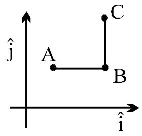
GUIDED REVISION

SECTION-I

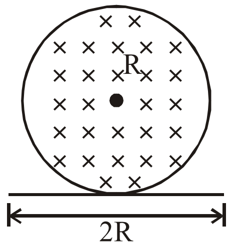
Single Correct Answer Type **9 Q. [3 M (–1)]**

1. There is a uniform magnetic field B normal to the xy plane. A conductor ABC has length AB = l_1, parallel to the x-axis, and length BC = l_2, parallel to the y-axis. ABC moves in the xy plane with velocity $v_x\hat{i}+v_y\hat{j}$. The potential difference between A and C is proportional to :-



(A) $v_x l_1 + v_y l_2$ (B) $v_x l_2 + v_y l_1$ (C) $v_x l_2 - v_y l_1$ (D) $v_x l_1 - v_y l_2$

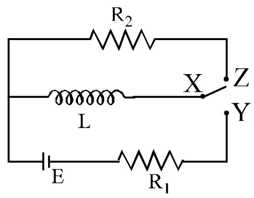
2. A uniform but time varying magnetic field is present in a circular region of radius R. The magnetic field is perpendicular and into the plane of the loop and the magnitude of field is increasing at a constant rate α. There is a straight conducting rod of length 2R placed as shown in figure. The magnitude of induced emf across the rod is



(A) $\pi R^2\alpha$ (B) $\frac{\pi R^2\alpha}{2}$

(C) $\frac{R^2\alpha}{\sqrt{2}}$ (D) $\frac{\pi R^2\alpha}{4}$

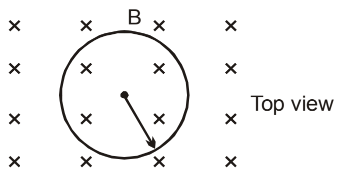
3. In the circuit shown, X is joined to Y for a long time, and then X is joined to Z. The total heat produced in R_2 is :



(A) $\frac{LE^2}{2R_1^2}$ (B) $\frac{LE^2}{2R_2^2}$

(C) $\frac{LE^2}{2R_1R_2}$ (D) $\frac{LE^2R_2}{2R_1^2}$

4. A non conducting ring (of mass m, radius r, having charge Q) is placed on a rough horizontal surface (in a region with transverse magnetic field). The field is increasing with time at the rate R and coefficient of friction between the surface and the ring is μ. For ring to remain in equilibrium μ should be greater than:-



(A) $\frac{QrR}{mg}$ (B) $\frac{QrR}{2mg}$ (C) $\frac{QrR}{3mg}$ (D) $\frac{2QrR}{mg}$

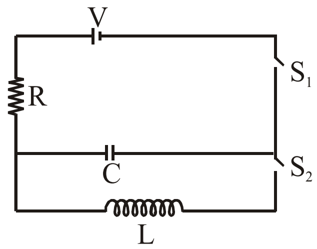
5. A composite rod of length ℓ is one fourth insulator and remaining conductor is made to rotate freely with angular velocity ω, in a space free of any gravitational, electric & magnetic field. Then potential difference across the conducting region will be (rotation is about insulating end).

(A) $\frac{3m_e\omega^2\ell^2}{4e}$ (B) $\frac{1}{4}\frac{m_e\omega^2\ell^2}{e}$ (C) $\frac{1}{16}\frac{m_e\omega^2\ell^2}{e}$ (D) $\frac{15}{32}\frac{m_e\omega^2\ell^2}{e}$

6. A resistor of 500 Ω and an inductor of 0.5 H are in series with an AC voltage source which is given by $V = 100\sqrt{2}$ sin (1000 t). The power factor of the combination is :

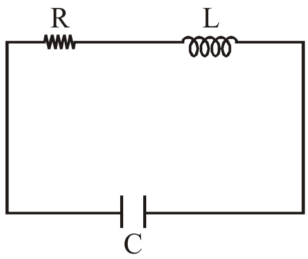
(A) $\frac{1}{\sqrt{2}}$ (B) $\frac{1}{\sqrt{3}}$ (C) 0.5 (D) 0.6

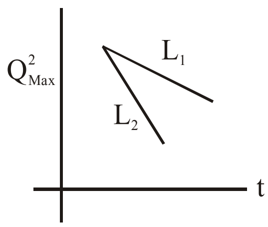
7. In an LCR circuit as shown below both switches are open initially. Now switch S_1 is closed, S_2 kept open, (q is charge on the capacitor and τ = RC is Capacitive time constant). Which of the following statement is correct? **[JEE Main-2013]**

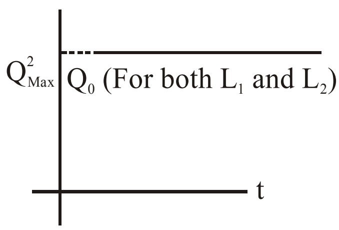


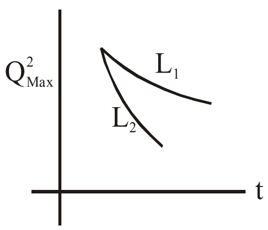
(A) Work done by the battery is half of the energy dissipated in the resistor
(B) At t = τ, q = CV/2
(C) At t = 2τ, q = CV(1–e^{-2})
(D) At $t = \frac{\tau}{2}$, q = CV(1–e^{-1})

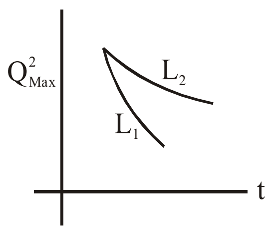
8. An LCR circuit is equivalent to a damped pendulum. In an LCR circuit the capacitor is charged to Q_0 and then connected to the L and R as shown below. If a student plots graphs of the square of maximum charge (Q^2_{Max}) on the capacitor with time (t) for two different values L_1 and L_2 $(L_1 > L_2)$ of L then which of the following represents this graph correctly ? (plots are schematic and not drawn to scale) **[JEE Main-2015]**



(A)


(B)


(C)


(D)


9. In an a. c. circuit, the instantaneous e.m.f. and current are given by
$e = 100 \sin 30t$

$i = 20 \sin\left(30t - \frac{\pi}{4}\right)$

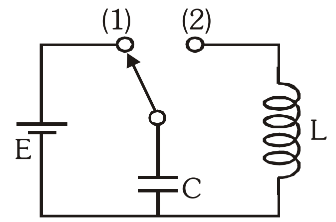
In one cycle of a.c., the average power consumed by the circuit and the wattless current are, respectively.

[JEE Main-2018]

(A) $\frac{1000}{\sqrt{2}}, 10$ (B) $\frac{50}{\sqrt{2}}, 0$ (C) 50, 0 (D) 50, 10

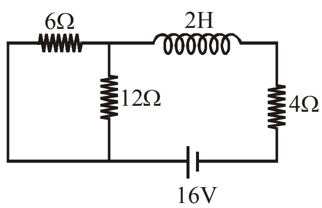
Multiple Correct Answer Type 6 Q. [4 M (–1)]

10. Initially key was placed on (1) till the capacitor got fully charged. Key is placed on (2) at t = 0. The time when the energy in both capacitor and inductor will be same-



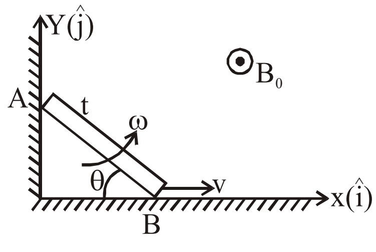
(A) $\frac{\pi\sqrt{LC}}{4}$ (B) $\frac{\pi\sqrt{LC}}{2}$ (C) $\frac{5\pi\sqrt{LC}}{4}$ (D) $\frac{5\pi\sqrt{LC}}{2}$

11. For the circuit shown. Which of the following statements is correct :-



(A) Its time constant is 0.25 second
(B) In steady state, current through inductance will be equal to zero
(C) In steady state, current through inductor is 2A
(D) Current grows to 1.5A in $t = \ell n\sqrt{2}$

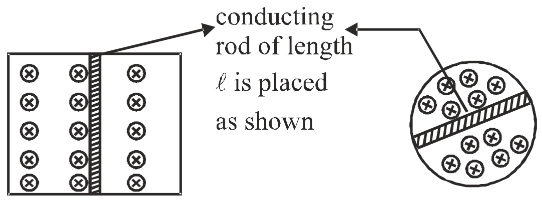
12. A thin conducting rod of length ℓ is moved such that its end B moves along the X-axis while end A moves along the Y-axis. A uniform magnetic field $B = B_0\hat{k}$ exists in the region. At some instant, velocity of end B is v and the rod makes an angle of $\theta = 60°$ with the X-axis as shown in the figure. Then, at this instant



(A) angular speed of rod AB is $\omega = \frac{2v}{\sqrt{3}\ell}$ (B) angular speed of rod AB is $\omega = \frac{\sqrt{3}v}{2\ell}$

(C) e.m.f. induced in rod AB is $B\ell v\sqrt{3}$ (D) e.m.f. induced in rod AB is $B\ell v/2\sqrt{3}$

13. Magnetic field in the regions shown is varying with respect to time then potential difference across the length of the rod :-



Magnetic field is confined within the square boundary

I

Rod is along the diameter

Magnetic field is confined within the cylindrical boundary

II

(A) is zero in case II

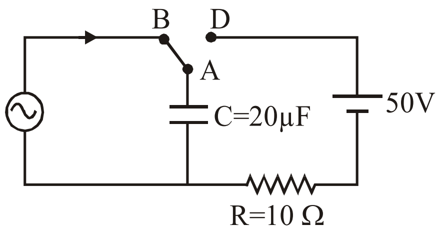
(B) is non-zero in case I

(C) is zero in both the cases

(D) is zero in case II and can not be determined in case I

14. At time t = 0, terminal A in the circuit shown in the figure is connected to B by a key and an alternating current $I(t) = I_0\cos(\omega t)$, with $I_0 = 1A$ and $\omega = 500$ rad s^{-1} starts flowing in it with the initial direction shown in the figure. At $t=\frac{7\pi}{6\omega}$, the key is switched from B to D. Now onwards only A and D are connected. A total charge Q flows from the battery to charge the capacitor fully. If C = 20 μF, R = 10 Ω and the battery is ideal with emf of 50 V, identify the correct statement (s).

[JEE Advance-2014]



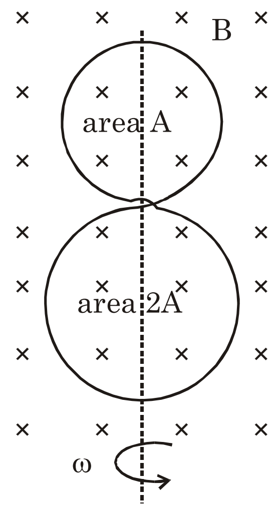
(A) Magnitude of the maximum charge on the capacitor before $t=\frac{7\pi}{6\omega}$ is 1×10^{-3}C.

(B) The current in the left part of the circuit just before $t=\frac{7\pi}{6\omega}$ is clockwise.

(C) Immediately after A is connected to D, the current in R is 10A

(D) $Q = 2 \times 10^{-3}$ C

15. A circular insulated copper wire loop is twisted to form two loops of area A and 2A as shown in the figure. *At the point of crossing the wires remain electrically insulated from each other.* The entire loop lies in the plane (of the paper). A uniform magnetic field $\vec{B}$ points into the plane of the paper. At t = 0, the loop starts rotating about the common diameter as axis with a constant angular velocity ω in the magnetic field. Which of the following options is/are correct? **[JEE Advance-2017]**



(A) The rate of change of the flux is maximum when the plane of the loops is perpendicular to plane of the paper

(B) The net emf induced due to both the loops is proportional to cos ωt

(C) The emf induced in the loop is proportional to the sum of the areas of the two loops

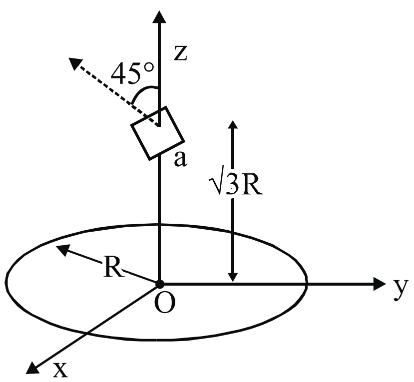
(D) The amplitude of the maximum net emf induced due to both the loops is equal to the amplitude of maximum emf induced in the smaller loop alone

SECTION-III

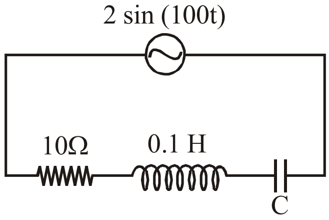
Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. A circular wire loop of radius R is placed in the x-y plane centred at the origin O. A square loop of side a (a<<R) having two turns is placed with its centre at z = $\sqrt{3}$ R along the axis of the circular wire loop, as shown in figure. The plane of the square loop makes an angle of 45° with respect to the z-axis. If the mutual inductance between the loops is given by $\frac{\mu_0 a^2}{2^{p/2} R}$, then the value of p is :-

[JEE 2012]



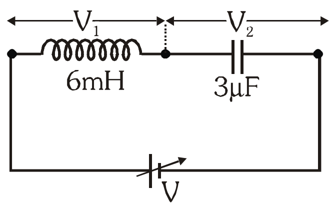
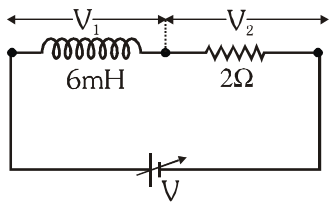
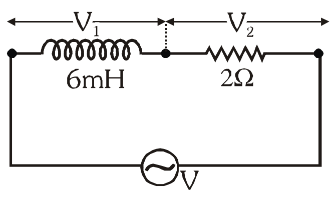
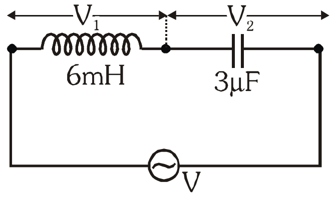
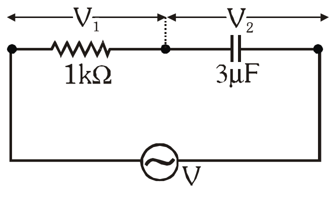
2. The power factor of the circuit is $\frac{1}{\sqrt{2}}$. If the capacitance of the circuit is (125 λ) μF. Find the value of λ.



SECTION-IV

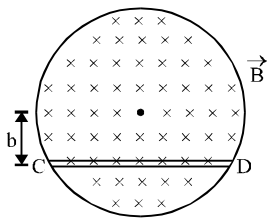
Matrix Match Type (4 × 5) **1 Q. [8 M (for each entry +2(0)]**

1. You are given many resistances, capacitors and inductors. These are connected to a variable DC voltage source (the first two circuits) or an AC voltage source of 50 Hz frequency (the next three circuits) in different ways as shown in **Column II**. When a current I (steady state for DC or rms for AC) flows through the circuit, the corresponding voltage V_1 and V_2 (indicated in circuits) are related as shown in **Column I**. Match the two **[JEE 2010]**

Column-I	Column-II
(A) $I \neq 0$, V_1 is proportional to I	(P) 
(B) $I \neq 0$, $V_2 > V_1$	(Q) 
(C) $V_1 = 0$, $V_2 = V$	(R) 
(D) $I \neq 0$, V_2 is proportional to I	(S) 
	(T) 

Subjective Type 12 Q. [4 M (0)]

1. A uniform magnetic field $\vec{B}$ fills a cylindrical volumes of radius R. A metal rod CD of length l is placed inside the cylinder along a chord of the circular cross-section as shown in the figure. If the magnitude of magnetic field increases in the direction of field at a constant rate dB/dt, find the magnitude and direction of the EMF induced in the rod.



2. An inductor of inductance 2.0mH,is connected across a charged capacitor of capacitance 5.0μF and the resulting LC circuit is set oscillating at its natural frequency. Let Q denote the instantaneous charge on the capacitor, and I the current in the circuit .It is found that the maximum value of Q is 200μC.

(a) when Q = 100μC, what is the value of $|dI/dt|$?

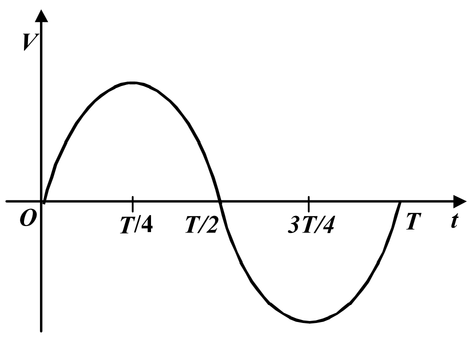
(b) when Q = 200 μC, what is the value of I ?

(c) Find the maximum value of I.

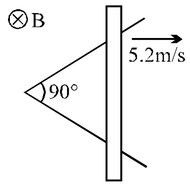
(d) when I is equal to one half its maximum value, what is the value of $|Q|$

3. An LCR series circuit with 100Ω resistance is connected to an ac source of 200 V and angular frequency 300 rad/s. When only the capacitance is removed, the current lags behind the voltage by 60°. When only the inductance is removed, the current leads the voltage by 60°. Calculate the current and the power dissipated in the LCR circuit.

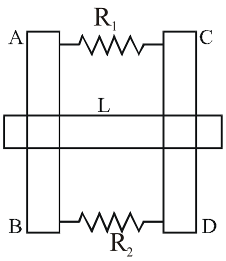
4. In an LR series circuit, a sinusoidal voltage $V = V_o \sin \omega t$ is applied. It is given that L = 35 mH, $R = 11\ \Omega$, $V_{rms} = 220$ V, $\frac{\omega}{2\pi} = 50$ Hz and $\pi = 22/7$. Find the amplitude of current in the steady state and obtain the phase difference between the current and the voltage. Also plot the variation of current for one cycle on the given graph. **[JEE 2004]**



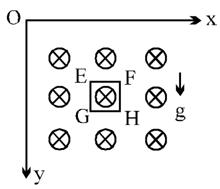
5. Two straight conducting rails form a right angle where their ends are joined. A conducting bar contact with the rails starts at vertex at the time t = 0 & moves symmetrically with a constant velocity of 5.2 m/s to the right as shown in figure. A 0.35 T magnetic field points out of the page. Calculate:
(i) The flux through the triangle by the rails & bar at t = 3.0 s.
(ii) The emf around the triangle at that time.
(iii) In what manner does the emf around the triangle vary with time .



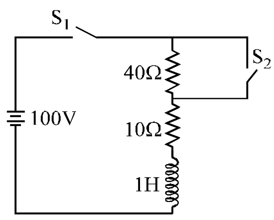
6. Two parallel vertical metallic rails AB & CD are separated by 1 m. They are connected at the two ends by resistance R_1 & R_2 as shown in the figure. A horizontally metallic bar L of mass 0.2 kg slides without friction, vertically down the rails under the action of gravity. There is a uniform horizontal magnetic field of 0.6T perpendicular to the plane of the rails, it is observed that when the terminal velocity is attained, the power dissipated in R_1 & R_2 are 0.76 W & 1.2 W respectively. Find the terminal velocity of bar L & value R_1 & R_2.



7. A magnetic field $B = (B_0 y / a)\ \hat{k}$ is into the plane of paper in the +z direction. B_0 and a are positive constants. A square loop EFGH of side a, mass m and resistance R, in x-y plane, starts falling under the influence of gravity. Note the directions of x and y axes in the figure. Find
(a) the induced current in the loop and indicate its direction,
(b) the total Lorentz force acting on the loop and indicate its direction,
(c) an expression for the speed of the loop, v(t) and its terminal value.

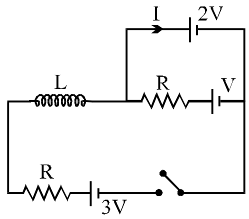


8. In the circuit shown in the figure the switched S_1 and S_2 are closed at time t = 0. After time t = (0.1) ln 2 sec, switch S_2 is opened. Find the current in the circuit at time t = (0.2) ln 2 sec.



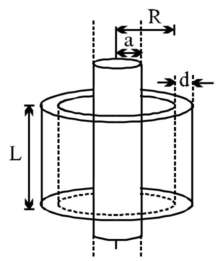
9. A zero resistance coil of inductance L connects the upper ends of two vertical parallel long conductors. A horizontal sliding conductor, free to slide up and down, always maintaining contact with the vertical conductors, starts falling from rest at t = 0, due to its own weight mg. A uniform magnetic field of magnitude B exists in the region horizontally and perpendicular to the plane of the conductors. The distance between the vertical conductors is 'l'. After what time does the conductor come back to its starting position? Also find maximum speed achieved.

10. In the LR circuit shown, what is the variation of the current I as a function of time? The switch is closed at time t = 0 sec.



11. A box P and a coil Q are connected in series with an ac source of variable frequency. The emf of source is 10 V. Box P contains a capacitance of 1μF in series with a resistance of 32Ω while coil Q has a self-inductance 4.9 mH and a resistance of 68Ω series. The frequency is adjusted so that the maximum current flows in P and Q. Find the impedance of P and Q at this frequency. Also find the voltage across P and Q respectively.

12. A long solenoid of radius a and number of turns per unit length n is enclosed by cylindrical shell of radius R, thickness d (d <<R) and length L. A variable current $i = i_0 \sin \omega t$ flows through the coil. If the resistivity of the material of cylindrical shell is ρ, find the induced current in the shell. **[JEE 2005]**



SECTION-I

Single Correct Answer Type **9 Q. [3 M (–1)]**

1. Ans. (C) **2. Ans. (D)** **3. Ans. (A)** **4. Ans. (B)**
5. Ans. (D) **6. Ans. (A)** **7. Ans. (C)** **8. Ans. (C)**
9. Ans. (A)

Multiple Correct Answer Type **6 Q. [4 M (–1)]**

10. Ans. (A,C) 11. Ans. (A,C,D) 12. **Ans. (A, D)** **13. Ans. (A, D)**
14. Ans. (C,D) **15. Ans. (A, D)**

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) **2 Q. [4 M (0)]**

1. Ans. 7 **2. Ans. 4**

SECTION-IV

Matrix Match Type (4 × 5) **1 Q. [8 M (for each entry +2(0)]**

1. Ans. (A)-R,S,T; (B)-Q,R,S,T; (C)-P,Q; (D)-Q,R,S,T

Subjective Type **12 Q. [4 M (0)]**

1. Ans. $\frac{l}{2}\frac{dB}{dt}\sqrt{R^2-\frac{l^2}{4}}$ **2. Ans.** (a)10^4A/s (b) 0 (c) 2A (d) $100\sqrt{3}\,\mu C$

3. Ans. 2A, 400W **4. Ans.** 20 A, $\pi/4$, **5. Ans.** (i) 85.22 Tm^2; (ii) 56.8 V; (iii) linearly

6. Ans. $V = 1\ ms^{-1}$, $R_1 = 0.47\ \Omega$, $R_2 = 0.30\ \Omega$

7. Ans. (a) $i = \frac{B_0av}{R}$ in anticlockwise direction, v = velocity at time t, (b) $F_{nett}=B_0^2a^2V/R$,

(c) $V = \frac{mgR}{B_0^2a^2}\left(1-e^{-\frac{B_0^2a^2t}{mR}}\right)$

8. Ans. 67/32 A **9. Ans.** $2\pi\frac{\sqrt{mL}}{lB}, g\frac{\sqrt{mL}}{lB}$ **10. Ans.** $-\frac{V}{R}e^{-\frac{Rt}{L}}$

11. Ans. 77Ω, 97.6Ω, 7.7 V, 9.76 V **12. Ans.** $I = \frac{(\mu_0 n i_0 \omega\cos\omega t)\pi a^2(Ld)}{\rho 2\pi R}$

SOLUTIONS
SECTION-I

Single Correct Answer Type **9 Q. [3 M (–1)]**

1. **Ans. (C)**

Sol. $\Delta V = \left(\vec{V} \times \vec{B}\right) \cdot \vec{\ell}$

$\left[\left(v_x\hat{i} + v_y\hat{j}\right) \times B\hat{k}\right] \cdot \left(\ell_1\hat{i} + \ell_2\hat{j}\right)$

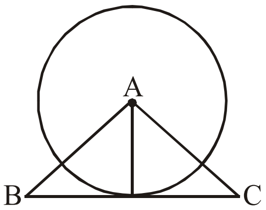
$= \left(-v_xB\hat{j} + v_yB\hat{i}\right) \cdot \left(\ell_1\hat{i} + \ell_2\hat{j}\right)$

$= -v_xB\ell_2 + v_yB\ell_1$

$|\Delta V| \propto \left(v_x\ell_2 - v_y\ell_1\right)$

2. **Ans. (D)**

Sol.



$$\int_{AB} \vec{E}.\overrightarrow{d\ell} + \int_{BC} \vec{E}.\overrightarrow{d\ell} + \int_{CA} \vec{E}d\ell = \frac{\pi R^2}{4}\alpha$$

$$0 + \Delta\varepsilon + 0 = \frac{\pi R^2\alpha}{4}$$

3. **Ans. (A)**

Sol. Current through inductor

$$i = \frac{E}{R_1}$$

Energy stored in inductor = heat produced

$$= \frac{1}{2}Li^2 = \frac{1}{2}L\left(\frac{E}{R_1}\right)^2$$

4. **Ans. (B)**

Sol. $E(2\pi r) = \pi r^2 \frac{dB}{dt}$ (induced electric field)

$$E = \left(\frac{r}{2}\right)\frac{dB}{dt} = \frac{r}{2}R$$

$$\tau_f = \mu mg(r)$$

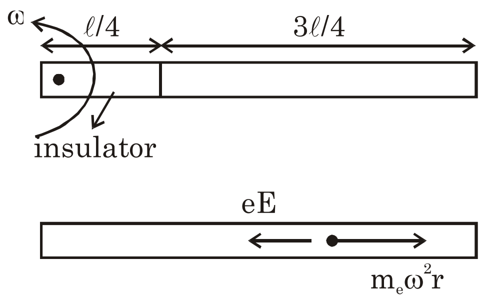
$$\tau_{field} = Q\left(\frac{r}{2}R\right)r$$

$$\mu_{min} mg\, r = \frac{QrR}{2} r$$

$$\mu_{min} = \frac{QrR}{2mg}$$

5. Ans. (D)

Sol. $eE = m_e \omega^2 r$



$$E = \frac{m_e \omega^2 r}{e}$$

$$|\Delta V| = \int E d\ell = \int_{\ell/4}^{\ell} \frac{m_e \omega^2 r}{e} dr$$

$$|\Delta V| = \frac{m_e \omega^2}{2e}\left(\ell^2 - \frac{\ell^2}{16}\right) = \frac{m_e \omega^2 15\ell^2}{32\,e}$$

6. Ans. (A)

Sol. $R = 500\ \Omega$

$X_L = \omega \times L = 1000 \times 0.5 = 500$

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

7. Ans. (C)

Sol. For charging of capacitor

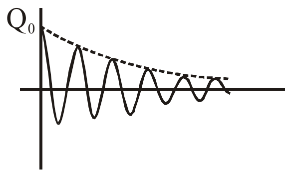
$q = CV\,(1 - e^{-\tau/RC})$ $\qquad \tau = RC$

here $t = 2\tau$

$q = CV\,(1 - e^{-2\tau/\tau}) = CV\,(1 - e^{-2})$

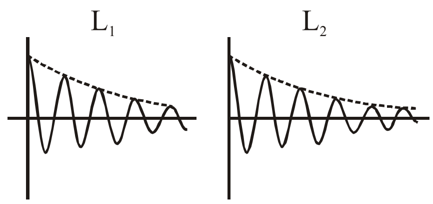
8. Ans. (C)

Sol. As damping is happening its amplitude would vary as



The oscillations decay exponentially and will be proportional to $e^{-\gamma t}$ where γ depends inversely on L. So as inductance increases decay becomes slower

$\therefore$ for



9. Ans. (A)

Sol. $P_{avg} = V_{rms}\, I_{rms} \cos\theta$

$$= \left(\frac{V_0}{\sqrt{2}}\right)\left(\frac{I_0}{\sqrt{2}}\right)\cos\theta$$

$= \left(\frac{100}{\sqrt{2}}\right)\left(\frac{20}{\sqrt{2}}\right)\cos 45^\circ$

$= \frac{1000}{\sqrt{2}}$ watt

wattless current = $I_{rms}\ \sin\theta$

$= \frac{I_0}{\sqrt{2}}\sin\theta$

$= \frac{20}{\sqrt{2}}\ \sin 45^\circ$

= 10 amp.

Multiple Correct Answer Type 6 Q. [4 M (–1)]

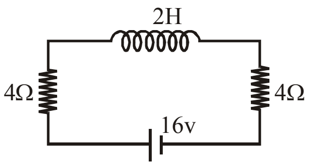
10. Ans. (A,C)

Sol. For given situation $\frac{q}{C} + L\frac{di}{dt} = 0 \Rightarrow \frac{d^2q}{dt^2} + \frac{q}{LC} = 0 \Rightarrow \frac{d^2q}{dt^2} + \omega^2 q = 0 \Rightarrow q = q_0 \cos \omega t$ & $i = -q_0\omega\sin\omega t$

According to given conditions $\frac{q^2}{2C} = \frac{1}{2}Li^2 \Rightarrow \frac{q_0^2\cos^2\omega t}{2C} = \frac{1}{2}Lq_0^2\omega^2\sin^2\omega t$

$\Rightarrow \cot^2\omega t = 1 \Rightarrow \omega t = \frac{\pi}{4}, \frac{3\pi}{4}, \frac{5\pi}{4}, \frac{7\pi}{4}$ .... $\left(\omega = \frac{1}{\sqrt{LC}}\right)$

11. Ans. (A,C,D)

Sol. 

$\tau = \frac{L}{R}$ $R_{eq} = 8$

$\tau = \frac{2}{8} = \frac{1}{4}$

equivalent diagram.

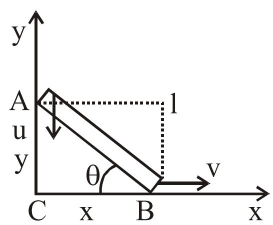
$i = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$

$i = \frac{16}{8}\left(1 - e^{-\frac{\ell n\sqrt{2}}{0.25}}\right)$

i = 1.5 A

12. Ans. (A, D)

Sol. $u = v\cot\theta$



$\omega = \frac{v}{\ell\sin\theta} = \frac{2v}{\sqrt{3}\ell}$

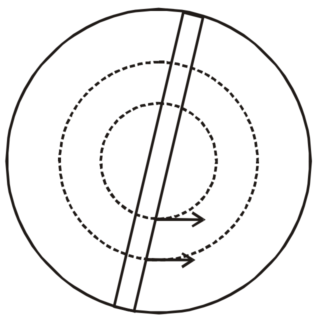
Consider an imaginary conducting loop ABC. $\phi = \left(\frac{1}{2}xy\right)B$

e.m.f. in this loop = motional e.m.f. in the rod = $-\frac{B}{2}\frac{d(xy)}{dt} = -\frac{B}{2}[yv - xu]\left[\because \frac{dy}{dt} = -u\right]$

$= \frac{B\ell v\cos 2\theta}{2\sin\theta}$

13. Ans. (A, D)

Sol. Component of electric field along rod is zero



14. Ans. (C,D)

Sol. As current leads voltage by $\pi/2$ in the given circuit initiallty, then ac voltage can be represent as

$V = V_0 \sin\omega t$

$q = CV_0\sin\omega t = Q\sin\omega t,\ i = \frac{dq}{dt}$

Where, $Q = 2 \times 10^{-3}$ C

At $t = 7\pi/6\omega$; $I = -\frac{\sqrt{3}}{2}I_0$ and hence currrent is anticlockwise.

Current 'i' immediately after $t = \frac{7\pi}{6\omega}$ is

$i = \frac{V_C + 50}{R} = 10A$

- Charge flow = $Q_{final} - Q_{(7\pi/6\omega)} = 2 \times 10^{-6}$ C

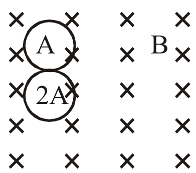
Hence C & D are correct options.

15. Ans. (A, D)

Sol. $\phi = |B||A|\cos\theta$

$= BA\cos(\omega t)$

$\varepsilon = -\frac{d\phi}{dt} = BA\omega\sin(\omega t)$



so, ε & $\frac{d\phi}{dt} \propto \sin(\omega t)$

so, maximum when , $\omega t = \theta = \frac{\pi}{2}$.

Net emf will be difference of emfs in both loops because their polarities are opposite.

$\varepsilon_{Net} = \varepsilon_{2A} - \varepsilon_A = B(2A)\omega\sin\omega t - B(A)\omega\sin(\omega t)$

$= B(2A - A)\omega\sin\omega t = BA\omega\sin\omega t$

SECTION-III

Numerical Grid Type (Ranging from 0 to 9) 2 Q. [4 M (0)]

1. Ans. 7

Sol. Magnetic field at a distance x along axis of a circular coil is given by $B(x) = \dfrac{\mu_0 i R^2}{2(R^2 + x^2)^{3/2}}$

Flux linked with N coils of square loop inclined at $\theta = 45°$ with vertical is given by

$$\phi(x) = \left[\frac{\mu_0 i R^2}{2(R^2 + x^2)^{3/2}}\right] N(a^2)(\cos 45°)$$

As $\phi = Mi$ So $M = \dfrac{\mu_0 R^2 (2)}{2\left[R^2 + (\sqrt{3}R)^2\right]^{3/2}}\left(\dfrac{a^2}{\sqrt{2}}\right) = \dfrac{\mu_0 a^2}{2^{7/2} R}$ thus $p = 7$

2. Ans. 4

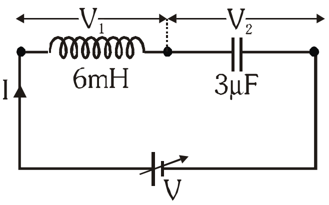
Sol. $\cos\phi = \dfrac{R}{\sqrt{R^2 + \left(\dfrac{1}{\omega C} - \omega L\right)^2}}$

SECTION-IV

Matrix Match Type (4 × 5) 1 Q. [8 M (for each entry +2(0)]

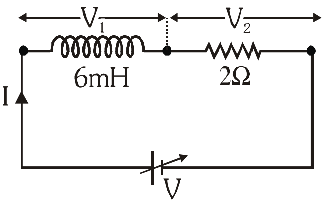
1. Ans. (A)-R,S,T; (B)-Q,R,S,T; (C)-P,Q; (D)-Q,R,S,T

Sol. For (p)



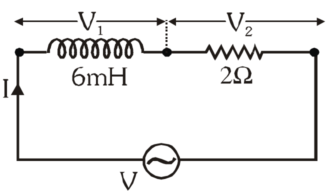
$V_1 + V_2 = V \Rightarrow L\dfrac{dI}{dt} + \dfrac{q}{C} = V \Rightarrow L\dfrac{d^2I}{dt^2} + \dfrac{I}{C} = 0 \Rightarrow$ L.C. oscillation

For (q)



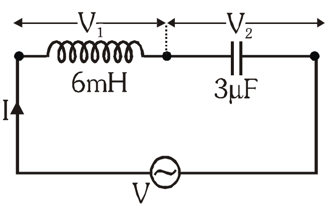
$I \neq 0, V_1 = 0, V_2 = V$ and $V_2 = V = IR \Rightarrow V_2 \propto I$

For (r)

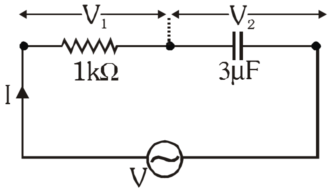


$I \neq 0, V_1^2 + V_2^2 = V^2$ Here $X_L < 2\Omega$ So $V_2 > V_1$

For (s)



Here $\omega \neq \dfrac{1}{\sqrt{LC}}$ so $I \neq 0$ Here $X_C > X_L$ so $V_2 > V_1$

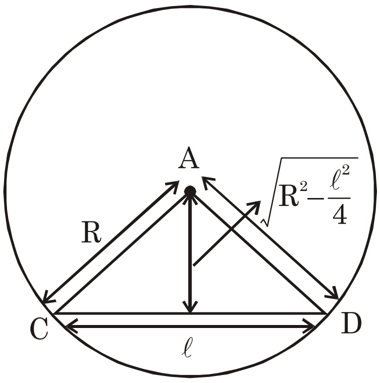
For (t) 

$I \neq 0, V^2 = V_1^2 + V_2^2$ Here $X_C < 1000$ so $V_2 > V_1$

Subjective Type **12 Q. [4 M (0)]**

1. **Ans.** $\frac{l}{2}\frac{dB}{dt}\sqrt{R^2 - \frac{l^2}{4}}$

Sol.



$$\phi_{ACD} = \left(\frac{1}{2}\ell\sqrt{R^2 - \frac{\ell^2}{4}}\right)B$$

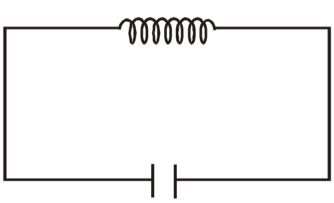
$$\varepsilon_{ACD} = \left(\frac{1}{2}\ell\sqrt{R^2 - \frac{\ell^2}{4}}\right)\frac{dB}{dt}$$

$$\underbrace{\cancel{\varepsilon_{AC}}}_{O} + \varepsilon_{CD} + \underbrace{\cancel{\varepsilon_{DA}}}_{O} = \varepsilon_{ACD}$$

$$|\varepsilon_{CD}| = \frac{\ell}{2}\frac{dB}{dt}\sqrt{R^2 - \frac{\ell^2}{4}}$$

2. **Ans.** (a) 10^4 A/s (b) 0 (c) 2A (d) $100\sqrt{3}\ \mu C$

Sol.



$Q_0 = 200\mu C$

Given : $C = 5\ \mu F$ $L = 2mH$

$|V_C| = |V_L|$

(a) $\frac{Q_0}{C} = L\left|\frac{di}{dt}\right| \Rightarrow \left|\frac{di}{dt}\right| = 10^4$

(b) When Q is maximum

$$\frac{dQ}{dt} = i = 0$$

(c) Using energy conservation

$$\frac{Q_0^2}{2C} = \frac{1}{2}Li_0^2$$

$$\frac{\left(200\times10^{-6}\right)^2}{2\times5\times10^{-6}} = \frac{1}{2}\times2\times10^{-3}i_0^2$$

(d) Using energy conservation

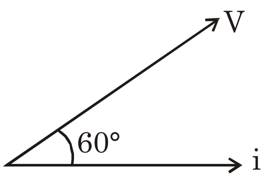
$$\frac{Q_0^2}{2C} = \frac{1}{2}L\left(\frac{i_0}{2}\right)^2 + \frac{Q^2}{2C} = \frac{\frac{1}{2}Li_0^2}{4} + \frac{Q^2}{2C}$$

$$\frac{Q_0^2}{2C} = \frac{\left(\frac{Q_0^2}{2C}\right)}{4} + \frac{Q^2}{2C}$$

$$Q = \frac{\sqrt{3}}{2}Q_0 = 100\sqrt{3}$$

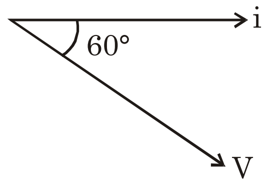
3. **Ans.** 2A, 400W

Sol.



When capacitor is removed

$$\tan 60° = \frac{X_L}{R}$$



When inductor is removed

$$\tan 60° = \frac{X_C}{R}$$

$\Rightarrow X_L = X_C$

When both are present circuit is in resonance

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

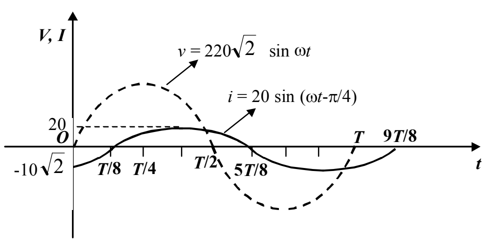
$$i = \frac{200}{100} = 2$$

$P = i^2R$

$P = 400$

4. **Ans.** 20 A, $\pi/4$,

Sol. $\therefore$ Steady state current $i = 20\sin\pi\left(100t - \frac{1}{4}\right)$



$$\tan\theta = \frac{X_L}{R} = \frac{\omega L}{R} = \frac{(100\pi)35\times10^{-3}}{11} = 1$$

$$Z = \sqrt{X_L^2 + R^2} = 11\sqrt{2}$$

$$i_{RMS} = \frac{220}{11\sqrt{2}}$$

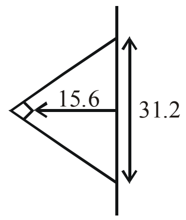
$\theta = 45°$

(i Lags)

$$i_{peak} = \frac{220}{11} = 20$$

5. **Ans.** (i) 85.22 Tm^2; (ii) 56.8 V; (iii) linearly

Sol. at t = 3 sec



$$\phi = BA = 0.35 \times \frac{1}{2} \times 31.2 \times 15.6 = 85.176$$

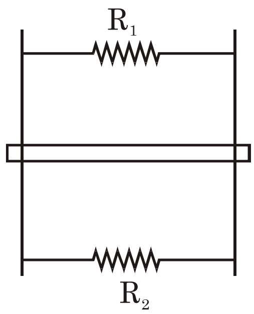
$$E = -\frac{d\phi}{dt} = -B\frac{dA}{dt}$$

$= -BLV = -0.35 \times 31.2 \times 5.2 = 56.8$ volt

EMF is varying linearly with time, as L = vT B, are constant.

6. **Ans.** $V = 1\ ms^{-1}$, $R_1 = 0.47\ \Omega$, $R_2 = 0.30\ \Omega$

Sol.



m = 0.2 kg

$$\frac{V^2}{R_1} = 0.76 \qquad V = Bv\ell$$

$$\frac{V^2}{R_2} = 1.2$$

$$mgv = \frac{V^2}{R_1} + \frac{V^2}{R_2} = 1.96$$

v = 1 m/s

$v = Bv\ell = 0.6$

$$\frac{(0.6)^2}{R_1} = 0.76 \Rightarrow R_1 = 0.47$$

$$\frac{(0.6)^2}{R_2} = 1.2 \Rightarrow R_2 = 0.3$$

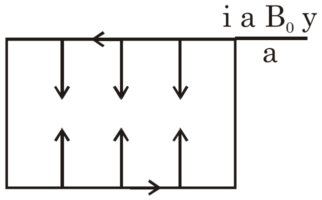
7. **Ans.** (a) $i = \dfrac{B_0 av}{R}$ in anticlockwise direction, v = velocity at time t, (b) $F_{nett} = B_0^{\,2} a^2 V/R$,

(c) $V = \dfrac{mgR}{B_0^2 a^2}\left(1 - e^{-\frac{B_0^2 a^2 t}{mR}}\right)$

Sol. $\phi = \left(\dfrac{B_0 y}{a}\right) a^2 = B_0 a y$

$|\varepsilon| = B_0 a v \qquad\qquad \left|\dfrac{dy}{dt}\right| = v$

(a) $i = \dfrac{B_0 av}{R}$ (as y↑ ϕ↑ So i is ACW)

(b) 

$$\frac{i\,a\,B_0\,(y+a)}{a}$$

$$F_{net} = \frac{iaB_0\,(y+a)}{a} - \frac{iaB_0 y}{a}$$

$$= \frac{iaB_0 a}{a} = iaB_0$$

$$= \left(\frac{B_0 av}{R}\right) aB_0$$

$$= \frac{B_0^2 a^2 v}{R}$$

(c) For terminal velocity

$\Sigma F = 0 \qquad\qquad mg = \dfrac{B_0^2 a^2 v}{R}$

$$v = \frac{mgR}{B_0^2 a^2}$$

$$\Sigma F = ma$$

$$mg - \frac{B_0^2 a^2 v}{R} = m\frac{dv}{dt}$$

$$\int_0^v \frac{dv}{mg - \dfrac{B_0^2 a^2 v}{R}} = \int_0^t \frac{dt}{m}$$

$$\frac{\ell n\left(mg - \frac{B_0^2a^2v}{R}\right)\Bigg|_0^v}{-\frac{B_0^2a^2}{R}} = \frac{t}{m}$$

$$\ell n\left(\frac{mg - \frac{B_0^2a^2v}{R}}{mg}\right) = \frac{-B_0^2a^2t}{mR}$$

$$v = \frac{mgR}{B_0^2a^2}\left(1 - e^{-\frac{B_0^2a^2t}{mR}}\right)$$

8. **Ans.** 67/32 A

Sol. When both are closed

$$i = \frac{100}{10}\left(1 - e^{-\frac{10t}{1}}\right) = 10\left(1 - e^{-10t}\right)$$

at $t = 0.1\ \ell n2$

$i = 10\ (1 - e^{\ell n\ 2}) = 5$

When S_2 is opened (initial current is 5 A) ($i_0 = 5A$)

$$i = i_0e^{-\frac{Rt}{L}} + \frac{V_0}{R}\left(1 - e^{-\frac{Rt}{L}}\right)$$

$$i = 5e^{-\frac{50t}{1}} + \frac{100}{50}\left(1 - e^{-\frac{50t}{1}}\right)$$

$\Delta t = 0.2\ \ell n2 - 0.1\ \ell n2 = 0.1\ \ell n\ 2$

$$i = 5e^{-50(0.1\ell n2)} + 2\left(1 - e^{-50(0.1\ell n2)}\right)$$

$$= \frac{5}{32} + 2\left(1 - \frac{1}{32}\right)$$

$$= \frac{67}{32}$$

9. **Ans.** $2\pi\frac{\sqrt{mL}}{lB}, g\frac{\sqrt{mL}}{lB}$

Sol. $mg - i\ell B = ma$

$$L\frac{di}{dt} = Bv\ell \Rightarrow \frac{di}{dt} = \frac{Bv\ell}{L}$$

$$mg - i\ell B = m\frac{dv}{dt}$$

$$-\ell B\frac{di}{dt} = m\frac{d^2v}{dt^2}$$

$$-\ell B\left(\frac{Bv\ell}{L}\right)=m\frac{d^2v}{dt^2}$$

$$\frac{d^2v}{dt^2}=-\frac{B^2\ell^2v}{mL}$$ (equation of SHM)

$$\omega=\frac{B\ell}{\sqrt{mL}}$$

$$T=\frac{2\pi}{\omega}$$

at t = 0 $\qquad a = g = \omega^2 A$

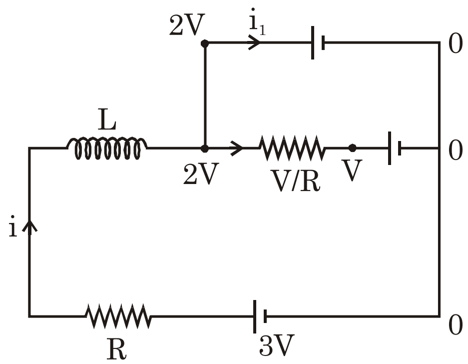
$$A=\frac{g}{\omega^2}$$

$$v_{max}=\omega A=\frac{\omega g}{\omega^2}=\frac{g}{\omega}$$

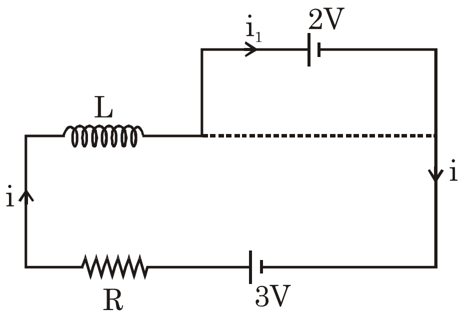
$$v_{max}=\frac{g\sqrt{mL}}{B\ell}$$

10. Ans. $-\dfrac{V}{R}e^{-\frac{Rt}{L}}$

Sol.



Considering this loop



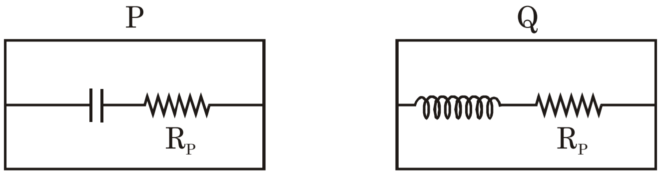
$$i=\frac{V}{R}\left(1-e^{-\frac{Rt}{L}}\right)$$

$$i=i_1+\frac{V}{R}$$ (kirchoffs law)

$$\Rightarrow i_1 = \frac{V}{R}\left(1 - e^{-\frac{Rt}{L}}\right) - \frac{V}{R} = \frac{-V}{R} e^{-\frac{Rt}{L}}$$

11. Ans. 77Ω, 97.6Ω, 7.7 V, 9.76 V

Sol.



For maximum current in series $Z_{net} = R$

$X_L = X_C$

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

$$Z_P = \sqrt{X_C^2 + R_P^2} = \sqrt{\frac{1}{\omega^2 C^2} + R_P^2} = \sqrt{\frac{L}{C} + R_P^2} \approx 77$$

$$Z_Q = \sqrt{X_L^2 + R_Q^2} = \sqrt{\omega^2 L^2 + R_Q^2} = \sqrt{\frac{L}{C} + R_Q^2} \approx 97.6$$

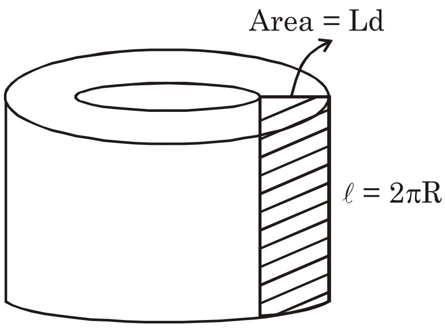
$$i = \frac{V}{Z_{net}} = \frac{10}{100} = \frac{1}{10}$$

$V_P = iZ_P = 7.7$

$V_R = i\,Z_Q = 9.76$

12. Ans. $I = \dfrac{(\mu_0 n i_0 \omega \cos\omega t)\pi a^2 (Ld)}{\rho 2\pi R}$

Sol.



$$\text{Resistance} = \frac{\rho\ell}{\text{Area}}$$

$\phi = (\mu_0 n i_0 \sin\omega t)\ \pi a^2$

$\varepsilon = \mu_0 n i_0\ \pi a^2 \omega \cos\ \omega t$

$$i = \frac{\mu_0 n i_0 \pi a^2 \omega \cos\omega t}{\left(\frac{\rho 2\pi R}{Ld}\right)} = \frac{(\mu_0 n i_0 \omega \cos\omega t)\pi a^2 Ld}{\rho 2\pi R}$$