-100 \times 10^{-3}}{100 \times 10^{-3}}} = \frac{1}{e}$$

53. **(d)** $e = -\frac{d\phi}{dt} = -\frac{d(N\vec{B}.\vec{A})}{dt}$

$$= -N\frac{d}{dt}(BA\cos\omega t) = NBA\omega \sin\omega t$$

$\Rightarrow e_{max} = NBA\omega$

54. **(a)** Phase difference for R–L circuit lies between $\left(0, \frac{\pi}{2}\right)$ but 0 or $\pi/2$

55. **(b)** Given, Resistance of circuit, $R = 12\,\Omega$

Imedance of circuit, $Z = 15\,\Omega$

Power factor = $\cos\phi = \frac{R}{Z} = \frac{12}{15} = \frac{4}{5} = 0.8$

56. **(a)** Current in inductor circuit is given by,

$$i = i_0\left(1 - e^{-\frac{Rt}{L}}\right)$$

$$\frac{i_0}{2} = i_0(1 - e^{-\frac{Rt}{L}}) \Rightarrow e^{-\frac{Rt}{L}} = \frac{1}{2}$$

Taking log on both the sides,

$$-\frac{Rt}{L} = \log 1 - \log 2$$

$$\Rightarrow t = \frac{L}{R}\log 2 = \frac{300 \times 10^{-3}}{2} \times 0.69$$

$\Rightarrow t = 0.1$ sec.

57. **(d)** For maximum power, $X_L = X_C$, which yields

$$C = \frac{1}{(2\pi n)^2 L} = \frac{1}{4\pi^2 \times 50 \times 50 \times 10}$$

$$\therefore C = 0.1 \times 10^{-5} F = 1\mu F$$

58. **(d)** In a series LCR circuit voltage across the inductor and capacitor are in opposite phase

$\therefore$ Net voltage difference across

$LC = 50 - 50 = 0$

59. **(a)** Resonant frequency, $F_r = \frac{1}{2\pi\sqrt{LC}}$

For resonant frequency to remain same

LC = constant

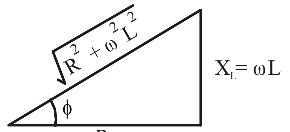
$\therefore LC = L'C'$

$\Rightarrow LC = L' \times 2C$

$$\Rightarrow L' = \frac{L}{2}$$

60. **(b)** Resistance of the inductor, $X_L = \omega L$

The impedance triangle for resistance (R) and inductor (L) connected in series is shown in the figure.



Net impedance of circuit $Z = \sqrt{X_L^2 + R^2}$

Power factor, $\cos\phi = \frac{R}{Z}$

$$\Rightarrow \cos\phi = \frac{R}{\sqrt{R^2 + \omega^2 L^2}}$$

61. **(d)** All three inductors are connected in parallel. The equivalent inductance L_p is given by

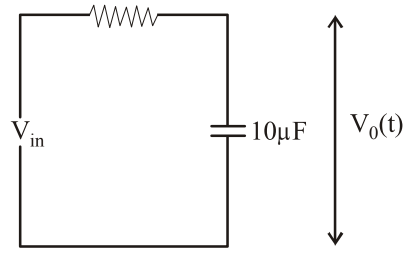
$$\frac{1}{L_p} = \frac{1}{L_1} + \frac{1}{L_2} + \frac{1}{L_3} = \frac{1}{3} + \frac{1}{3} + \frac{1}{3} = \frac{3}{3} = 1$$

$\therefore L_p = 1$

62. **(a)** When first pulse is applied, the potential across capacitor

$$V_0(t) = V_{in}\left(1 - e^{\frac{1}{RC}}\right)$$

At $t = 5\mu s = 5 \times 10^{-6} s$



$$V_0(t) = 5\left(1 - e^{\frac{5\times10^{-6}}{10^3\times10\times10^{-9}}}\right) = 5(1-e^{-0.5}) = 2V$$

When no pulse is applied, capacitor will discharge.
Now, $V_{in} = 0$ means discharging.

$$V_0(t) = 2e^{\frac{1}{RC}} = 2e^{-0.5} = 1.21 \text{ V}$$

Now for next 5 μs

$$V_0(t) = 5 - 3.79e^{\frac{1}{RC}}$$

After 5 μs again, $V_0(t) = 2.79$ Volt ≈ 3 V

Hence, graph (a) correctly depicts.

63. **(c)** Power output $(V_2I_2) = 2.2$ kW

$$\therefore\ V_2 = \frac{2.2\text{kW}}{(10\text{A})} = 220 \text{ volts}$$

$\therefore$ Input voltage for step-down transformer

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = 2$$

$$V_{input} = 2 \times V_{output} = 2 \times 220$$
$$= 440 \text{ V}$$

Also $\frac{I_1}{I_2} = \frac{N_2}{N_1}$

$$\therefore\quad I_1 = \frac{1}{2}\times 10 = 5\text{A}$$

64. **(b)** Efficiency, $\eta = \frac{P_{out}}{P_{in}} = \frac{V_sI_s}{V_pI_p}$

$$\Rightarrow 0.9 = \frac{230\times I_s}{2300\times5}$$

$$\Rightarrow I_s = 0.9\times50 = 45\text{A}$$

Output current = 45A

65. **(c)** Given : $V_P = 2300$ V, $V_s = 230$ V, $I_P = 5$ A, n = 90% = 0.9

Efficiency n = 0.9 $= \frac{P_s}{P_P} \Rightarrow P_s = 0.9\ P_p$

$V_sI_s = 0.9\times V_PI_P$ $(\because P = VI)$

$$I_s = \frac{0.9\times2300\times5}{230} = 45\text{A}$$

66. **(c)** When the capacitor is completely charged, the total energy in the LC circuit is with the capacitor and that energy is given by

$$U_{max} = \frac{1}{2}\frac{Q^2}{C}$$

When half energy is with the capacitor in the form of electric field between the plates of the capacitor we get

$$\frac{U_{max}}{2} = \frac{1}{2}\frac{q'^2}{C}$$

Here q' is the charge on the plate of capacitor when energy is shared equally.

$$\therefore\ \frac{1}{2}\times\frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}\frac{q'^2}{C} \Rightarrow q' = \frac{Q}{\sqrt{2}}$$

67. **(a)** Laminated core provide less area of cross-section for the current to flow. Because of this, resistance of the core increases and current decreases there by decreasing the energy loss due to eddy current.

68. **(b)** Number of turns in primary

$N_p = 140$

Number of turns in secondary $N_s = 280$, $I_p = 4A$, $I_s = ?$

Using transformation ratio for a transformer $\frac{I_s}{I_p} = \frac{N_p}{N_s}$

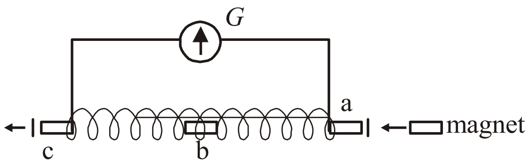
$$\Rightarrow \frac{I_s}{4} = \frac{140}{280}$$

$$\Rightarrow I_s = 2\,A$$

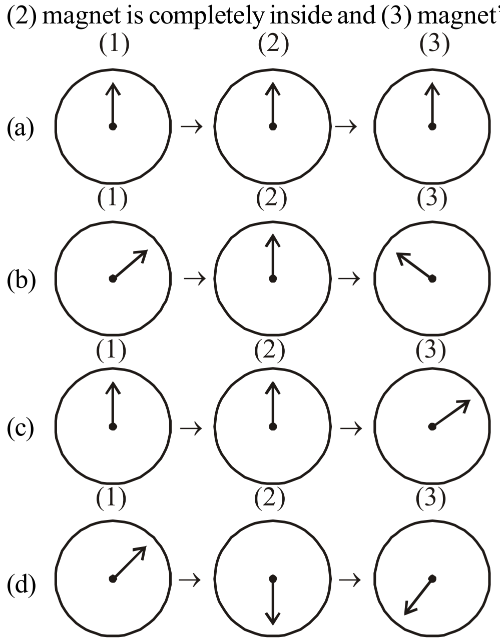
TOPIC 1 Magnetic Flux, Faraday's and Lenz's Law

1. Two concentric circular coils, C_1 and C_2, are placed in the XY plane. C_1 has 500 turns, and a radius of 1 cm. C_2 has 200 turns and radius current 20 cm. C_2 carries a time dependent current $I(t) = (5t^2 - 2t + 3)$ A Where t is in s. The emf induced in C_1 (in mV), at the instant $t = 1$ s is $\frac{4}{x}$. The value of x is ______. **[NA Sep. 05, 2020 (I)]**

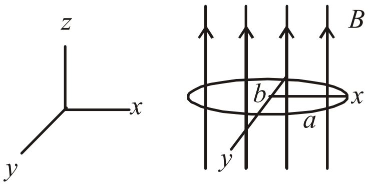
2. A small bar magnet is moved through a coil at constant speed from one end to the other. Which of the following series of observations will be seen on the galvanometer G attached across the coil ? **[Sep. 04, 2020 (I)]**



Three positions shown describe : (1) the magnet's entry (2) magnet is completely inside and (3) magnet's exit.



3. An elliptical loop having resistance R, of semi major axis a, and semi minor axis b is placed in a magnetic field as shown in the figure. If the loop is rotated about the x-axis with angular frequency ω, the average power loss in the loop due to Joule heating is : **[Sep. 03, 2020 (I)]**



(a) $\frac{\pi^2 a^2 b^2 B^2 \omega^2}{2R}$ (b) zero

(c) $\frac{\pi abB\omega}{R}$ (d) $\frac{\pi^2 a^2 b^2 B^2 \omega^2}{R}$

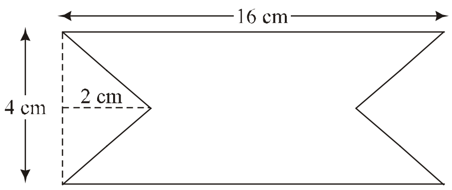
4. A uniform magnetic field B exists in a direction perpendicular to the plane of a square loop made of a metal wire. The wire has a diameter of 4 mm and a total length of 30 cm. The magnetic field changes with time at a steady rate $dB/dt = 0.032\ \text{Ts}^{-1}$. The induced current in the loop is close to (Resistivity of the metal wire is $1.23 \times 10^{-8}\ \Omega$ m) **[Sep. 03, 2020 (II)]**

(a) 0.43 A (b) 0.61 A (c) 0.34 A (d) 0.53 A

5. A circular coil of radius 10 cm is placed in a uniform magnetic field of 3.0×10^{-5} T with its plane perpendicular to the field initially. It is rotated at constant angular speed about an axis along the diameter of coil and perpendicular to magnetic field so that it undergoes half of rotation in 0.2 s. The maximum value of EMF induced (in μV) in the coil will be close to the integer _____. **[NA Sep. 02, 2020 (I)]**

6. In a fluorescent lamp choke (a small transformer) 100 V of reverse voltage is produced when the choke current changes uniformly from 0.25 A to 0 in a duration of 0.025 ms. The self-inductance of the choke (in mH) is estimated to be ______. **[NA 9 Jan. 2020 I]**

7. At time $t = 0$ magnetic field of 1000 Gauss is passing perpendicularly through the area defined by the closed loop shown in the figure. If the magnetic field reduces linearly to 500 Gauss, in the next 5 s, then induced EMF in the loop is: **[NA 8 Jan. 2020 I]**



(a) 56 μV (b) 28 μV (c) 48 μV (d) 36 μV

8. Consider a circular coil of wire carrying constant current I, forming a magnetic dipole. The magnetic flux through an infinite plane that contains the circular coil and excluding the circular coil area is given by ϕ_i. The magnetic flux through the area of the circular coil area is given by ϕ_0. Which of the following option is correct? **[7 Jan. 2020 I]**

(a) $\phi_i = \phi_0$ (b) $\phi_i > \phi_0$ (c) $\phi_i < \phi_0$ (d) $\phi_i = -\phi_0$

9. A long solenoid of radius R carries a time (t) - dependent current $I(t) = I_0 t(1-t)$. A ring of radius $2R$ is placed coaxially near its middle. During the time interval $0 \le t \le 1$, the induced current (I_R) and the induced $EMF(V_R)$ in the ring change as: **[7 Jan. 2020 I]**

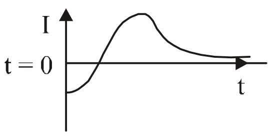
(a) Direction of I_R remains unchanged and V_R is maximum at $t = 0.5$
(b) At $t = 0.25$ direction of I_R reverses and V_R is maximum
(c) Direction of I_R remains unchanged and V_R is zero at $t = 0.25$
(d) At $t = 0.5$ direction of I_R reverses and V_R is zero

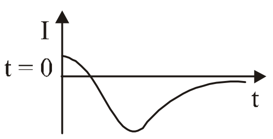
10. A loop ABCDEFA of straight edges has six corner points $A(0, 0, 0)$, $B\{5, 0, 0)$, $C(5, 5, 0)$, $D(0, 5, 0)$, $E(0, 5, 5)$ and $F(0, 0, 5)$. The magnetic field in this region is $\vec{B} = (3\hat{i} + 4\hat{k})$T. The quantity of flux through the loop $ABCDEFA$ (in Wb) is _________. **[NA 7 Jan. 2020 I]**

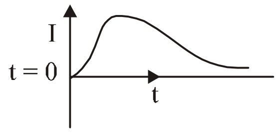
11. A planar loop of wire rotates in a uniform magnetic field. Initially, at $t = 0$, the plane of the loop is perpendicular to the magnetic field. If it rotates with a period of 10 s about an axis in its plane then the magnitude of induced emf will be maximum and minimum, respectively at: **[7 Jan. 2020 II]**

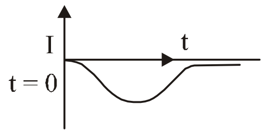
(a) 2.5 s and 7.5 s (b) 2.5 s and 5.0 s
(c) 5.0 s and 7.5 s (d) 5.0 s and 10.0 s

12. A very long solenoid of radius R is carrying current $I(t) = kte^{-\alpha t}$ ($k > 0$), as a function of time ($t \geq 0$). Counter clockwise current is taken to be positive. A circular conducting coil of radius 2R is placed in the equatorial plane of the solenoid and concentric with the solenoid. The current induced in the outer coil is correctly depicted, as a function of time, by: **[9 Apr. 2019 II]**

(a)


(b)


(c)


(d)


13. Two coils 'P' and 'Q' are separated by some distance. When a current of 3A flows through coil 'P', a magnetic flux of 10^{-3} Wb passes through 'Q'. No current is passed through 'Q'. When no current passes through 'P' and a current of 2A passes through 'Q', the flux through 'P' is: **[9 Apr. 2019 II]**

(a) 6.67×10^{-4} Wb (b) 3.67×10^{-3} Wb
(c) 6.67×10^{-3} Wb (d) 3.67×10^{-4} Wb

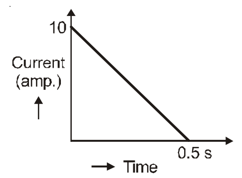
14. The self induced emf of a coil is 25 volts. When the current in it is changed at uniiform rate from 10 A to 25 A in 1s, the change in the energy of the inductance is: **[9 Jan. 2019 II]**

(a) 740 J (b) 437.5 J
(c) 540 J (d) 637.5 J

15. A conducting circular loop made of a thin wire, has area $3.5 \times 10^{-3} m^2$ and resistance 10Ω. It is placed perpendicular to a time dependent magnetic field B (t) = (0.4T) sin (50πt). The the net charge flowing through the loop during t = 0 s and t = 10 ms is close to: **[9 Jan. 2019 I]**

(a) 14 mC (b) 7 mC (c) 21 mC (d) 6 mC

16. In a coil of resistance 100 Ω, a current is induced by changing the magnetic flux through it as shown in the figure. The magnitude of change in flux through the coil is **[2017]**



(a) 250 Wb
(b) 275 Wb
(c) 200 Wb
(d) 225 Wb

17. A conducting metal circular–wire–loop of radius r is placed perpendicular to a magnetic field which varies with time as $B = B_0 e^{-t/\tau}$, where B_0 and τ are constants, at time t = 0. If the resistance of the loop is R then the heat generated in the loop after a long time $(t \to \infty)$ is ; **[Online April 10, 2016]**

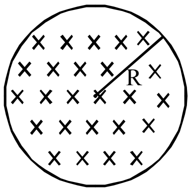
(a) $\dfrac{\pi^2 r^4 B_0^4}{2\tau R}$ (b) $\dfrac{\pi^2 r^4 B_0^2}{2\tau R}$

(c) $\dfrac{\pi^2 r^4 B_0^2 R}{\tau}$ (d) $\dfrac{\pi^2 r^4 B_0^2}{\tau R}$

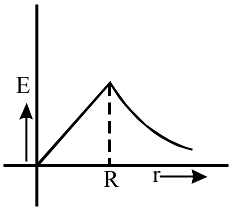
18. When current in a coil changes from 5 A to 2 A in 0.1 s, average voltage of 50 V is produced. The self - inductance of the coil is : **[Online April 10, 2015]**

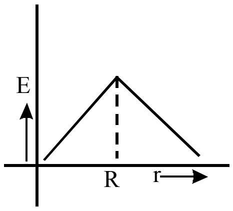
(a) 6 H (b) 0.67 H
(c) 3 H (d) 1.67 H

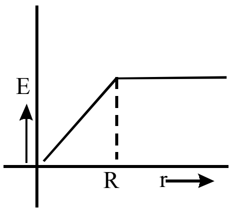
19. Figure shows a circular area of radius R where a uniform magnetic field $\vec{B}$ is going into the plane of paper and increasing in magnitude at a constant rate.

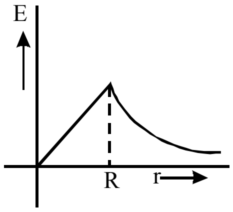


In that case, which of the following graphs, drawn schematically, correctly shows the variation of the induced electric field E(r)? **[Online April 19, 2014]**

(a)


(b)


(c)


(d)


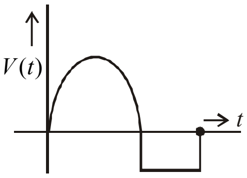
20. A coil of circular cross-section having 1000 turns and 4 cm^2 face area is placed with its axis parallel to a magnetic field which decreases by 10^{-2} Wb m^{-2} in 0.01 s. The e.m.f. induced in the coil is: **[Online April 11, 2014]**

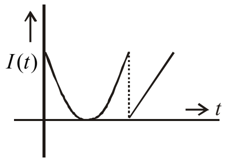
(a) 400mV (b) 200mV
(c) 4mV (d) 0.4mV

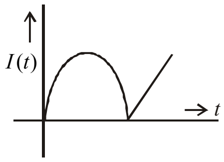
21. A circular loop of radius 0.3 cm lies parallel to amuch bigger circular loop of radius 20 cm. The centre of the small loop is on the axis of the bigger loop. The distance between their centres is 15 cm. If a current of 2.0 A flows through the smaller loop, then the flux linked with bigger loop is **[2013]**

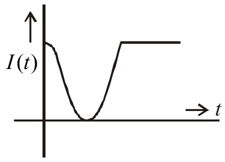
(a) 9.1×10^{-11} weber (b) 6×10^{-11} weber
(c) 3.3×10^{-11} weber (d) 6.6×10^{-9} weber

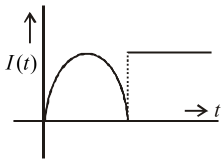
22. Two coils, X and Y, are kept in close vicinity of each other. When a varying current, $I(t)$, flows through coil X, the induced emf ($V(t)$) in coil Y, varies in the manner shown here. The variation of $I(t)$, with time, can then be represented by the graph labelled as graph : **[Online April 9, 2013]**



(A)


(B)


(C)


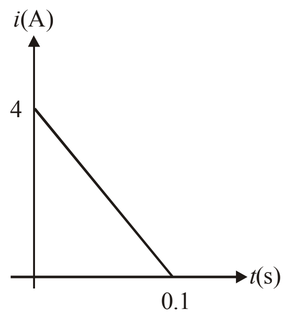
(D)


(a) A (b) C
(c) B (d) D

23. A coil is suspended in a uniform magnetic field, with the plane of the coil parallel to the magnetic lines of force. When a current is passed through the coil it starts oscillating; It is very difficult to stop. But if an aluminium plate is placed near to the coil, it stops. This is due to : **[2012]**

(a) developement of air current when the plate is placed
(b) induction of electrical charge on the plate
(c) shielding of magnetic lines of force as aluminium is a paramagnetic material.
(d) electromagnetic induction in the aluminium plate giving rise to electromagnetic damping.

24. Magnetic flux through a coil of resistance 10 Ω is changed by Δϕ in 0.1 s. The resulting current in the coil varies with time as shown in the figure. Then |Δϕ| is equal to (in weber) **[Online May 12, 2012]**



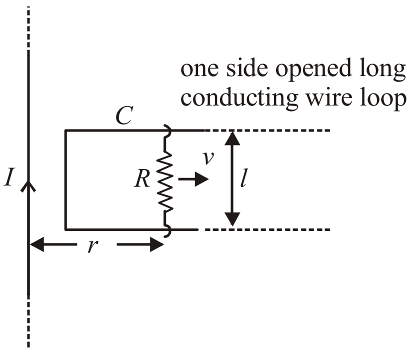
(a) 6 (b) 4
(c) 2 (d) 8

25. The flux linked with a coil at any instant 't' is given by $\phi = 10t^2 - 50t + 250$. The induced emf at $t = 3s$ is **[2006]**

(a) –190 V (b) –10 V
(c) 10 V (d) 190 V

TOPIC 2 Motional and Static EMI and Application of EMI

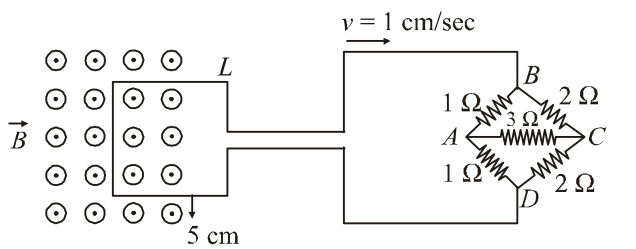
26. An infinitely long straight wire carrying current I, one side opened rectangular loop and a conductor C with a sliding connector are located in the same plane, as shown in the figure. The connector has length l and resistance R. It slides to the right with a velocity v. The resistance of the conductor and the self inductance of the loop are negligible. The induced current in the loop, as a function of separation r, between the connector and the straight wire is : **[Sep. 05, 2020 (II)]**



(a) $\frac{\mu_0}{4\pi}\frac{Ivl}{Rr}$ (b) $\frac{\mu_0}{\pi}\frac{Ivl}{Rr}$

(c) $\frac{2\mu_0}{\pi}\frac{Ivl}{Rr}$ (d) $\frac{\mu_0}{2\pi}\frac{Ivl}{Rr}$

27. The figure shows a square loop L of side 5 cm which is connected to a network of resistances. The whole setup is moving towards right with a constant speed of 1 cm s^{-1}. At some instant, a part of L is in a uniform magnetic field of 1 T, perpendicular to the plane of the loop. If the resistance of L is 1.7 &!, the current in the loop at that instant will be close to : **[12 Apr. 2019 I]**

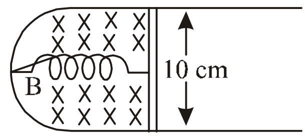


(a) 60μA (b) 170 μA
(c) 150 μA (d) 115 μA

28. The total number of turns and cross-section area in a solenoid is fixed. However, its length L is varied by adjusting the separation between windings. The inductance of solenoid will be proportional to: **[9 April 2019 I]**

(a) L (b) L^2 (c) 1/ L^2 (d) 1/L

29. A thin strip 10 cm long is on a U shaped wire of negligible resistance and it is connected to a spring of spring constant 0.5 Nm^{-1} (see figure). The assembly is kept in a uniform magnetic field of 0.1 T. If the strip is pulled from its equilibrium position and released, the number of oscillations it performs before its amplitude decreases by a factor of e is N. If the mass of strip is 50 grams, its resistance 10Ω and air drag negligible, N will be close to : **[8 April 2019 I]**



(a) 1000 (b) 50000 (c) 5000 (d) 10000

30. A 10 m long horizontal wire extends from North East to South West. It is falling with a speed of 5.0 ms^{-1}, at right angles to the horizontal component of the earth's magnetic field, of 0.3×10^{-4} Wb/m^2. The value of the induced emf in wire is : **[12 Jan. 2019 II]**

(a) 1.5×10^{-3} V (b) 1.1×10^{-3} V
(c) 2.5×10^{-3}V (d) 0.3×10^{-3} V

31. There are two long co-axial solenoids of same length l. The inner and outer coils have radii r_1 and r_2 and number of turns per unit length n_1 and n_2, respectively. The ratio of mutual inductance to the self-inductance of the inner-coil is : **[11 Jan. 2019 I]**

(a) $\frac{n_1}{n_2}$ (b) $\frac{n_2}{n_1}\cdot\frac{r_1}{r_2}$

(c) $\frac{n_2}{n_1}\cdot\frac{r_2^2}{r_1^2}$ (d) $\frac{n_2}{n_1}$

32. A copper wire is wound on a wooden frame, whose shape is that of an equilateral triangle. If the linear dimension of each side of the frame is increased by a factor of 3, keeping the number of turns of the coil per unit length of the frame the same, then the self inductance of the coil: **[11 Jan. 2019 II]**

(a) decreases by a factor of 9
(b) increases by a factor of 27
(c) increases by a factor of 3
(d) decreases by a factor of $9\sqrt{3}$

33. A solid metal cube of edge length 2 cm is moving in a positive y-direction at a constant speed of 6 m/s. There is a uniform magnetic field of 0.1 T in the positive z-direction. The potential difference between the two faces of the cube perpendicular to the x-axis, is: **[10 Jan. 2019 I]**

(a) 12 mV (b) 6 mV
(c) 1 mV (d) 2 mV

34. An insulating thin rod of length l has a linear charge density $\rho(x) = \rho_0 \frac{x}{l}$ on it. The rod is rotated about an axis passing through the origin ($x = 0$) and perpendicular to the rod. If the rod makes n rotations per second, then the time averaged magnetic moment of the rod is: **[10 Jan. 2019 I]**

(a) $\pi n \rho l^3$ (b) $\frac{\pi}{3} n \rho l^3$

(c) $\frac{\pi}{4} n \rho l^3$ (d) $n \rho l^3$

35. A coil of cross-sectional area A having n turns is placed in a uniform magnetic field B. When it is rotated with an angular velocity ω, the maximum e.m.f. induced in the coil will be **[Online April 16, 2018]**

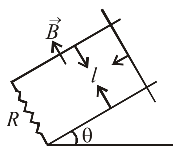
(a) nBAω (b) $\frac{3}{2}$nBAω

(c) 3nBAω (d) $\frac{1}{2}$nBAω

36. An ideal capacitor of capacitance 0.2 μF is charged to a potential difference of 10V. The charging battery is then disconnected. The capacitor is then connected to an ideal inductor of self inductance 0.5mH. The current at a time when the potential difference across the capacitor is 5V, is: **[Online April 15, 2018]**

(a) 0.17A (b) 0.15A (c) 0.34A (d) 0.25A

37. A copper rod of mass m slides under gravity on two smooth parallel rails, with separation 1 and set at an angle of θ with the horizontal. At the bottom, rails are joined by a resistance R. There is a uniform magnetic field B normal to the plane of the rails, as shown in the figure. The terminal speed of the copper rod is: **[Online April 15, 2018]**



(a) $\frac{mgR\cos\theta}{B^2 l^2}$ (b) $\frac{mgR\sin\theta}{B^2 l^2}$

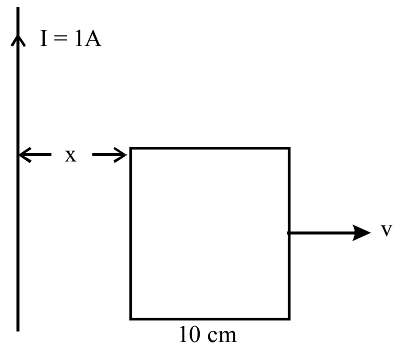
(c) $\frac{mgR\tan\theta}{B^2 l^2}$ (d) $\frac{mgR\cot\theta}{B^2 l^2}$

38. At the centre of a fixed large circular coil of radius R, a much smaller circular coil of radius r is placed. The two coils are concentric and are in the same plane. The larger coil carries a current I. The smaller coil is set to rotate with a constant angular velocity ω about an axis along their common diameter. Calculate the emf induced in the smaller coil after a time t of its start of rotation. **[Online April 15, 2018]**

(a) $\frac{\mu_0 I}{2R}\omega r^2 \sin\omega t$ (b) $\frac{\mu_0 I}{4R}\omega\pi r^2 \sin\omega t$

(c) $\frac{\mu_0 I}{2R}\omega\pi r^2 \sin\omega t$ (d) $\frac{\mu_0 I}{4R}\omega r^2 \sin\omega t$

39. A square frame of side 10 cm and a long straight wire carrying current 1 A are in the plate of the paper. Starting from close to the wire, the frame moves towards the right with a constant speed of 10 ms^{-1} (see figure).

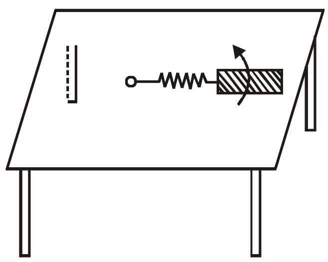


The e.m.f induced at the time the left arm of the frame is at x = 10 cm from the wire is: **[Online April 19, 2014]**

(a) 2 μV (b) 1 μV

(c) 0.75 μV (d) 0.5 μV

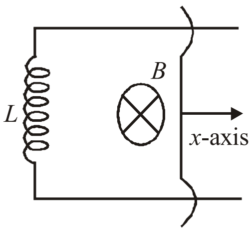
40. A metallic rod of length 'ℓ' is tied to a string of length 2ℓ and made to rotate with angular speed ω on a horizontal table with one end of the string fixed. If there is a vertical magnetic field 'B' in the region, the e.m.f. induced across the ends of the rod is **[2013]**

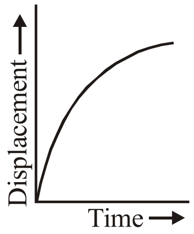


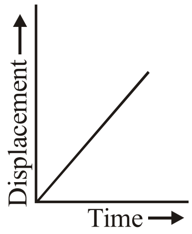
(a) $\frac{2B\omega\ell^2}{2}$ (b) $\frac{3B\omega\ell^2}{2}$

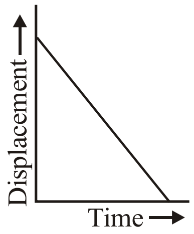
(c) $\frac{4B\omega\ell^2}{2}$ (d) $\frac{5B\omega\ell^2}{2}$

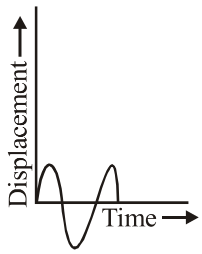
41. A coil of self inductance L is connected at one end of two rails as shown in figure. A connector of length l, mass m can slide freely over the two parallel rails. The entire set up is placed in a magnetic field of induction B going into the page. At an instant $t = 0$ an initial velocity v_0 is imparted to it and as a result of that it starts moving along x-axis. The displacement of the connector is represented by the figure. **[Online May 19, 2012]**



(a) 

(b) 

(c) 

(d) 

42. This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: Self inductance of a long solenoid of length L, total number of turns N and radius r is less than $\frac{\pi\mu_0 N^2 r^2}{L}$.

Statement 2: The magnetic induction in the solenoid in Statement 1 carrying current I is $\frac{\mu_0 NI}{L}$ in the middle of the solenoid but becomes less as we move towards its ends. **[Online May 19, 2012]**

(a) Statement 1 is true, Statement 2 is false.
(b) Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.
(c) Statement 1 is false, Statement 2 is true.
(d) Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.

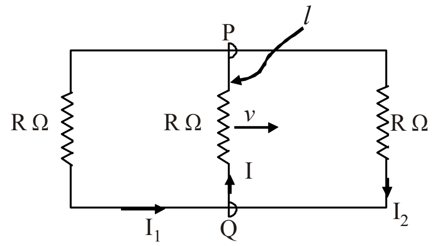
43. A boat is moving due east in a region where the earth's magnetic field is 5.0×10^{-5} NA^{-1} m^{-1} due north and horizontal. The boat carries a vertical aerial 2 m long. If the speed of the boat is 1.50 ms^{-1}, the magnitude of the induced emf in the wire of aerial is: **[2011]**

(a) 0.75 mV (b) 0.50 mV
(c) 0.15 mV (d) 1 mV

44. A horizontal straight wire 20 m long extending from east to west falling with a speed of 5.0 m/s, at right angles to the horizontal component of the earth's magnetic field 0.30×10^{-4} Wb/m^2. The instantaneous value of the e.m.f. induced in the wire will be **[2011 RS]**

(a) 3 mV (b) 4.5 mV (c) 1.5 mV (d) 6.0 mV

45. A rectangular loop has a sliding connector PQ of length l and resistance R Ω and it is moving with a speed v as shown. The set-up is placed in a uniform magnetic field going into the plane of the paper. The three currents I_1, I_2 and I are **[2010]**



(a) $I_1 = -I_2 = \frac{Blv}{6R},\ I = \frac{2Blv}{6R}$

(b) $I_1 = I_2 = \frac{Blv}{3R}, I = \frac{2Blv}{3R}$

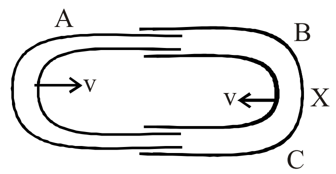
(c) $I_1 = I_2 = I = \frac{Blv}{R}$

(d) $I_1 = I_2 = \frac{Blv}{6R},\ I = \frac{Blv}{3R}$

46. Two coaxial solenoids are made by winding thin insulated wire over a pipe of cross-sectional area A = 10 cm^2 and length = 20 cm. If one of the solenoid has 300 turns and the other 400 turns, their mutual inductance is **[2008]**
($\mu_0 = 4\pi \times 10^{-7}$ Tm A^{-1})

(a) $2.4\pi \times 10^{-5}$ H (b) $4.8\pi \times 10^{-4}$ H
(c) $4.8\pi \times 10^{-5}$ H (d) $2.4\pi \times 10^{-4}$ H

47. One conducting U tube can slide inside another as shown in figure, maintaining electrical contacts between the tubes. The magnetic field B is perpendicular to the plane of the figure. If each tube moves towards the other at a constant speed v, then the emf induced in the circuit in terms of B, l and v where l is the width of each tube, will be **[2005]**



(a) – Blv (b) Blv
(c) 2 Blv (d) zero

48. A metal conductor of length 1 m rotates vertically about one of its ends at angular velocity 5 radians per second. If the horizontal component of earth's magnetic field is 0.2×10^{-4}T, then the e.m.f. developed between the two ends of the conductor is **[2004]**

(a) 5 mV (b) 50 μV
(c) 5 μV (d) 50 mV

49. A coil having n turns and resistance $R\Omega$ is connected with a galvanometer of resistance $4R\Omega$. This combination is moved in time t seconds from a magnetic field W_1 weber to W_2 weber. The induced current in the circuit is **[2004]**

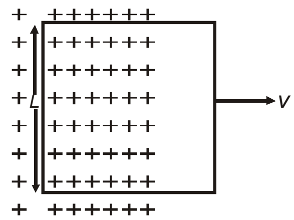
(a) $-\frac{(W_2 - W_1)}{Rnt}$ (b) $-\frac{n(W_2 - W_1)}{5\ Rt}$

(c) $-\frac{(W_2 - W_1)}{5\ Rnt}$ (d) $-\frac{n(W_2 - W_1)}{Rt}$

50. Two coils are placed close to each other. The mutual inductance of the pair of coils depends upon **[2003]**
(a) the rates at which currents are changing in the two coils
(b) relative position and orientation of the two coils
(c) the materials of the wires of the coils
(d) the currents in the two coils

51. When the current changes from +2 A to –2A in 0.05 second, an e.m.f. of 8 V is induced in a coil. The coefficient of self -induction of the coil is **[2003]**
(a) 0.2 H (b) 0.4 H (c) 0.8 H (d) 0.1 H

52. A conducting square loop of side L and resistance R moves in its plane with a uniform velocity v perpendicular to one of its sides. A magnetic induction B constant in time and space, pointing perpendicular and into the plane at the loop exists everywhere with half the loop outside the field, as shown in figure. The induced emf is **[2002]**



(a) zero (b) RvB (c) vBL/R (d) vBL

Hints & Solutions

1. **(5)**
For coil C_1, No. of turns $N_1 = 500$ and radius, $r = 1$ cm.
For coil C_2, No. of turns $N_2 = 200$ and radius, $R = 20$ cm

$$I = (5t^2 - 2t + 3) \Rightarrow \frac{dI}{dt} = (10t - 2)$$

$$\phi_{\text{small}} = BA = \left(\frac{\mu_0 I N_2}{2R}\right)(\pi r^2)$$

Induced emf in small coil,

$$e = \frac{d\phi}{dt} = \left(\frac{\mu_0 N_2}{2r}\right)\pi r^2 N_1 \frac{di}{dt} = \left(\frac{\mu_0 N_1 N_2 \pi r^2}{2R}\right)(10t - 2)$$

At $t = 1$ s

$$e = \left(\frac{\mu_0 N_1 N_2 \pi r^2}{2R}\right)8 = 4\frac{\mu_0 N_1 N_2 \pi r^2}{R}$$

$$= \frac{4(4\pi)10^{-7} \times 200}{20} \times 500 \times \frac{10^{-4}}{10^{-2}}\pi$$

$$= 80 \times \pi^2 \times 10^{-7} \times 10 \times 10^2 \times 10^{-2}$$

$$= 8 \times 10^{-4} \text{ volt} = 0.8 \text{ mV} = \frac{4}{x} \Rightarrow x = 5.$$

2. **(b) Case (a) :** When bar magnet is entering with constant speed, flux (ϕ) will change and an e.m.f. is induced, so galvanometer will deflect in positive direction.
Case (b) : When magnet is completely inside, flux (ϕ) will not change, so galvanometer will show null deflection.
Case (c) : When bar magnet is making on exit, again flux (ϕ) will change and an e.m.f. is induced in opposite direction so galvanometer will deflect in negative direction i.e. reverse direction.

3. **(a)** As we know, emf $\varepsilon = NAB\omega\cos\omega t$, Here $N = 1$
Average power,

$$<P> = <\frac{\varepsilon^2}{R}> = <\frac{A^2B^2\omega^2\cos^2\omega t}{R}> = \frac{A^2B^2\omega^2}{R}\left(\frac{1}{2}\right)$$

Therefore average power loss in the loop due to Joule heating

$$<P> = \frac{\pi^2 a^2 b^2 B^2}{2R}(\omega^2)$$

4. **(b)** Given,
Length of wire, $l = 30$ cm
Radius of wire, $r = 2$ mm $= 2 \times 10^{-3}$ m
Resistivity of metal wire, $\rho = 1.23 \times 10^{-8}\ \Omega$m

Emf generated, $|e| = \frac{d\phi}{dt} = \frac{dB}{dt}(A)$ $\quad (\because \phi = \text{B.A.})$

Current, $i = \frac{e}{R}$

But, resistance of wire, $R = \rho\frac{l}{A}$

$$\therefore i = \left|\frac{dB}{dt}\right|\frac{(A)^2}{\rho l} = \frac{0.032 \times \{\pi \times 2 \times 10^{-3}\}^2}{1.23 \times 10^{-8} \times 0.3} = 0.61\text{ A}.$$

5. **(15)**
Here, $B = 3.0 \times 10^{-5}$ T, $R = 10$ cm $= 0.1$ m

$$\omega = \frac{2\pi}{2T} = \frac{\pi}{0.2}$$

Flux as a function of time $\phi = \vec{B} \cdot \vec{A} = AB\cos(\omega t)$

Emf induced, $e = \frac{-d\phi}{dt} = AB\omega\sin(\omega t)$
Max. value of Emf $= AB\omega = \pi R^2 B\omega$

$$= 3.14 \times 0.1 \times 0.1 \times 3 \times 10^{-5} \times \frac{\pi}{0.2}$$

$$= 15 \times 10^{-6}\text{ V} = 15\ \mu\text{V}$$

6. **(10)** Given $dI = 0.25 - 0 = 0.25$ A
$dt = 0.025$ ms
Induced voltage
$E_{ind} = 100$ v
Self-inductance, L = ?

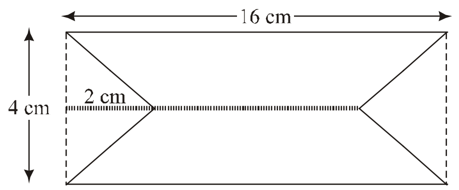
Using, $E_{\text{ind}} = \frac{\Delta\phi}{\Delta t} \Rightarrow 100 = \frac{L(0.25 - 0)}{.025 \times 10^{-3}}$

$\Rightarrow L = 10^{-3}$ H $= 10$ mH

7. **(a)** According to question, $dB = 1000 - 500 = 500$ gauss $= 500 \times 10^{-4} T$
Time $dt = 5$ s
Using faraday law

Induced EMF, $e = \left|-\frac{d\phi}{dt}\right| = \left|A\frac{dB}{dt}\right|$

$$\frac{dB}{dt} = \frac{1000 - 500}{5} \times 10^{-4} = 10^{-2}\text{ T/sec}$$



Area, A = ar of ▭ – 2 ar of Δ = (16 × 4 – 2 × Area of triangle) cm^2

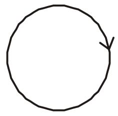
$$= \left(64 - 2 \times \frac{1}{2} \times 2 \times 4\right)\text{cm}^2$$

$= 56 \times 10^{-4}$ m^2

$\therefore \varepsilon_{\text{induced}} = \left|A\frac{dB}{dt}\right| = 56\times10^{-4}\times10^{-2} = 56\times10^{-6}V = 56\mu V$

8. **(d)** As magnetic field lines form close loop, hence every magnetic field line creating magnetic flux through the inner region (ϕ_i) must be passing through the outer region. Since flux in two regions are in opposite region.

$\therefore \quad \phi_i = -\phi_0$



9. **(d)** According to question,

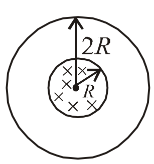
$I(t) = I_0 t(1-t)$

$\therefore I = I_0 t - I_0 t^2$

$\phi = B.A$

$\phi = (\mu_0 nI)\times(\pi R^2)$

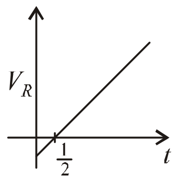
$(\because B = \mu_0 nI \text{ and } A = \pi R^2)$



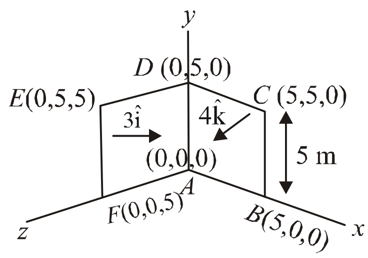
$V_R = \frac{-d\phi}{dt}$

$V_R = \mu_0 n\pi R^2(I_0 - 2I_0 t)$

$\Rightarrow V_R = 0 \text{ at } t = \frac{1}{2}s$



10. **(175.00)**



Flux through the loop ABCDEFA,

$\phi = \vec{B}.\vec{A} = (3\hat{i}+4\hat{k}).(25\hat{i}+25\hat{k})$

$\Rightarrow \phi = (3\times25)+(4\times25) = 175$ weber

11. **(b)** We have given, time period, $T = 10$s

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

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

Emf induced, $E = \frac{-d\phi}{dt} = BA\omega\sin\omega t = BA\omega\sin(\omega t)$

Induced emf, $|\varepsilon|$ is maximum when $\omega t = \frac{\pi}{2}$

$\Rightarrow t = \frac{\frac{\pi}{2}}{\frac{\pi}{5}} = 2.5$ s

For induced emf to be minimum i.e zero

$\omega t = \pi \quad \Rightarrow \quad t = \frac{\pi}{\frac{\pi}{5}} = 5\ s$

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

12. **(a)** $Q = BA$

$= (\mu_0 n_i)A$

$= \mu_0 n(kt\,e^{-\alpha t})A$

$e = -\frac{dQ}{dt} = -\mu_0 nAk\frac{d}{dt}(te^{-\alpha t})$

$= -\mu_0 nAk[t(-1)e^{-\alpha t} + e^{-\alpha t}\times1]$

$= -\mu_0 nAk[e^{-\alpha t}(1-t)]$

$i = \frac{e}{R} = \frac{-\mu_0 nAk}{R}[e^{-\alpha t}(1-t)]$

At $t = 0$, $i \Rightarrow$ –ve

13. **(a)** $Q_{\text{coil}} = (NQ) \propto i$

So, $\frac{Q_1}{Q_2} = \frac{i_1}{i_2} = \frac{3}{2}$

or $Q_2 = \frac{2}{3}Q_1 = \frac{2}{3}\times10^{-3} = 6.67\times10^{-4}$ Wb

14. **(b)** According to faraday's law of electromagnetic induction, $e = \frac{-d\phi}{dt}$

$L\times\frac{di}{dt} = 25 \Rightarrow L\times\frac{15}{1} = 25$ or $L = \frac{5}{3}H$

Change in the energy of the inductance,

$\Delta E = \frac{1}{2}L(i_1^2 - i_2^2) = \frac{1}{2}\times\frac{5}{3}\times(25^2 - 10^2)$

$= \frac{5}{6}\times525 = 437.5J$

15. **[Bonus]**

Net charge $Q = \frac{\Delta\phi}{R} = \frac{1}{10}A(B_f - B_i) = \frac{1}{10}\times3.5\times10^{-3}$

$\left(0.4\sin\frac{\pi}{2} - 0\right)$

$= \frac{1}{10}(3.5\times10^{-3})(0.4-0)$

$= 1.4\times10^{-4}$

No option matches, So it should be a bonus.

16. **(a)** According to Faraday's law of electromagnetic induction, $\varepsilon = \frac{d\phi}{dt}$

Also, $\varepsilon = iR$

$\therefore \quad iR = \frac{d\phi}{dt} \quad \Rightarrow \quad \int d\phi = R\int i\,dt$

Magnitude of change in flux ($d\phi$) = $R \times$ area under current vs time graph

or, $d\phi = 100 \times \frac{1}{2} \times \frac{1}{2} \times 10 = 250$ Wb

17. **(b)** Electric flux is given by
$\phi = B.A$

$$\phi = B_0 \pi r^2 e^{-t/\tau} \qquad \left(\because B = B_0 e^{-t/\tau}\right)$$

Induced E.m.f. $\varepsilon = \frac{d\phi}{dt} = \frac{B_0 \pi r^2}{\tau^2} e^{-t/\tau}$

Heat $= \int_0^\infty \frac{\varepsilon^2}{R} = \frac{\pi^2 r^4 B_0^2}{2\tau R}$

18. **(d)** According to Faraday's law of electromagnetic induction,

Induced emf, $e = \frac{Ldi}{dt}$

$$50 = L\left(\frac{5-2}{0.1\text{sec}}\right)$$

$\Rightarrow \quad L = \frac{50 \times 0.1}{3} = \frac{5}{3} = 1.67$ H

19. **(a)** Inside the sphere field varies linearly i.e., $E \propto r$ with distance and outside varies according to $E \propto \frac{1}{r^2}$

Hence the variation is shown by curve (a)

20. **(a)** **Given:** No. of turns $N = 1000$
Face area, $A = 4\text{ cm}^2 = 4 \times 10^{-4}\text{ m}^2$
Change in magnetic field,
$\Delta B = 10^{-2}\text{ wbm}^{-2}$
Time taken, $t = 0.01\text{s} = 10^{-2}$ sec
Emf induced in the coil $e = ?$
Applying formula,

Induced emf, $e = \frac{-d\phi}{dt} = N\left(\frac{\Delta B}{\Delta t}\right) A\cos\theta$

$$= \frac{1000 \times 10^{-2} \times 4 \times 10^{-4}}{10^{-2}} = 400\text{ mV}$$

21. **(a)** As we know, Magnetic flux, $\phi = B.A$

$$\frac{\mu_0 (2)(20 \times 10^{-2})^2}{2[(0.2)^2 + (0.15)^2]} \times \pi (0.3 \times 10^{-2})^2$$

On solving
$= 9.216 \times 10^{-11} = 9.2 \times 10^{-11}$ weber

22. **(a)** Induced emf

$$\varepsilon \propto \frac{-di}{dt}$$

23. **(d)** Because of the Lenz's law of conservation of energy.
Length of straignt wire, $\ell = 20$m Earth's Magneti field, $B = 0.30 \times 10^{-4}\text{ Wb/m}^2$.

24. **(c)** As $e = \frac{\Delta\phi}{\Delta t}$ or $Ri = \frac{\Delta\phi}{\Delta t}$ $\quad (\because e = Ri)$

$\Rightarrow \Delta\phi = R(i.\Delta t)$
$= R \times$ area under $i - t$ graph
$= 10 \times \frac{1}{2} \times 4 \times 0.1 = 2$ weber

25. **(b)** Electric flux, $\phi = 10t^2 - 50t + 250$

Induced emf, $e = -\frac{d\phi}{dt} = -(20t - 50)$
$e_{t=3} = -10\ V$

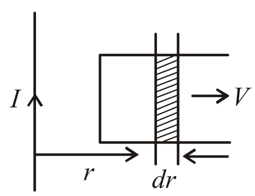
26. **(d)** Magnetic field at a distance r from the wire

$$B = \frac{\mu_0 I}{2\pi r}$$

Magnetic flux for small displacement dr,

$\phi = B \cdot A = Bldr \qquad [\because A = l\,dr$ and $B.A = BA\cos 0°]$

$$\Rightarrow \phi = \frac{\mu_0 I}{2\pi r} l\,dr$$



Emf, $e = \frac{d\phi}{dt} = \frac{\mu_0 Il}{2\pi r} \cdot \frac{dr}{dt} \Rightarrow e = \frac{\mu_0}{2\pi} \cdot \frac{Ivl}{r}$

Induce current in the loop, $i = \frac{e}{R} = \frac{\mu_0}{2\pi} \cdot \frac{Ivl}{Rr}$

27. **(b)** Induced emf,
$e = Bv\ell = 1 \times 10^{-2} \times 0.05 = 5 \times 10^{-4}$ V
Equivalent resistance,

$$R = \frac{4 \times 2}{4 + 2} + 1.7 = \frac{4}{3} + 1.7 \simeq 3\,\Omega$$

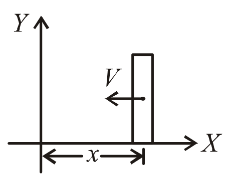
Current, $i = \frac{e}{R} = \frac{5 \times 10^{-4}}{3} \simeq 170\ \mu$A

28. **(d)** Inductance $= \frac{\mu_0 N^2 A}{L}$

29. **(c)** Force on the strip when it is at stretched position x from mean position is

$$F = -kx - iIB = -kx - \frac{BIv}{R} \times IB$$

$$F = -kx - \frac{B^2 I^2}{R} \times v$$



Above expression shows that it is case of damped oscillation, so its amplitude can be given by

$\Rightarrow A = A_0 e^{-\frac{bt}{2m}}$

$\Rightarrow \frac{A_0}{e} = A_0 e^{-\frac{bt}{2m}}$ [as per question $A = \frac{A_0}{e}$]

$\Rightarrow t = \frac{2m}{\left(\frac{B^2 l^2}{R}\right)} = \frac{2 \times 50 \times 10^{-3} \times 10}{0.01 \times 0.01}$

Given, $m = 50 \times 10^{-3}$ kg
B = 0.1 T
l = 0.1 m
R = 10 Ω
k = 0.5 N

Time period, $T = 2\pi\sqrt{\frac{m}{k}} \simeq 2$ s

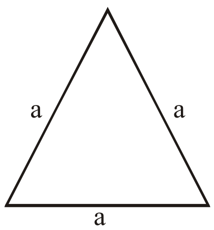
so, required number of oscillations,

$N = \frac{10000}{2} = 5000$

30. (a) Induced emf, $\varepsilon = Bv\ell$
$= 0.3 \times 10^{-4} \times 5 \times 10$
$= 1.5 \times 10^{-3}$ V

31. (d) The rate of mutual inductance is given by
$M = \mu_0 n_1 n_2 \pi r_1^2$ ...(i)
The rate of self inductance is given by
$L = \mu_0 n_1^2 \pi r_1^2$ ...(ii)
Dividing (i) by (ii) $\Rightarrow \frac{M}{L} = \frac{n_2}{n_1}$

32. (c) As total length L of the wire will remain constant
L = (3a) N (N = total turns)
and length of winding = (d) N



(d = diameter of wire)
self inductance = $\mu_0 n^2 A\ell$

$= \mu_0 n^2 \left(\frac{\sqrt{3}a^2}{4}\right) dN$

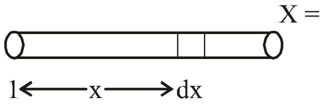
$\propto a^2 N \propto a$ [as $N = L/3a \Rightarrow N \propto \frac{1}{a}$]

Now 'a' increased to '3a'

So self inductance will become 3 times

33. (a) Potential difference between two faces perpendicular to x-axis
$= l V.B = 2 \times 10^{-2} (6 \times 0.1) = 12$ mV

34. (c)



Magnetic moment, M = NIA
dQ = ρ dx

$dI = \frac{dQ}{2\pi}.\omega$

dM = dI × A

$= \frac{\omega}{2\pi}.\frac{\rho_0}{\ell}.x\pi x^2\, dx \Rightarrow M = \frac{\rho_0}{\ell} n\pi \int_0^{\ell} x^3\, dx$

$= \frac{\pi}{4}.n\rho\ell^3$

35. (a) Induced emf in a coil, $e = -\frac{d\phi}{dt} = NBA \sin\omega t$
Also, $e = e_0 \sin\omega t$
∴ Maximum emf induced, $e_0 = nBA\omega$

36. (a) Given: Capacitance, $C = 0.2\ \mu F = 0.2 \times 10^{-6}$ F
Inductance L = 0.5 mH = 0.5×10^{-3} H
Current I = ?
Using energy conservation

$\frac{1}{2}CV^2 = \frac{1}{2}CV_1^2 + \frac{1}{2}LI^2$

$\frac{1}{2} \times 0.2 \times 10^{-6} \times 10^2 + 0$

$= \frac{1}{2} \times 0.2 \times 10^{-6} \times 5^2 + \frac{1}{2} \times 0.5 \times 10^{-3} I^2$

∴ $I = \sqrt{3} \times 10^{-1}$ A $= 0.17$ A

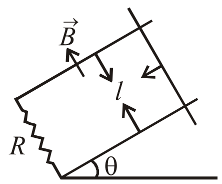
37. (b) From Faraday's law of electomagnetic induction,

$e = \frac{d\phi}{dt} = \frac{d(BA)}{lt} = \frac{d(Bll)}{dt}$

$= \frac{Bdl \times l}{dt} = BVl$

Also, $F = ilB = \left(\frac{BV}{R}\right)(l^2 B) = \frac{B^2 l^2 V}{R}$

At equilibrium



$mg\sin\theta = \frac{B^2 lV}{R} \Rightarrow V = \frac{mgR\sin\theta}{B^2 l^2}$

38. **(c)** According to Faraday's law of electromagnetic induction,

$$e=-\frac{d\phi}{dt} \text{ and } \phi = BA\cos\omega t = B\pi r^2 \cos\omega t$$

$$\Rightarrow \quad e=-\frac{d}{dt}(\pi r^2 B\cos\omega t)=\pi r^2 B\sin\omega t\,(\omega)$$

$$\therefore \quad e=\frac{\mu_0 I}{2R}\,\pi\omega r^2\sin\omega t \quad \left(\because\ B=\frac{\mu_0 I}{2R}\right)$$

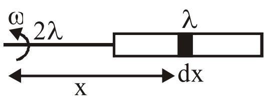
39. **(b)** In the given question,
Current flowing through the wire, I = 1A
Speed of the frame, v = 10 ms^{-1}
Side of square loop, l = 10 cm
Distance of square frame from current carrying wires x = 10 cm.
We have to find, e.m.f induced e = ?
According to Biot-Savart's law

$$B=\frac{\mu_0}{4\pi}\frac{Idl\sin\theta}{x^2}$$

$$=\frac{4\pi\times10^{-7}}{4\pi}\times\frac{1\times10^{-1}}{\left(10^{-1}\right)^2}$$

$= 10^{-6}$
Induced e.m.f. e = Blv
$= 10^{-6}\times10^{-1}\times10 = 1\ \mu v$

40. **(d)** Here, induced e.m.f.



$$e=\int_{2\ell}^{3\ell}(\omega x)Bdx = B\omega\frac{[(3\ell)^2-(2\ell)^2]}{2}$$

$$=\frac{5B\ell^2\omega}{2}$$

41. **(d)**

42. **(b)** Self inductance of a long solenoid is given by

$$L=\frac{\mu_0 N^2 A}{l}$$

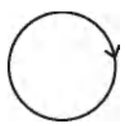
Magnetic field at the centre of solenoid

$$B=\frac{\mu_0 NI}{l}$$

So both the statements are correct and statement 2 is correct explanation of statement 1

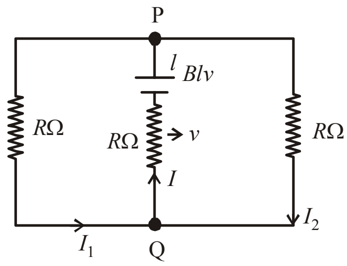
43. **(d)** As magnetic field lines form close loop, hence every magnetic field line creating magnetic flux through the inner region (ϕ_i) must be passing through the outer region. Since flux in two regions are in opposite region.

$\therefore\ \phi_i = -\phi_0$



44. **(a)** Induced, emF, $\varepsilon = Bv\ell$
$= 0.3\times10^{-4}\times5\times20$
$= 3\times10^{-3}$ V = 3 mV.

45. **(b)** Due to the movement of resistor R, an emf equal to Blv will be induced in it as shown in figure clearly,



$I = I_1 + I_2 \qquad$ Also, $I_1 = I_2$
Solving the circuit,

we get $I_1 = I_2 = \dfrac{Blv}{3R}$

and $I = 2I_1 = \dfrac{2Blv}{3R}$

46. **(d)** Given, Area of cross-section of pipe,
$A = 10\ cm^2$
Length of pipe, $\ell = 20$ cm

$$M=\frac{\mu_0 N_1 N_2 A}{\ell}$$

$$=\frac{4\pi\times10^{-7}\times300\times400\times100\times10^{-4}}{0.2}$$

$$M=\frac{\mu_0 N_1 N_2 A}{\ell}$$

$= 2.4\pi\times10^{-4}$ H

47. **(c)** Relative velocity of the tube of width l,
$= v-(-v)\ v = 2v$
$\therefore$ Induced emf. $= B.l\,(2v)$

48. **(b)** Given, length of conductor $\ell = 1$m,
Angular speed, $\omega = 5$ rad/s,
Magnetic field, $B = 0.2\times10^{-4}\ T$
EmF generated between two ends of conductor

$$\varepsilon=\frac{B\omega l^2}{2}=\frac{0.2\times10^{-4}\times5\times1}{2}=50\mu V$$

49. **(b)** $\dfrac{\Delta\phi}{\Delta t}=\dfrac{(W_2-W_1)}{t}$

$$R_{tot}=(R+4R)\Omega = 5R\,\Omega$$

$$i=\frac{nd\phi}{R_{tot}dt}=\frac{-n(W_2-W_1)}{5Rt}$$

($\because W_2$ & W_1 are magnetic flux)

50. **(b)** Mutual inductance depends on the relative position and orientation of the two coils.

51. **(d)** Induced emf,

$$e = -\frac{\Delta\phi}{\Delta t} = \frac{-\Delta(LI)}{\Delta t} = -L\frac{\Delta I}{\Delta t}$$

$$\therefore |e| = L\frac{\Delta I}{\Delta t}$$

$$\Rightarrow 8 = L \times \frac{[2-(-2)]}{0.05}$$

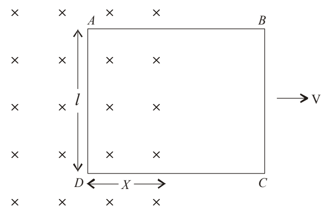
$$\Rightarrow L = \frac{8 \times 0.05}{4} = 0.1\text{H}$$

52. **(d)** As the side BC is outside the field, no emf is induced across BC. Further, sides AB and CD are not cutting any flux. So, they will not centribute in flux.

Only side AD is cutting the flux 50 emf will be induced due to AD only.

The induced emf is

$$e = \frac{-d\phi}{dt} = -\frac{d(\vec{B}\cdot\vec{A})}{dt} = \frac{-d(BA\cos 0^{\circ})}{dt}$$



$$\therefore \boldsymbol{e} = -B\frac{dA}{dt} = -B\frac{d(\ell \times x)}{dt}$$

$$\therefore e = -B\ell\frac{dx}{dt} = -B\ell v$$